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Deliverable 11.2

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

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Content

1 Introduction

1.1 ECOPOTENTIAL Project

1.1.1 Aim

The ECOPOTENTIAL project aims to improve future ecosystem benefits in Protected Areas through the use of Earth Observation considering stakeholder involvement and needs.

1.1.2 Project Framework

The ECOPOTENTIAL project framework is based on three main ideas:

1. The concept of ecosystem services connects the natural environment to the socio-economic realm. For example, food production, pollination and flood protection are services that benefit human society.
2. Quantification of ecosystem services requires a combination of Earth Observation, in-situ measurements and environmental modelling. Management and (spatial) planning of Protected Areas require reliable and practical indicators to be used for effective communication, consideration of alternatives and adequate reporting.
3. Protected Area managers and environmental scientists can be connected through the development of and application of reliable and practical indicators. This science-policy interface connects relevant people, facilitating the two-way flow between information need and information supply.

1.2 Synthesis Study for ECOPOTENTIAL

1.2.1 Objectives

The main objective of Work Package (WP) 11, 'Earth Observation supported policy development and integration', is to facilitate and enhance the understanding and use of Earth Observation and in-situ data, tools/services and of modelling results in decision-making, in particular, at the level of Protected Area management. WP11, therefore, focuses on scientific tools into practical use and then integration this knowledge into policy- and decision-making processes.

1.2.2 Overview

The synthesis study is the chronologically the fourth deliverable in WP11 of the ECOPOTENTIAL project. Significant input came from the second deliverable, D11.2, 'Surveys/ assessments at the local level (Protected Areas) on the use of Earth Observation in decision making', and in part from D11.4, 'Locally, tailor-made specification of research outputs as needed by stakeholders during participatory focus groups'.

The synthesis study focuses on Protected Area management and managers and the integration of knowledge and understanding of ecosystem services and EO. It investigates the following main questions:

I. What are the needs and wishes of Protected Area managers for the application and quantification of ecosystem services?
II. What is the current use of Earth Observation in policy, management and decision-making of Protected Areas?
III. What research needs should ECOPOTENTIAL address?
IV. How should research results be designed and communicated?

In this report we focus on the first three questions, in particular considering the needs of the managers and potential for application of Earth Observation services. The fourth question was addressed in D11.4.

Results from this study will be conveyed to the other work packages. Critically, they will help inform how Protected Area managers may become engaged in ECOPOTENTIAL research and how research results will be communicated. A follow up workshop with the Protected Area managers is planned for spring 2017.

1.2.3 Methodology

Twenty-two Protected Areas and their managers are involved in ECOPOTENTIAL. The Protected Areas are distributed across mountain (14), arid/semi-arid (5), and coastal and marine ecosystems (7). Please note that some Protected Areas are represented by more than one ecosystem type, accounting for the discrepancy in totals. Information was collected from questionnaires provided to each Protected Area manager or other relevant staff member (see Appendix of D.11.4 for complete questionnaire). Contained within the questionnaire package sent to the Protected Areas was an introduction to the ECOPOTENTIAL project, an introduction to the concept of ecosystem services, and an overview of the use and possibilities of Earth Observation. This introduction aimed to create a shared basic understanding of the terminology and meanings and the project framework.

The questionnaire addresses three thematic areas:

- *Goals and management of and challenges faced by the Protected Areas* (Section 1)
- *Data collection methods and additional known needs* (Section 2)
- *Potential collaboration with ECOPOTENTIAL* (Section 3) (*communication of results, also in this section, is addressed in D.11.4)*

This analysis focusses on parts of all three areas of the questionnaire. The specific questions addressed in this report are found in Appendix 1.

The questionnaires were completed by the Protected Area managers or other relevant staff for seventeen of the twenty two participating areas (see Appendix 2 for a list of the Protected Areas and details of questionnaire completion). Twelve of the represented areas are located within eleven EU member states, while the other five are in Moldova, Switzerland, Israel, Norway and South Africa.

1.3 Overview of EU frameworks relating to Ecosystem Services

In this section, we provide a European policy context for the management of Protected Areas in ECOPOTENTIAL. We discuss existing instruments that deal with environmental and/or ecological protection on a European scale, and their relation to the conservation of Protected Areas and ecosystem services. Since Earth Observation is a potentially valuable tool for measuring ecosystem services, we also look at the application of Earth Observation in Protected Areas. We look into both the legislation as well as policy instruments for all environments in which the concept of ecosystem services is being used, and provide a brief overview of any specific policies for the marine/coastal, mountain and semi-arid environments.

1.3.1 European legislation and policy instruments on ecosystem services

1.3.1.1 Biodiversity Strategy 2020

The main European policy instrument to protect biodiversity is the Biodiversity Strategy, which is based on the global Convention of for Biological Diversity (CBD). The goal of this instrument is *'Halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss'*. The 2020 Biodiversity Strategy includes targets to maintain and restore ecosystems and their services (Target 2, Action 5). The major framework provided to Member States as a means to achieving this target is the Mapping and

Assessment of Ecosystems and their Services (MAES). The framework is based on the premise that biodiversity contributes to ecosystem functioning and therefore to delivering ecosystem services. MAES provides steps that can be taken to increase the knowledge and status of ecosystems and their services but seems to be more applicable on a regional or national level rather than on a protected area level. Earth Observation is not explicitly mentioned in the Biodiversity Strategy.

The MAES framework has been worked out methodologically but its application still is in its infancy. Various EU projects have been developed (and finished) lately that take MAES as a starting point from which the application of the ecosystem services concept is further developed (e.g. MESEU, MARS, ESMERALDA). For the marine and coastal aquatic environment in particular, the methodology is insufficiently developed. The European Environment Agency (EEA) is currently undertaking work to further develop and operationalize the MAES approach for the marine environment for application at the EU level.

Of key importance for the classification, description and assessment of ecosystems and thereby the ecosystem services within Europe are the following directives:

1.3.1.2 Regulation on Invasive Alien Species

The EU Regulation on Invasive Alien Species (EU No 1143/2014) addresses the problem of invasive alien species and aims to protect endemic biodiversity and related ecosystem services. It provides a list of species that should be prevented from entering the territory of the EU due to potential deleterious impacts. The regulation requires EU Member States to develop action plans to control invasive alien species, restore damaged ecosystems, and establish a surveillance system. The use of Earth Observation data as an aid to surveillance is not referred to in the regulation.

1.3.1.3 Birds Directive

The Birds Directive (EC 1979, amended 2009) is the oldest piece of legislation on the EU environment. It aims to protect the 500 wild bird species occurring in the European Union through the designation of Special Protection Areas (SPAs), and by establishing specific hunting protocols, restricting destructive activities, outlawing specific hunting activities, and promoting research that underpins the protection of birds. The Directive does not mention either ecosystem services or Earth Observations.

1.3.1.4 Habitats Directive

The Habitats Directive (EC 1992) is aimed at the protection of specific habitats and the wild plant and animal species living in and dependent upon them, through the establishment of Special Areas of Conservation (SACs). In addition, generic protection plans have been set up within Member States that aim for strict protection of these species across the European Union outside of SPAs and SACs. Lastly, exploitation and taking of species in the wild must be compatible with the Favourable Conservation Status (FCS) of these species. The Directive does not mention either ecosystem services or Earth Observation.

Together, The Birds Directive and The Habitats Directive form the basis of the Natura 2000 network. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, as listed under the two directives. A 2013 report from the European Environment Agency on the economic benefits of the Natura 2000 network makes the link to ecosystem services. Although this is not a directive or legislation it does emphasize the importance of the Natura 2000 network in relation to human

benefits from the environment. It also includes recommendations for accruing these benefits. In 2009, the Institute for European Environmental Policy (IEEP) published a toolkit for assessing the socio-economic benefits of Natura 2000 (Kettunen et al. 2009[1]). This toolkit describes how to derive the social and economic values (defined as ecosystem services) from Natura 2000 areas for use in management and follows the MA (2005) approach.

Many of the Protected Areas listed as focal points within the ECOPOTENTIAL project are Natura 2000 sites (except those outside the EU territorial borders), with relatively strict and judicially well-embedded protection regimes. The habitats and species of these sites are well described in management plans, as are the desired states of the natural environment in these areas.

1.4 Earth Observation Application

1.4.1 Overview

The uses and potential opportunities for Earth Observation have been expanding rapidly with the increasing selection of satellite sensors and measurements, alongside the growing computational and modelling capacity. Earth Observation now has wide and varied application across multiple sectors and thematic areas ranging from global change research examining greenhouse gas and aerosol concentrations through to monitoring of deforestation, and even individual ships or whales at sea (see Table 1).

Table 1. Some uses and applications of Earth Observation

Sector/Thematic area	Applications of Satellite Imagery
Agriculture and Food Security	Crop health mapping and monitoring Crop insurance damage assessment Yield estimates Illicit crop monitoring (e.g. opium poppy cultivation) Pest and invasive species monitoring Monitoring agri-environmental measures Assessing storm damage
Forestry	Surveying, evaluating and monitoring forest health Forest acreage, stand density Estimating fire, storm and other extreme events Mapping of deforestation (including illegal deforestation) Monitoring of forest regrowth and conservation activities
Urbanised areas	Rainwater runoff and flood risk Monitoring urban growth and unplanned developments Planning control Land cover classification
Emergency Management	Flood prediction and flood extent mapping Monitoring of forest fires, floods, earthquakes, tsunamis Humanitarian responses Oil spills
Maritime uses	Ship tracking Bathymetric data Monitoring marine resources (e.g., fish, mammals, coral reefs) Marine environmental protection

[1] Kettunen, M., Bassi, S., Gantioler, S. & ten Brink, P. 2009. Assessing Socio-economic Benefits of Natura 2000 – a Toolkit for Practitioners (September 2009 Edition). Output of the European Commission project "Financing Natura 2000: Cost estimate and benefits of Natura 2000 " (Contract No.: 070307/2007/484403/MAR/B2). Institute for European Environmental Policy (IEEP), Brussels, Belgium. 191 pp. + Annexes.

	Oil spill monitoring Illegal fishing activities
Atmospheric monitoring/global change research	Greenhouse gases Reactive gases Ozone and solar UV radiation Aerosols
Water sector	Flood monitoring Snow and ice monitoring Water level monitoring Icebergs and ice floe
Sources: information sourced from Surrey Satellite Technology Limited. Applications of Earth Observation (Data, Information, Knowledge). https://www.sstl.co.uk/Downloads/Brochures/SSTL-Applications-Brochure-Web (accessed 29 August 2016); Earthzine, 2012. Roles of Earth Observation in ensuring Global Sustainability. http://earthzine.org/2012/02/06/roles-of-earth-observation-in-ensuring-global-sustainability/ (accessed 29 August 2016); ESA, 2016. Sentinel Online. https://sentinel.esa.int/web/sentinel/thematic-areas (accessed 29 August 2016)	

1.4.2 Application of Earth Observation to ecosystem services

The potential scope for applying Earth Observation to the ecological and ecosystem services is also large. Earth Observation is increasingly used across basic ecological research, monitoring of ecosystem services, and tracking of natural capital. Earth Observations often can provide the only means of measuring across broad areas the characteristics of habitats and land cover, assessing the bio-geophysical properties of ecosystems, or detecting environmental changes that occur as a result of human or natural processes (Kerr & Ostrovsky, 2003[2]). Table 2 provides some typical examples of how Earth Observation is used to monitor ecosystems and their services.

Table 2: Examples of ecological and ecosystem service evaluations through satellite and remote sensing

	Ecosystems	**Applications**
Terrestrial	Forests	Tree cover density map Tree height and volume Stem volume and carbon changes Extent and spatial distribution of structural forest type Forest cover mapping Spatial configuration of forested areas Deforestation, afforestation mapping Wildlife corridor mapping
	Drylands	Decadal soil water index
	Mountains	Digital elevation models (outlining watersheds and catchment areas)
Aquatic	Freshwater	Rainfall estimates (mm) Monitoring of open water bodies and seasonal induced changes
	Marine	Seagrass canopy density Spatial maps of coral reef habitats Biodiversity map of shallow water habitats Map of water depth (shallow water bathymetry) Sea surface temperature maps Coastal wave exposure Dredge plume monitoring and benthic light levels Coral thermal stress
	Coastal	High resolution coastal change mapping

[2] Kerr, J.T. & Ostrovsky, M. 2003. From space to species: ecological applications for remote sensing. Trends in Ecology and Evolution 18 (6): 299-305.

		Coastal erosion monitoring Coastal land use mapping Coastal infrastructure mapping Mangrove mapping Sea level rise and storm surge scenarios Boat detection
Source: ESA. 2014. Space4Ecosystems. http://www.space4ecosystems.com (access 29 August 2016)		

2 Synthesis Report Findings

2.1 Basic summary of responses received

Of the 22 total Protected Areas participating in the ECOPOTENTIAL project, nineteen responses were received, from twelve (of fourteen) mountain ecosystems, six (of seven) coastal/marine and five (of five) arid/semi-arid. (Please note that some Protected Areas represent more than one ecosystem type (see Appendix 2.)

The responses to the questionnaire varied in their completeness and the level of voluntary detail provided but all responses contributed to this analysis. Additionally, differences in the types of details provided were evident, likely influenced by the respondent and his/her position and types of responsibilities, e.g., more scientific information might have been provided by researchers in comparison to managers.

Analyses were done as best as possible given the amount of data generated by the questionnaire. However, more detailed or more precise analysis was difficult due to the low number of total responses.

As stated above, a full blank questionnaire can be found in the appendices of Deliverable 11.4. Here, in Appendix 1, we provide only the questions applicable to this report. Appendix 2 details the list of questionnaire respondents with basic details of the associated Protected Area (also found in the Deliverable 11.4 appendices).

2.2 Mountain ecosystems

2.2.1 Overview of the Mountain Protected Areas

Fourteen mountain Protected Areas are included in the project, twelve of which responded to the questionnaire, including Samaria National Park which is classified as both arid/semi-arid and mountainous.

	Mountain Protected areas
1	Hardangervidda Nasjonalpark
2	Lake Ohrid
3	Swiss National Park
4	Caldera de Taburiente - La Palma
5	Natura 2000 – La Palma
6	Lake Prespa
7	Tatra Mountains
8	Samaria National Park
9	Gran Paradiso National Park
10	Kalkalpen National Park
11	Sierra Nevada
12	Peneda-Gerês

13	Abisko – no response
14	Bayerischer Wald – no response

Objectives of the Protected Areas

The main objectives of the Protected Areas are protecting the ecosystems and their natural processes, including biodiversity, endemism, key species and habitats. Cultural services appear to be a second priority and these include recreation, education, research, and cultural heritage. Other ecosystem services provided were generally not identified as immediate priorities (apart from two of twelve Protected Areas noting the protection of fresh water resources as an aim).

Provisioning of ecosystem services is not formally recognized in the objectives of the Protected Areas. The reason for this may be that the ecosystem services approach is still in its early stages of development and was not prevalent at the time when the Protected Areas were established. Earth Observation was also not used in the creation of the Protected Areas. Some respondents note that Earth Observation data was not available at the time that the protected area was established. In the case of Lake Prespa, the outer borders of the park as well as the inner borders of the park zones were designed with use and help of Earth Observation data (aerial photos).

Property regime

60% of the area protected in these ten mountainous Protected Areas is publicly owned, while 40% is privately owned (e.g. by farmers, homeowners and companies). The distribution of ownership between the two varies significantly, from 15% public ownership in Caldera de Taburiente to 100% in the Swiss National Park. Although the public has access to the majority of the area in most areas, it varies from 100% in, for example, Hardangarvidda to only on marked trails in Swiss National Park and the Tatra Mountains.

Average (out of 10):

37.4% Private (from 0-85%)

60.0% Public (from 15-100%)

Funding and revenue

Nearly all the funding to the Protected Areas in this study is public although some also receive small private donations in addition.

The revenue generated appears to vary significantly between the Protected Areas. Three areas make no revenue, while some charge entrance fees and/or rent out venues. 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 revenue (2.15 and 1 million Euros, respectively)

Policy and normative frameworks relevant to protected area management

There were overall patchy responses on the policies at the supranational level. Nine of the twelve Protected Areas noted the relevance of the Bird and Habitat Directives to the management of their Protected Area and two noted the Water Framework directive (Hardangervidda and Swiss National Park are in non-EU countries).

All respondents noted the relevance of at least one national law to their Protected Area, and a provincial law is listed for six.

Engagement with stakeholders in decision-making

A wide range of mechanisms are used to engage with stakeholders including having stakeholder representatives at annual meetings, and on management boards or governing councils. National and regional/local governments, researchers, NGOs and local communities are, to varying degrees, formally involved in these institutions. Informal engagement includes informing stakeholders through online media and publications.

2.2.2 Pressures and Ecosystem Services

What are the pressures facing the Protected Areas?

Perceived pressures on mountain ecosystem Protected Areas are shown in Figure 1. Overall, tourism, climate change and invasive species are the most important common pressures facing the Protected Areas in the survey. Six out of the twelve respondents found that tourism was a high pressure. Invasive species was ranked second overall, where seven out of the twelve Protected Areas found that the pressures were of either high or medium pressure. Climate change, which ranked third overall, was a pressure felt by all Protected Areas with a larger share of medium or low pressure rankings overall. Interestingly, only a few pressures are felt by all or most of the Protected Areas; the other pressures were felt not uniformly or not noted as a concern. Only climate change was noted by all respondents. Ten of the twelve respondents also noted pressures from landscape fragmentation, invasive species, and tourism. At the other end of the scale, forestry and fishing were of no concern to half of the respondents. Some stand-alone pressures (in the “other” category) include wildfires, which was a high pressure for three protected areas (with the rest not noting this as a concern) and introduced herbivores and predators (Natura 2000 – La Palma), water use and erosion (Sierra Nevada).

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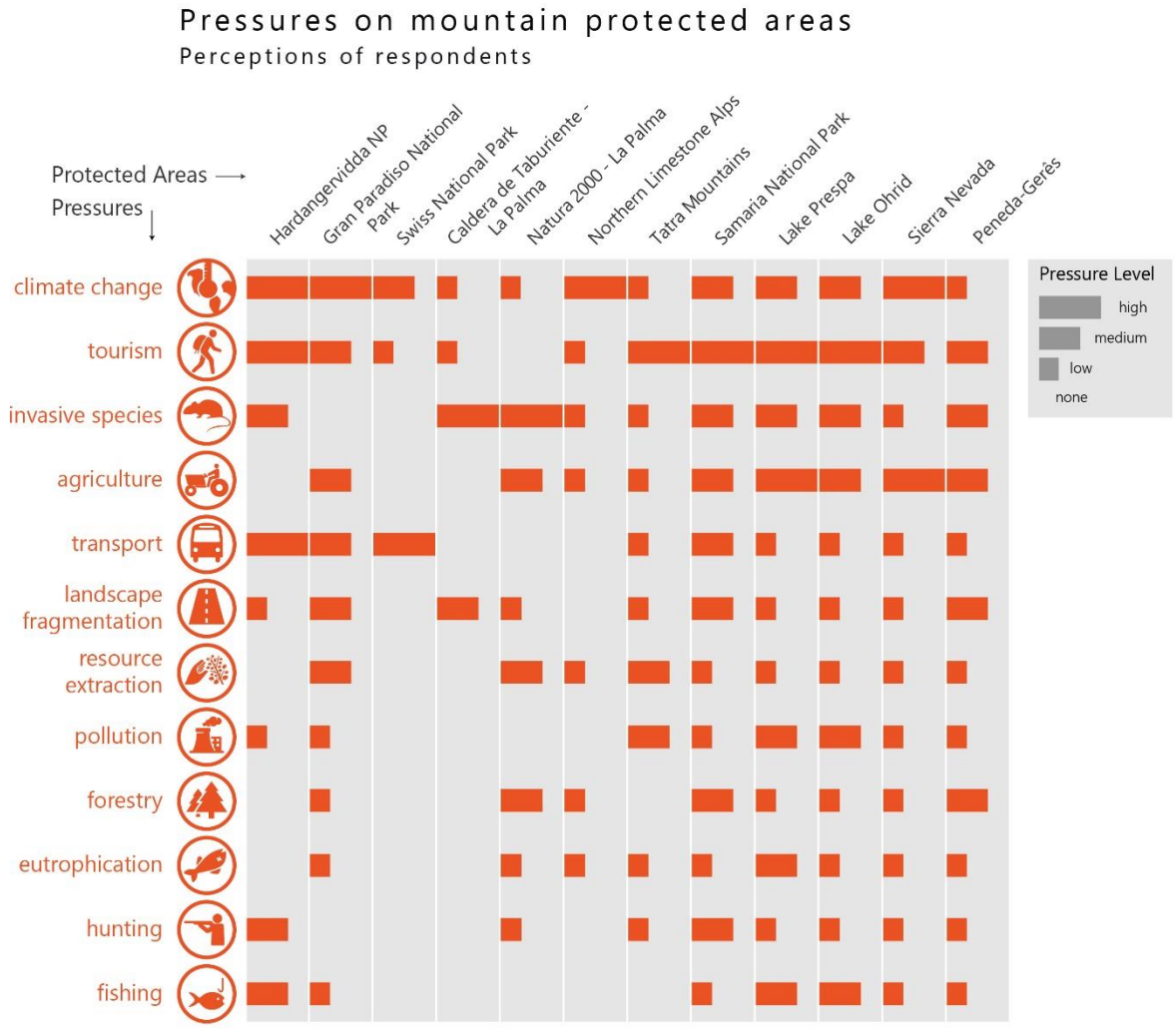

FIGURE 1. PERCEIVED PRESSURES ON PROTECTED AREA MOUNTAIN ECOSYSTEMS

What are the important ecosystem services?

The importance of various ecosystem services in mountain ecosystem Protected Areas is shown in Figure 2. Overall, cultural services are considered to be most important, followed by regulating services and then provisioning services. By far the most important ecosystem services noted by the respondents were cultural ecosystem services: recreation (noted as very important by all) followed closely by research, aesthetic qualities, and education. The regulating service of lifecycle and habitat protection was the top non-cultural service, followed closely by the provisioning service of freshwater. The importance of other services was generally not uniform across the Protected Areas surveyed. Flood prevention, for example, was very important for half of the areas surveyed but of varying degrees of importance to the other half. Some individual regulating and provisioning services appear to be very important. With the exception of farmed sea food, energy production, and timber, all of the provisioning and regulating services were considered of high importance in at least one.

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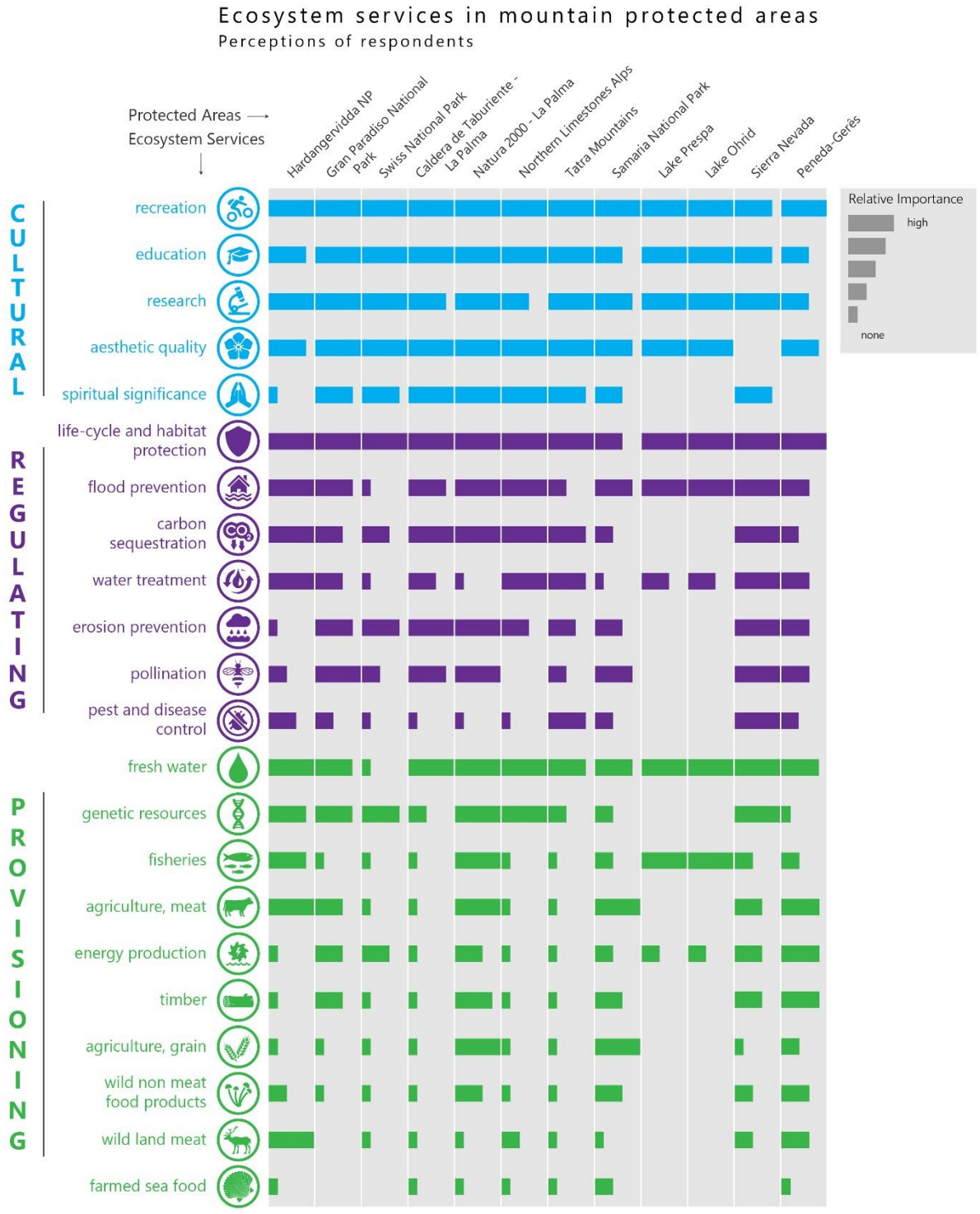

FIGURE 2. PERCEIVED IMPORTANCE OF ECOSYSTEM SERVICES IN PROTECTED AREA MOUNTAIN ECOSYSTEMS

Use of ecosystem service framework in protected area management

Only Lake Prespa and the Northern Limestone Alps responded that an ecosystem service framework is used in the management of the area. All others responded no. The reason given by the respondent from Lake Prespa for using the Ecosystem Services approach was: «*To better assess the values of tangible and non-*

tangible goods and services of the protected area and to raise the awareness of the local affected stakeholders and communities in the uniqueness of the area and involve them in the active sustainable management of the area`s resources». The Northern Limestone Alps referred to the requirement in the National Park Law in Upper Austria and the application of the IUCN framework.

The reasons given for not using an ecosystem services framework in the other Protected Areas varies from the concept not being known to a lack of systems or legal frameworks available for implementing the ecosystem services concept to the fact that the concept of ecosystem services is not aligned to the goals of the park (one respondent mentioned that the goal of the park was to preserve the ecosystems themselves, not their services).

Seven of twelve responded that no data is being used to quantify ecosystem services. For example, Caldera de Taburiente is using ecosystem services data to measure biodiversity (species richness, endemism, genetic diversity). Lake Prespa is measuring data to quantify direct values, including fishing, hunting, timber and firewood, hay, sand, wildlife viewing, research opportunities, educational opportunities, nature tourism, as well as indirect values such as flood mitigation, nutrient abatement, toxic abatement, sediment trapping, and wildlife habitat.

2.2.3 Use of Earth Observation and modelling

Data gathering

Substantial environmental data is collected by each of the Protected Areas, on for example weather, key species, habitats and water quality. However, the amount of research varies considerably between the areas. The respondents mostly provided long lists of peer reviewed research based on data collected in the areas. The most common socio-economic data gathered was visitor counts and other measurements of tourism. Some also collect data on demography and land use changes.

Earth Observation usage generally consists of aerial and satellite images. Eight of the twelve Protected Areas have dedicated staff working with Earth Observation data.

Only four respondents state that the data collected is used to quantify ecosystem services. However, eight respondents say they would like to quantify ecosystem services and one says that ecosystem services are not part of the aims of the park (the rest of the responses were blank).

Modelling

Seven of the twelve Protected Areas use modelling including models relating spectral indices to biomass, habitat suitability models, and ecological niche factor analysis. For Lake Prespa, lake ecosystem modelling coupled with water quality models is in development. There is a clear need for further modelling in the areas. Nine of the respondents noted the need for further modelling, and listed relevant models needed (two did not respond and Gran Paradiso responded that no further modelling was needed).

2.2.4 Main findings

- Cultural services are the most formalized ecosystem services in the management of the Protected Areas. Second to the features of the ecosystems themselves, such as biodiversity and endemism, natural beauty and recreation opportunities were the main reasons for designating the areas as Protected Areas. The use of Earth Observation to monitor other services, therefore, does not directly

help the management in achieving their aims. It does, however, have the potential to further justify the existence of the Protected Areas and their funding (almost exclusively public).

- Payment for ecosystem services occurs mainly through entry fees and venue rental for cultural services. Only two minor examples of payment for other services: reindeer hunting and timber sale. However, private actors own around 40% of the total land of the Protected Areas and they receive payments for ecosystem services, probably primarily through agriculture and tourism.
- Earth Observation data from aerial and satellite images is generally available. The use of such imagery, however, is limited in the management of the areas. There is a significant amount of research occurring in the national parks overall, although the respondents note that there is potential for greater use in management.
- The main challenges for using Earth Observation tools are lack of training and expertise, such as on how to apply ecosystem services framework to management, and lack of software/hardware for analysing data.
- The main ways in which Ecopotential can help, in their opinion, is to provide training, pre-analysed data relevant for management, knowledge exchange between Protected Areas on the topic, as well as procurement of relevant software/hardware/data.

2.3 Coastal and Marine ecosystems

2.3.1 Overview of the Coastal and Marine Protected Areas

Six of the seven coastal and Marine Protected Areas contacted for this study returned a completed questionnaire. In the case of the Curonian Lagoon, two questionnaires were completed, therefore, in total, seven questionnaires were analysed for the coastal and marine Protected Areas.

	Coastal and marine protected areas	Area within Protected Area (if applicable)	Remarks
1A	Curonian Lagoon	Curonian Spit National Park	
1B		Nemuno Delta Regional Park	
2	Large Marine Ecosystem: Mediterranean	Pelagos Sanctuary for Mediterranean Marine Mammals	
3	Wadden Sea	Dutch part of the Wadden Sea	*Filled in by researchers*
4	Danube Delta	Danube Delta Biosphere Reserve	
5	Camargue	-	
6	Doñana	Doñana National Park	
7	Large Marine Ecosystem: Caribbean – no response		

Objectives of the Protected Areas

The conservation and protection objective of five of the seven marine and coastal Protected Areas is related to biodiversity and unique ecosystems and landscapes. The Pelagos in the Mediterranean specifically targets the protection of marine mammal species. Doñana National Park also targets species, including aquatic bird populations, the Iberian lynx and the Spanish imperial eagle. In addition to biological or ecological aims, four out of seven Protected Areas also state cultural heritage as an aim of conservation and protection. The Camargue area, for example, indicates the combined protection of natural heritage (wetlands, coastal dunes, fauna, and flora) and cultural heritage (architecture, landscape, traditions). The Curonian Spit National Park was founded in 1991 to protect the most important natural and cultural heritage landscape complex which comprises a unique dune system and ethno-cultural sites.

Earth Observation did not play a role in the creation of the seven Protected Areas. Most of the areas predated the availability of Earth Observation data.

Property regime

One Protected Area (Nemuras) indicated that no data were available in the park's administration. Out of the remaining six, four are publically owned for at least 99%. The two with substantial private ownership are the Doñana National Park (30% private; mostly small family-owned enterprises and a small part is NGO owned) and the Camargue (85% private).

Average (out of 6, one no data):

20% Private (from 0-85%)

80% Public (from 0-100%)

Funding and revenue

The revenue generated varies substantially among the Protected Areas. Four areas make revenue, through a combination of payment for ecosystem services (three), entry fees (one) and visitor centre/tours (three). Two claimed to not make revenue and one did not answer. No respondents provided partial or total revenue in monetary figures. Interestingly, most respondents interpret the question as revenue *for the Protected Area itself* which is indicated as absent or limited, while revenue for society as a whole (e.g. through fisheries) is not identified as revenue by the managers.

Policy and normative frameworks relevant to protected area management

The European Habitats Directive and Bird Directive apply to six out of seven Protected Areas except for the Pelagos Sanctuary for Mediterranean Marine Mammals. According to the questionnaires, the Water Framework Directive applies in only three out seven, and the Marine Strategy Framework Directive applies to none. As the Water Framework Directive and the Marine Strategy Framework Directive apply to all water bodies, it could be considered as an omission.

Although regional and national policy frameworks also apply to the areas, since they vary from one to the next, they are not reported on in this document.

Engagement with stakeholders

Interaction with stakeholders – not including legal paths such as permitting or environmental impact assessments – occurs mostly through cooperation in projects and during workshops or other gatherings. The Pelagos area indicates involvement through establishment of a partnership scheme between the Sanctuary Agreement and the coastal municipalities. The Camargue describes an extensive arrangement of interactions through governance (e.g. steering platform, science council), awareness and outreach activities (e.g. Museum of the Camargue, awareness events such as guided tours and conferences) and internet (e.g. website, SIT interactive GIS platform). The Danube Delta Biosphere Reserve invites stakeholders for consultations about the regulations that the Biosphere Reserve Administration is requiring as part of their management plan. Doñana National Park has a Participation Council in which public administrations, scientists, farmers, enterprises and NGOs are represented. The Council has four Working Committees to

inform the Council on specific issues, i.e. Biodiversity, Sustainable Development and Water Management and Research.

Municipal governments appear to be most involved in the coastal and marine Protected Areas closely followed by national governments. Representatives of both NGOs and civil society, as well as scientific institutions are also involved, while private companies and visitors appear to be less so. It appears that stakeholder engagement is established but that the general level of engagement in the management is moderate and varies considerably between the Protected Areas.

2.3.2 Pressures and Ecosystem Services

What are the pressures facing the Protected Areas?

Perceived pressures on coastal and marine ecosystem Protected Areas are shown in Figure 2. Protected Area managers considered fishing to be the highest pressure to their coastal and marine areas. Five out of seven respondents indicated the fishing pressure as high and one placed it as medium and one as low. Transport ranked second as pressure, while the individual scoring is more varied than for fishing (three noted it as high, two as medium, and two as low). Eutrophication, tourism and pollution are on average considered as a medium level pressure. If the Pelagos response of “no eutrophication pressure” is ignored, eutrophication ranks as the second highest pressure with three out of six high and three out of six medium.

With the exception of fishing, for which the appraisal of the level of pressure is almost unanimously high, all other pressures show a considerable variation in appraisal between the areas. Sonar and sound pollution, for example, is considered a high pressure in the Pelagos, while considered as no pressure in the other five Protected Areas.

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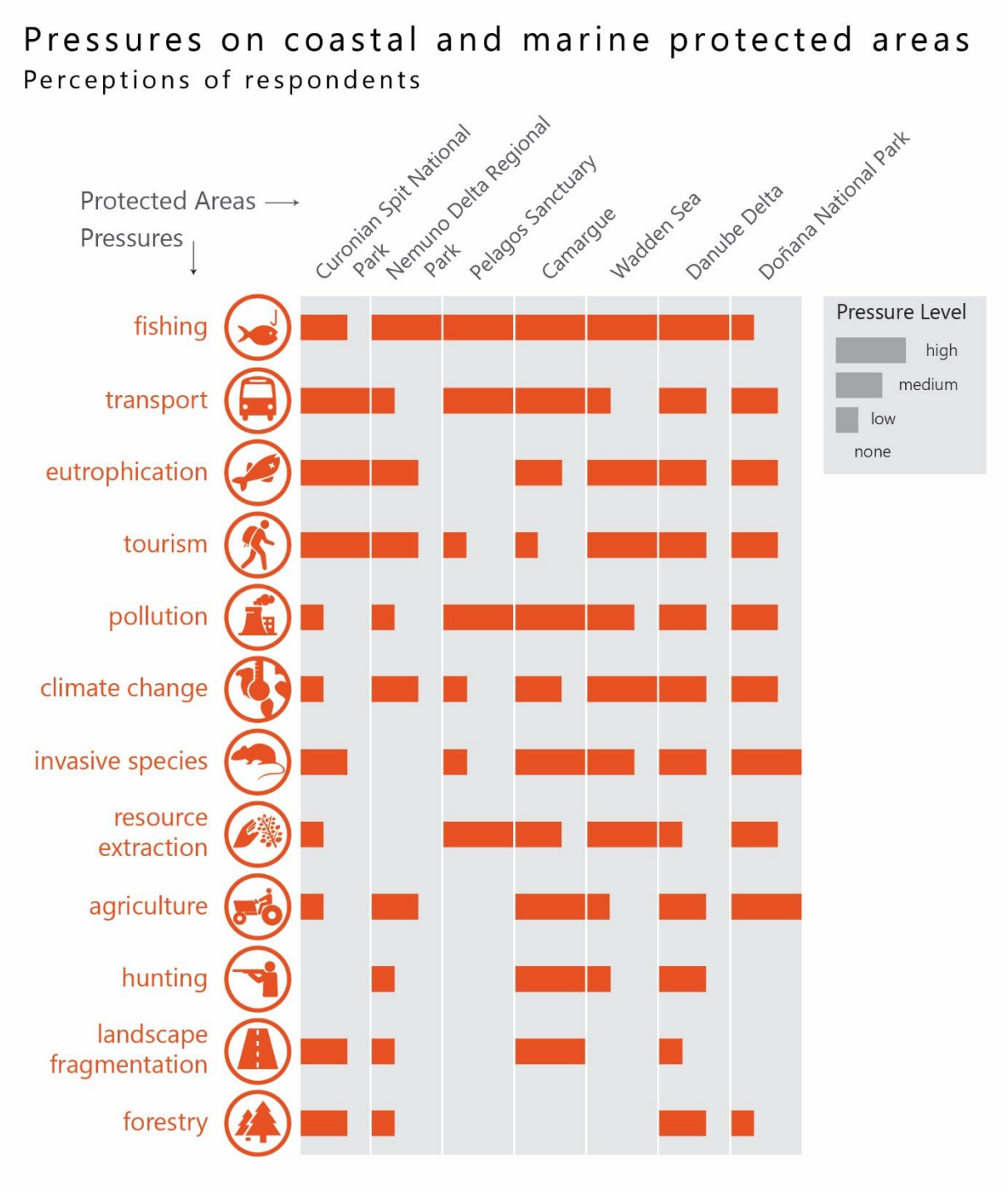

FIGURE 3. PERCEIVED PRESSURES ON PROTECTED AREA COASTAL AND MARINE ECOSYSTEMS

What are the important ecosystem services?

The importance of various ecosystem services in coastal and marine ecosystem Protected Areas is shown in Figure 4. The highest ranked ecosystem service in the coastal and marine areas is recreation and tourism, closely followed by fisheries and aesthetic qualities. The next two highest scoring ecosystem services are also cultural services (qualities, education and research), meaning that four out of the top five ecosystem services

are cultural, and one out of the top 5 is a provisioning service. Surprisingly, cultural heritage does not score high while the conservation and protection of cultural heritage is defined as a goal in four out of seven (see §3.3.1).

Except for agriculture (meat), none of the other provisioning services scores higher than 2.0. Fresh water and agriculture are the next highest provisioning services to fisheries. However, the variation across Protected Area reporting is large as fresh water has the highest mark in both the Danube delta and the Camargue and the lowest mark (0) in the four other Protected Areas. This indicates that cautious consideration of average scores is required for coastal and marine Protected Areas, as there is still a range in ecosystems from river deltas and estuaries, to coastal lagoons and the open sea.

Although varying between the seven Protected Areas, regulation services appear to be more important than provisioning services as their score is mostly in the range of 1.5-2.5 compared to 0.7-2.1 for provisioning services (except fisheries).

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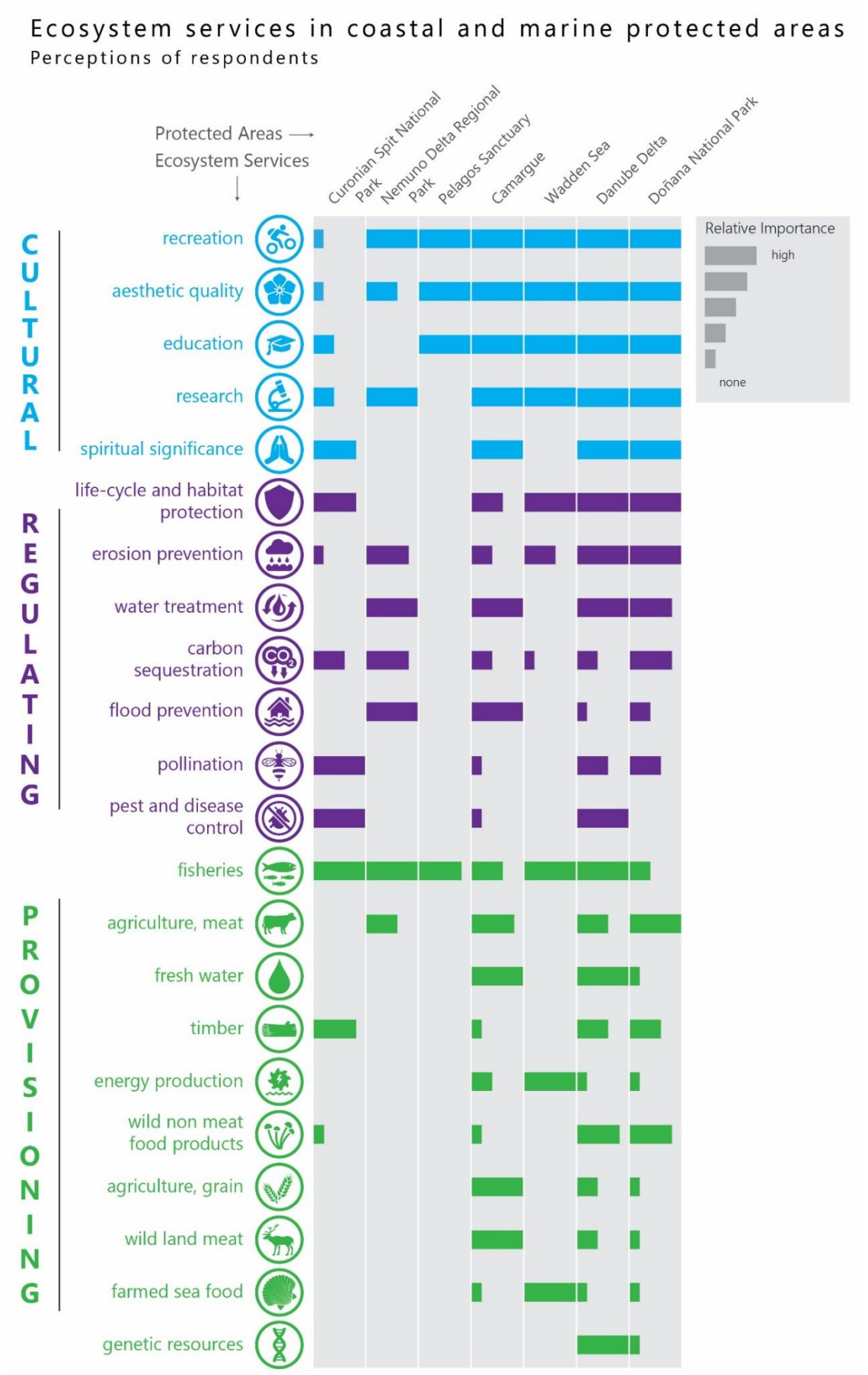

FIGURE 4. PERCEIVED IMPORTANCE OF ECOSYSTEM SERVICES IN PROTECTED AREA COASTAL AND MARINE ECOSYSTEMS

Use of ecosystem service framework in Protected Area management

With the exception of the Danube Delta and Doñana National Park, the ecosystem services concept is not used in Protected Area management. Hence, the available data are not used to quantify ecosystem services. All managers who responded showed an interest in the concept of ecosystem services but indicated that the concept is relatively new and not well known. How they could incorporate it into management is unclear as guidelines or protocols appear not to be available. Also, as there is no prerequisite through the European directives, there is no obligation to use an ecosystem services framework in Protected Area management.

2.3.3 Use of Earth Observation and modelling

Data gathering

Access to Earth Observation satellite-based data is good, as indicated by six out the seven areas that responded. Access to plane or drone images is even better as all responded positively. In contrast, however, only two out of seven actually use satellite data for their management, and only one uses satellite data for quantifying ecosystem services. One Protected Area uses satellite images as images not necessary as data, indicated by the use of Google Earth (observational use). Both the needs for Earth Observation resources and the wish to use further monitor ecosystem services score a positive response of six out of seven Protected Areas, and six out of six, respectively.

With the exception of the Pelagos Sanctuary, all Protected Areas employ staff members in monitoring. However, only in two did staff members work with Earth Observation data and then only very few (e.g., one staff member in the Camargue). Typically, in response to the use of or need for Earth Observation data, plane or drone images are mentioned, possibly indicating that satellites are not first in mind when managers think of Earth Observation. Of note, the Wadden Sea indicates many staff working with Earth Observation data, but as this questionnaire was filled in by researchers, the answer is assumed to refer to the scientific community most likely, not to the management organisation.

Modelling

Modelling was used in three of seven coastal and marine Protected Areas, including in at least one case where it was specified, by researchers. Models were used to determine habitat preferences for fin whales and striped dolphins based on bathymetry, sea surface temperature, chlorophyll-a; for habitat modelling for fin whales in the Mediterranean; and for 1D, 2D, 3D hydrodynamic and water quality models. Further modelling was done by researchers at one site but no further details were given.

Six of seven respondents thought that more modelling was needed. Examples given were for determining coastal erosion; land cover and habitat change, especially for invasive plant detection; detecting and predicting whale presence by coupling habitat suitability and trophic food web models with hydrodynamic-biogeochemical models; determining whether Chlorophyll-a information and measures of whale abundance and distribution can be used to better estimate and predict krill abundance; development of methods for using satellite and in situ data that for future management, e.g. for expanded, new, dynamic Marine Protected Areas, better management of shipping, noise regulation, industrialisation, tourism, pollution, plastics, etc.; and generally high resolution linkages between biodiversity and hydrology, and conservation

planning in management. Also, the need for integration and quantitative insight in cause-effect relations is mentioned as a purpose for modelling.

2.3.4 Main findings

- Cultural heritage is an aim for conservation and protection in most Protected Areas. Cultural ecosystem services score higher on average than regulating and provisioning ecosystem services. This raises the question as to what extent Earth Observation can support Protected area management in the conservation and protection of cultural heritage.
- The Habitats Directive and the Birds Directive apply to most Protected Areas. These European directives could, therefore, be a suitable vehicle to anchor the use of Earth Observation and ecosystem services related to natural heritage. Also, the Water Framework Directive and the Marine Strategy Framework Directive can provide additional support, although for the coastal and marine areas they appear to be less embedded in management as they were less mentioned in the questionnaires.
- For coastal and marine Protected Areas, fishing is considered the greatest pressure and fisheries as the second most important ecosystem service. It is worth considering if Earth Observation developments within ECOPOTENTIAL could target this.
- Protected Area managers have indicated the importance of cultural ecosystem services, as four out of the top five ranked services are cultural. Recreation and tourism ranks highest as ecosystem service. It is recommended that ECOPOTENTIAL pays some attention to cultural services as well.
- When considering ecosystem services, Protected Areas in the coastal and marine ecosystems have rather specific and/or individually distinctive ecosystem services, such as amber extraction in the Curonian Spit National Park or reed harvesting in the Wadden Sea.
- The managers indicate no or limited ecosystem services revenues, but on the other hand, the number of identified beneficiaries averages around fifteen (with a range from two to over 30). This indicates either the potential for ecosystem services revenues or that revenues are there but do not benefit the Protected Areas but others such as the national government (tax revenue) or the fisheries sector instead. Therefore, revenues are there but not recognized as ecosystem services from the Protected Area perspective.
- Access to Earth Observation data is good but use of Earth Observation data is limited. A similar response, although somewhat less consistent, holds for modelling. All managers indicate a wish and a need for better use. The inconsistency in responses shows the under-development of the application. However, it is also noted that managers rely on researchers to use Earth Observation data and modelling for them, i.e. to bridge the science-policy gap. Thus in general Protected Area management wishes to work with suitable data but relies on them to be provided. This connection between research and management could be better established through, e.g. capacity development effort.

2.4 Arid ecosystems

2.4.1 Overview of the Arid Protected Areas

Five of the five arid/semi-arid Protected Areas involved in the project responded to the questionnaire and are included in the analysis. Samaria National Park falls under both arid and mountain ecosystem categories.

	Arid/Semi-arid Protected Areas
1	Har HaNegev
2	Kruger National Park

3	Samaria National Park
4	Murgia Alta
5	Montado i Alentejo

Objectives of the Protected Areas

The primary objectives of these Protected Areas all national parks but one, a Natura 2000 site, were to develop, expand, manage and promote sustainable national parks and ecosystems having biodiversity, societal and heritage assets; and to protect high species diversity or specific species, habitats and essential ecosystem services and biodiversity characteristics that contribute to the functioning and sustainability of the system. More specific aims included, amongst others, to protect the Hydro-Geo-Eco system to insure provisioning, regulating and cultural ecosystem services and sustainable tourism.

In terms of Earth Observation support in park history, only one Protected Area acknowledged links and benefits to Earth Observation. In that case, Earth Observation use to 1) show the distribution of ancient agriculture (3000 years old), 2) help to map the geodiversity that supports life in the Protected Area, and 3) aid understanding of the penology of tree types of primary producers (cyanobacteria, annual and woody plants), contributed to the establishment of the Protected Area. Earth Observation data were not available when the other areas were founded.

Management and Property regime

Oversight or some level of management is done by government or government agencies in all five cases but two sites (Murgia Alta and Montado) are primarily privately or independently operated. Four sites allow public access (one site did not answer) with two having most of the park designated as public (Har HaNegev and Kruger) and the other two as mostly private with limited public access (Murgia Alta and Montado).

The two government managed Protected Areas were mostly public in terms of access and the two primarily privately managed were mostly private with limited public access. One site (Samaria) did not provide details.

Funding and revenue

Nearly all the funding received is a mixture of public and private donations as well as tourist fees.

It was not possible to assess the amount of revenue generated as respondents did not typically provide figures across the trends. However, all respondents (except Montado which did not provide a response) do generate some revenue through entry fees and visitor centres and tours, through rental of public spaces, and in one case through extractive industry funds. Three of the five indicated that no payment for ecosystem services (PES) schemes were in place and two did not respond to this question.

Policy and normative frameworks relevant to Protected Area management

Responses to these questions were patchy. The only framework to receive more than two acknowledgements was the Natura 2000 (4 of 5 had connections to it). There were two LTER-connected sites. Otherwise, national park agencies and Mediterranean/European agencies all were mentioned by only one Protected Area.

Only Samaria and Montado responded to having connections on the supranational framework level with Montado mentioning connections to the Habitat and Birds Directives, Convention on Biological Diversity

(CBD) and the common agricultural policy. No sub regional connections were provided and nationally, Kruger is connected to the Protected Areas Act, National Park Authorities and National Parks Act. Montado listed connections to seven specific national laws. Other sites did not provide details. No sites responded to the questions on sub-regional schemes or provincial and municipal level connections.

Engagement with stakeholders

Stakeholder engagement occurs on multiple levels, and is most active at the level of municipal and national governments, NGOs and civil society representatives, local communities and scientific institutions. Stakeholder engagement with private companies, downstream communities and visitors was mostly mentioned by Murgia Alta and Montado.

Only one area, Samaria National Park, described a mechanism for stakeholder engagement: a council with representatives from all levels of government (local, regional, central) and from NGOs. Thus the Protected Area acts as a coordinator, bringing together views related to the Protected Area management.

2.4.2 Pressures and Ecosystem Services

What are the pressures facing the Protected Areas?

Perceived pressures on arid and semi-arid ecosystem Protected Areas are shown in Figure 5. The greatest pressures overall facing arid/semi-arid ecosystems are climate change and agriculture, followed by tourism, forestry, and landscape fragmentation, and then invasive species and resource extraction.

Pressures such as poaching might be more localized or area specific as might eutrophication (although in arid ecosystems this might have been more universal than was found here).

There was considerable variation in how each Protected Area ranked the pressures facing them. Given that there were only five respondents, however, no conclusive statements can be made on trends.

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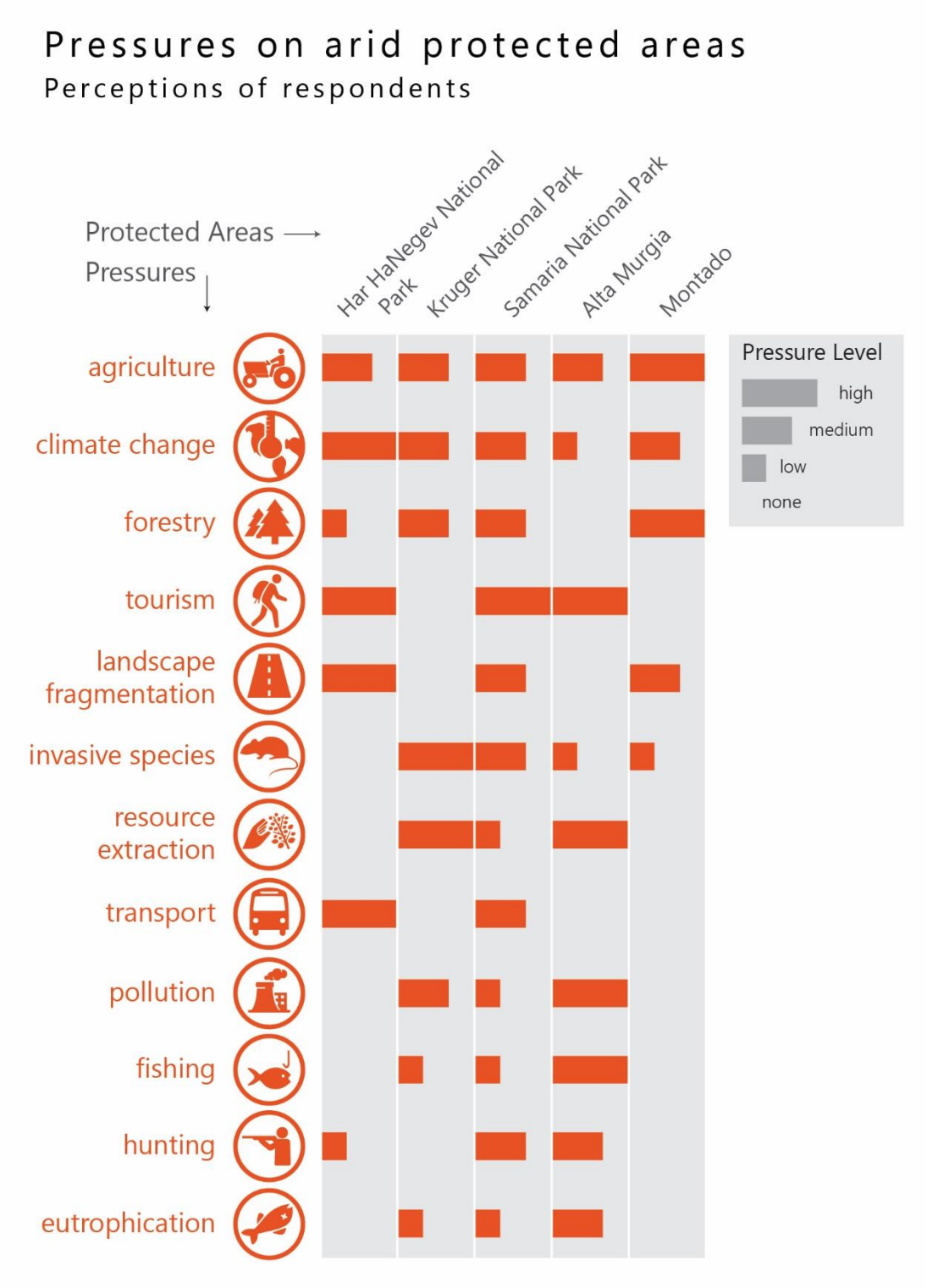

FIGURE 5. PERCEIVED PRESSURES ON PROTECTED AREA ARID AND SEMI-ARID ECOSYSTEMS

What are the important ecosystem services?

The importance of various ecosystem services in arid and semi-arid ecosystem Protected Areas is shown in Figure 6. Overall, respondents indicated cultural ecosystem services as the most important ecosystem

services, followed by regulating services and then provisioning services. This was similar to the responses provided by the Protected Areas in the mountain ecosystems and the coastal and marine ecosystems.

Within cultural ecosystem services, recreation/tourism, aesthetics and research, followed by education, were the most important, with spiritual significance being of the lowest value by a fair margin.

Life cycle and habitat, erosion prevention and flood control were the most important regulating services. Water treatment and pollination were the next most valued with carbon sequestration and pest and disease control being the lowest valued.

In terms of provisioning, freshwater - as might be expected in arid/semi-arid regions - was the most highly valued provisioning service followed by agriculture (both grain and meat based) and then energy production and wild non-meat and meat products.

Again, there was much individual variation and given the sample size of five, more specific trends are difficult to determine. Additionally whether a service was individually valuable or more broadly was also difficult to determine with only five Protected Areas in the analysis.

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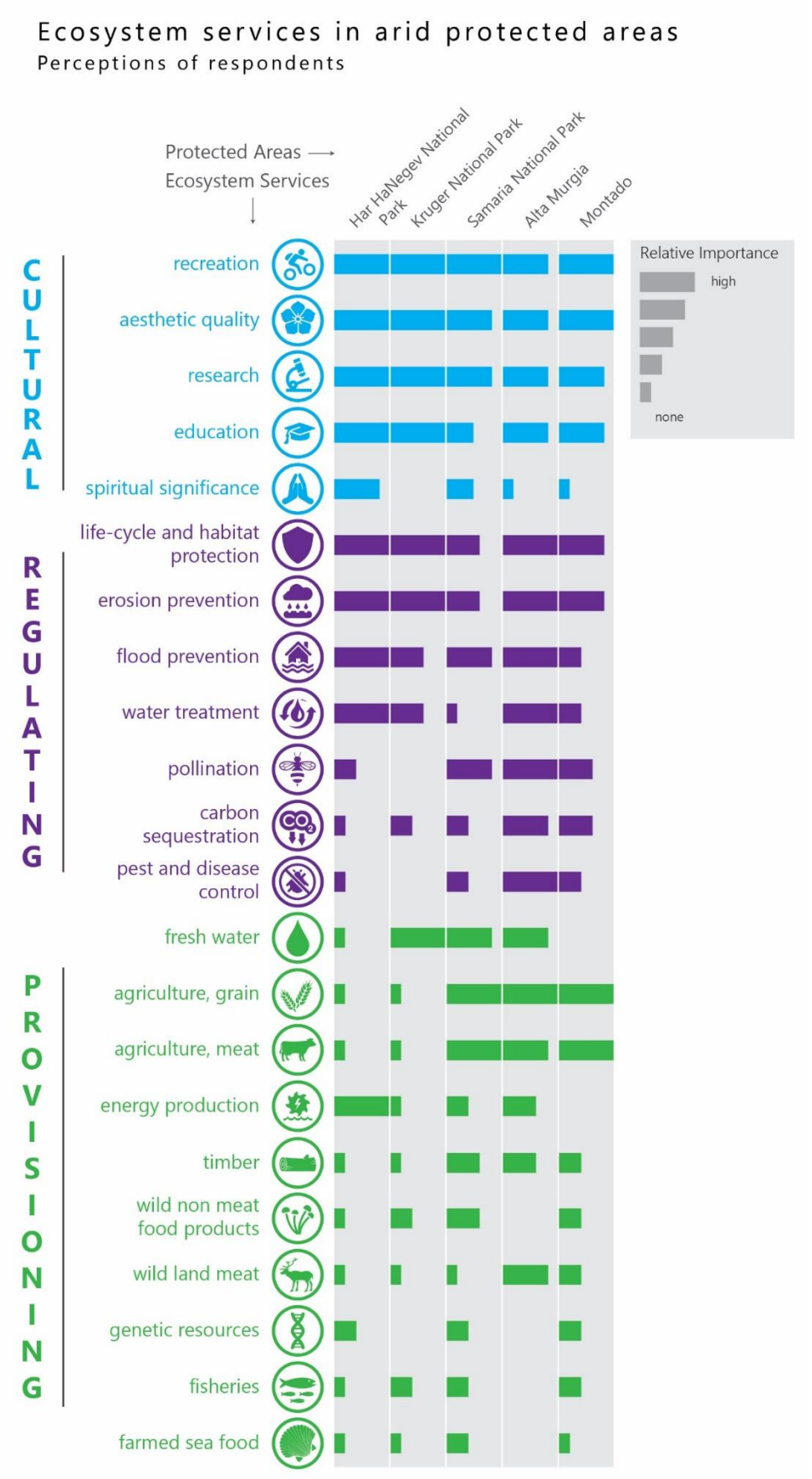


FIGURE 6. PERCEIVED IMPORTANCE OF ECOSYSTEM SERVICES IN PROTECTED AREA COASTAL AND MARINE ECOSYSTEMS

Use of ecosystem services framework in Protected Area management

Only two sites, Kruger and Montado, responded that ecosystem services were being considered in the area's management, specifically in relation to societal benefits and socio-ecological systems. The other sites responded that the approach had not yet been adopted or that no framework currently existed. This might suggest there was possibility in future.

In terms of beneficiaries of ecosystem services in the Protected Areas, local and downstream communities were generally seen as benefitting from harvesting of meat and grains and other local provisioning resources; governments from regulatory services such as flood prevention; private industries from local harvesting and provisions; and tourists, scientists and schools from cultural services.

2.4.3 Use of Earth Observation and of modelling, needs and wishes

Data gathering

Access to Earth Observation data is mixed among the Protected Areas, with only one having access to radar data, four of five having access to plane, drone and other airborne data (but not universally across these types), and all five having access to satellite/optical data.

All five arid/semi-arid Protected Areas use Earth Observation data to greater or lesser extents but only two have staff employed specifically for this purpose. There is a mix of skills ranging from data gathering through to more complex image processing and analysis, applied to, for example, vegetation analysis.

Three of the five Protected Areas believe that Earth Observation data could be further used in terms of both types of data and products (e.g., Sentinel SAR and Rapid Eye) and types of analysis/effort (e.g., monitoring).

Modelling

None of the areas used Earth Observation data for policy application and only one, Kruger, uses it for management purposes (using MODIS data to see if goals were met with regard to area of the Protected Area burnt). Three areas use Earth Observation data to a greater or lesser extent for indicators, assessments and reporting obligations but Murgia Alta and Montado did not report doing so.

Only two of the five Protected Areas suggested that data were being used to quantify ecosystem services, applied to carbon sequestration, crop production and spill protection (Montado) and river flow and carbon storage again (Kruger). Two Protected Areas (only one of the two mentioned in the previous statement) indicated that they would like to further monitor ecosystem services, generally amongst cultural, provisional and regulatory as detailed by one and specifically in terms of pollination, water purification and flood attenuation in the case of the second.

2.4.4 Main findings

- Lack of historical Earth Observation application means that it was unable to be integrated into Protected Area foundation or management before or early in the life of the Protected Areas with the exception of one arid area
- Frameworks did not play as large a role as they perhaps could in arid Protected Area management and this is one area that could be developed in future, perhaps helping uptake of understanding and knowledge of ecosystem services and Earth Observation application in the process

- As expected, main pressures on arid ecosystems were from climate change and agriculture, but also from tourism, forestry, fragmentation, invasive species and resource extraction, and the extent of the pressures felt were not universal across the five Protected Areas
- Cultural services are the most important overall ecosystem service type with recreation/tourism, aesthetics and research being the most valued; there was much variation in the regulating and provisioning services cited as important but life cycle and habitat, erosion prevention and flood control came up highest for the former and freshwater - as might be expected - followed agriculture and then energy production for the latter
- Only two of the five sites stated that ecosystem services were part of the Protected Area management regime; this suggest much potential exists for increased awareness and uptake of knowledge, skills and tools
- Access to Earth Observation data is mixed among the Protected Areas but access to satellite data is greatest with all five responding positively; all five use Earth Observation data to some degree and two have staff employed for this purpose with a mixed skill set across the five areas
- Three of the five Protected Areas believe that Earth Observation data could be used more both in terms of types of data and types of analysis/application; none use it for policy application and only one uses it for management purposes (using MODIS data to see if goals were met with regard to area of the Protected Area burnt). All three Protected Areas use Earth Observation data to a greater or lesser extent for indicators, assessments and reporting obligations.
- Only two of the five suggested that data were being used to quantify ecosystem services and two (one of which was quantifying Ecosystem Services with data) indicated that they would like to further monitor ecosystem services suggesting there is room for ECOPOTENTIAL in both ecosystem services and Earth Observation application in arid and semi-arid systems.

2.5 Summary assessment across ecosystem types

Looking collectively at the Protected Areas in the three ecosystem types, there are clear similarities and a few differences among them, (with the exception of obvious ones such as the importance of fisheries for coastal and marine ecosystems and fresh water from the mountains) in terms of the values placed on different ecosystem services and pressures felt. Also on the use of the ecosystem services framework and Earth Observation data for Protected Area management, there are clear similarities across the ecosystem types. Overall, the concept of ecosystem services is used in a small minority of the areas considered. Unfamiliarity with the concept and lack of an obligatory push from a legislative framework are given as the main reasons for lack of more universal uptake and application. The main formal aims of the Protected Areas are to protect the ecosystems themselves, in addition to providing recreation and other cultural services. From the responses, it seems the beauty of the landscapes and their value for recreation were the central benefits to society considered at the time the areas were protected.

Regardless, the Ecosystem Services approach seems to resonate positively with the respondents as logical and useful. An indication that the ecosystem services are intuitively grasped is that Protected Area managers could easily identify and prioritize the services relevant to their area. Interestingly, for all ecosystem types, cultural services ranked on average higher than the regulating and provisioning services. In all three ecosystem types, four out of the top five ecosystem services are cultural services: recreation, research, aesthetic qualities, and education. Managers also identified a substantial number of beneficiaries, i.e., people or organizations who benefit from the ecosystem services of Protected Areas. Payment for these benefits occurs mainly for cultural services, such as through entrance fees, guided tours and venue rental. Payment for provisioning and regulating services occurs only infrequently, or at least is not explicitly linked to the Protected Area. Examples from the respondents include payment for hunting and timber. The direct

revenue from the ecosystem services are spread across stakeholders, such as farmers and fishermen, and does not directly fund the Protected Areas.

The use of Earth Observation data for Protected Area management across all participating Protected Areas is, like with ecosystems services, limited, certainly when restricting Earth Observation to satellite data (aerial photography is used on several occasions). This does not, however, equate to or reveal a lack of interest in Earth Observation data: there is generally clear interest in the involvement of the ECOPOTENTIAL project to improve relevant understanding and use by the questionnaire respondents. The respondents generally indicated broad needs to allow them to effectively use Earth Observation data: technical training, training on applying the data in management, software and hardware were all noted as lacking. Respondents also said they need the data analysed with recommendations specific to their management, in addition to access to the raw data. A number of managers indicated that they work with and rely on the research community to make use of Earth Observation data. Overall, there is a significant amount of research occurring in the national parks, some of which does or could use Earth Observation, thus suggesting the potential for better integration. An important finding is that there are large gaps in the exchange between researchers and managers.

Decreasing this gap specifically might sharpen the focus on Earth Observation data relevant for addressing the ecosystems or ecological traits and data relevant for tourism, for example. But given the value placed on cultural ecosystem services across all Protected Areas, the question is raised as to how Earth Observation can be used to protect cultural heritage, landscapes and management of visitors.

Overall there was little use of Earth Observation data to quantify ecosystem services. As provisioning and regulating services are not directly part of the formal goals of the Protected Areas and do not directly provide funding to the areas, there are clear limitations for active use of quantification of ecosystem services with Earth Observation data in management. Until there are legal frameworks and the necessary funding in place, Earth Observation is not likely to be used to quantify ecosystem services as a central part of Protected Area management.

The Habitats Directive and the Birds Directive apply to many Protected Areas. These European directives could, therefore, be a suitable vehicle to anchor the use of Earth Observation and ecosystem services related to natural heritage. Also, the Water Framework Directive and the Marine Strategy Framework Directive can provide support, although for the coastal and marine Protected Areas where they appear to be less embedded, additional effort to strengthen the connections might be required first.

3 Assessment of gaps, needs and opportunities

3.1 Opportunities for application of Earth Observation

3.1.1 Applications of Earth Observation in ECOPOTENTIAL

The ECOPOTENTIAL project is at the forefront of developing new tools and methods of harnessing the data available both from Earth Observation and in-situ environmental monitoring data in order to characterise the current state and ongoing and expected changes in biodiversity, ecosystem functioning, processes and services. Several examples from the ECOPOTENTIAL project illustrate the use and application of Earth

Observation across the mountain, coastal and marine, and arid ecosystems[3]. Below three case studies are presented.

3.1.1.1 Case Studies

Case Study 1

Monitoring the health of sensitive, biodiverse mountain lakes

Location:

Prespa and Ohrid Lakes (Macedonia, Greece and Albania)

The Challenge

Mountain lakes face a number of pressures and threats, including growth in tourism, rapid urbanization, pollution, land use intensification, water uptake, increasing eutrophication, introduction of alien species and climate change. Responses to these pressures can include shifts in timing, magnitude and duration of phytoplankton blooms, as well as altered community composition. These in turn can lead to changes in water quality and a decrease in overall biodiversity.

The management of freshwater ecosystems generally relies on the availability of accurate in situ measurements and analyses of water samples. A lot of data on the physical, chemical and biological properties of the lake waters are available. In-situ data, however, give information only for a single point in time and space, thus providing limited information on spatial and temporal changes of environmental parameters across surface waters.

The Application of Earth Observation in ECOPOTENTIAL

The high spatial resolution of satellite images allows for the estimation of water quality and hydrological parameters, such as chlorophyll concentration, phenology metrics, surface currents and surface area. Information drawn from Earth Observation at the catchment scale on land cover, land use, vegetation status and forest fires also facilitates the establishment of linkages between catchment scale alterations and lake ecosystem processes.

As such, remote sensing data can complement and extend traditional lake sampling methods, facilitating understanding of the current state of lake ecosystems and supporting the application of appropriate management strategies.

[3] The ECOPOTENTIAL project partners have defined storylines, which link real-life issues to the project's Protected Areas. The storylines capture the need for Earth Observation data for ecosystem modelling, ecosystem services, cross-scale topics, demands for future protection, policy and capacity building. These are aimed to be broad yet locally relevant, engaging with stakeholders and decision-makers, forming the basis for further operational work in the field.

Case Study 2

Assessing the impact of urban expansion on the life-supporting capacity of dryland ecosystems

Location:

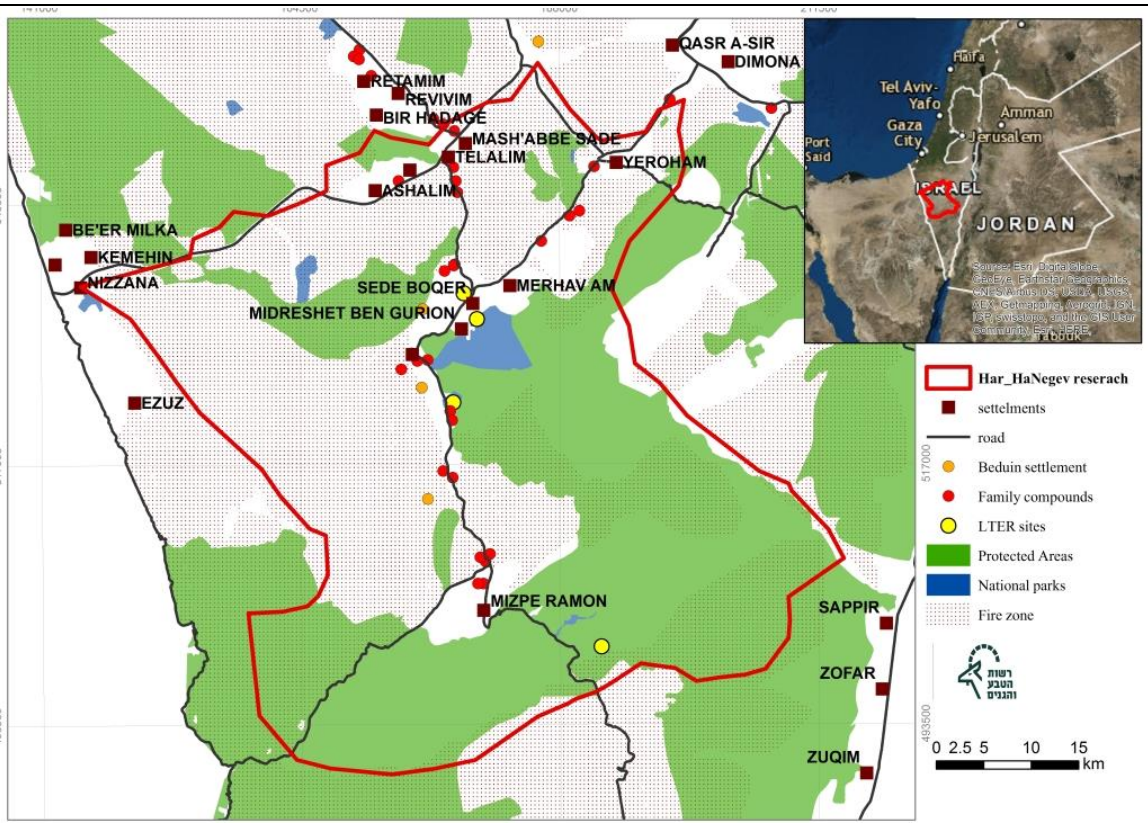
Har HaNegev, Israel

The Challenge:

Israel is one of the most densely populated countries in the world, and its fast-growing population drives an increasing pressure for rapid residential development. The Negev highland, within the southern arid part of Israel, is the largest undeveloped land resource of the country, and government policy encourages redirecting growth to this region. Residential development, therefore, is projected to expand to this area. It is crucial to understand the effect of such settlement on the ecological integrity of the system. The area also experiences competing land uses from mining, agriculture, grazing, tourism, and recreation. Army training also has a considerable impact.

The Application of Earth Observation in ECOPOTENTIAL:

While all these types of settlements and land uses have considerable effect on the biodiversity and the ecological integrity of Har HaNegev, these effects and ways to mitigate them are not well understood. Earth Observation systems are especially useful to understand the effect of land use pressure on the ecological integrity of Har HaNegev. A major goal within ECOPOTENTIAL is to develop tools to use Earth Observation in arid environment in order to track changes in biodiversity, ecosystem dynamics, and ecosystem services provisioning, driven by land use changes.



Case Study 3

Improving approaches for whale conservation and tourism in the Mediterranean

Location: Pelagos Sanctuary, Mediterranean Sea

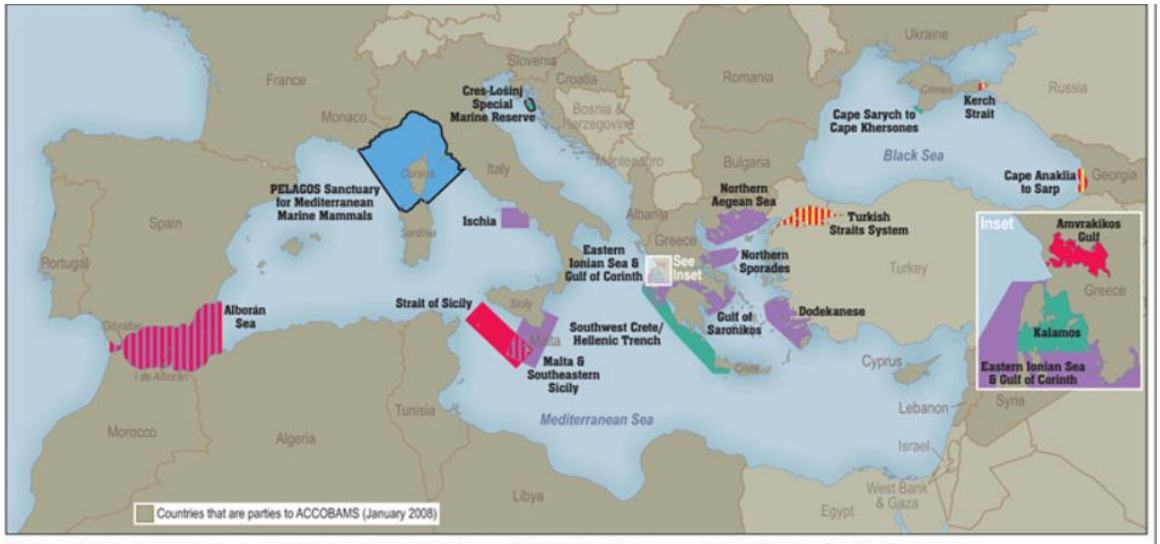
The Challenge:

Nine species of whales exist in the Mediterranean Sea, and these provide the basis for a whale watching tourism industry across several countries. These whale populations are also exposed to a number of threats, including overfishing, underwater noise, fisheries bycatch and plastic debris. The presence of big vessels also can also lead to death or injury from boat strikes.

A number of marine protected areas (MPAs) have been designated or are proposed to protect these species (see map). One of the existing MPAs is the Pelagos Mediterranean Sanctuary, which is located between the island of Sardinia and the coasts of Italy and France. However, a fragmented understanding currently exists about the movements and population status of whale species, and of the activities of tourism operators and fishing and shipping industries.

The Application of Earth Observation in ECOPOTENTIAL

The ECOPOTENTIAL project and its partners are applying several approaches to better understand the situation: applying ground-breaking approaches to using satellite data and images to count whales; applying ecological modelling methods to better understand and predict where species' critical habitats are located; and working with over 94 whale watching companies to understand how and where they operate. An important end-goal is to bring this information together to inform management decisions for the Pelagos Sanctuary.



Status of Existing and Proposed Marine Protected Areas (MPAs) for Whales and Dolphins in the Mediterranean and Black Seas by ACCOBAMS *(Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area)*

On 25th October 2007, at the Third Meeting of the Parties of ACCOBAMS, held in Dubrovnik, the Parties adopted Resolution 3.22 supporting in principle the creation of the MPAs shown above, as well as others to be defined, and welcoming the criteria and guidelines for setting up additional MPAs in the region which include management plans to address threats to cetaceans. The Parties have agreed to begin the process to work with local communities to designate these and other areas as set out in the criteria and guidelines.

- PELAGOS Sanctuary for Mediterranean Marine Mammals, designated 1999 in the waters of Italy, France and Monaco and the adjacent high seas and subsequently declared a SPAMI (Specially Protected Area of Mediterranean Interest)
- Cres-Lošinj Special Marine Reserve, granted 3-year preventive protection 2006, MPA designation pending
- Four pilot MPAs adopted by the Parties in 2002 as international priorities under the proposal of the Scientific Committee
- Six important cetacean areas in the Black and Mediterranean seas and contiguous Atlantic area proposed by the ACCOBAMS Scientific Committee in November 2006 and agreed in principle by the ACCOBAMS Parties in October 2007
- Three cetacean areas proposed for protection by the Black Sea Commission's Round Table on Conservation of Black Sea Cetaceans, Istanbul, May 2006
- Eight proposed MPAs recommended by the ACCOBAMS Scientific Committee as part of the Mediterranean Common Dolphin Conservation Plan

Please note: Boundaries for proposed areas are approximate as suggested by current research and will need to be drawn more precisely on a case-by-case basis as additional research is obtained.

UNEP CMS ACCOBAMS WDCS

3.1.2 Frameworks and directives relevant to ECOPOTENTIAL

A number of frameworks with relevance to the ECOPOTENTIAL project exist, as described below. It was determined from the questionnaire results that their use was more limited than might have been expected. This is one avenue to pursue with the Protected Area managers when we meet.

3.1.2.1 Coastal and Marine

Two main directives have been developed and implemented for the protection of the natural aquatic environment (fresh water, brackish water and marine water): the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD).

3.1.2.1.1 Water Framework Directive

The Water Framework Directive was implemented in 2000 (EC, 2000) and is aimed at the protection of the ecological quality of complete river basins, from source to the outer deltas they create. For ECOPOTENTIAL, its applications in so-called transitional waters and coastal waters are of most importance: lagoons and estuaries are part of the protection regime under the Water Framework Directive. All transitional and coastal waters up to 12 nautical miles from the territorial baseline are assigned as either a Transitional Water body,

or a Coastal Water body. The Water Framework Directive itself does not mention ecosystem services explicitly, but there is considerable literature linking the Water Framework Directive legislation to the use of ecosystem services.

3.1.2.1.2 Marine Strategy Framework Directive

The main policy document in the marine waters of the EU is the Marine Strategy Framework Directive, which aims to achievement of Good Environmental Status of the EU's marine waters by 2020. This directive promotes sustainable use of the seas and conserves marine ecosystems under the ecosystem-based approach. The Marine Strategy Framework Directive has divided the relevant characteristics of the marine environment to achieve Good Environmental Status into eleven descriptors, including, for example, biodiversity, eutrophication and marine litter. It is the first legislative piece that explicitly mentions ecosystem services (preamble 8), in the context of the ecosystem-based approach. The EEA has recently published it State of Europe's Sea report in which it shows a methodology to derive ecosystem services state based on information from assessment reporting under the Marine Strategy Framework Directive.

3.1.2.2 Mountains

No overarching directive for ecosystem services exists specifically for mountainous areas. The EEA released a report in 2010 (EEA 2010) on mountain ecosystems and the services they provide, however, there are no recommendations included on how these services should be conserved.

There are a few regional conventions, i.e., the Alpine Convention (1992) and Carpathian Convention (2003). However, these do not mention ecosystem services explicitly, even if ecosystem functioning and specific services such as tourism and recreation are discussed.

3.1.2.3 Semi-arid areas

On a European level, there are no directives that deal specifically with ecosystem services in semi-arid areas.

3.1.3 Analysis

The most relevant policy instrument for all Protected Areas is the EU Biodiversity Strategy 2020 and, more specifically, the Mapping and Assessment of Ecosystems and their Services (MAES) in which ecosystem services are explicitly mentioned and an approach is provided on how to implement it on a national level. MAES is currently being developed further within EU research projects MARS and ESMERALDA, based on the finished project MESEU. There are other relevant methodologies for deriving ecosystem services values from Natura 2000 areas, and specifically for the marine environment, currently a methodology is being developed at the EEA. MAES thus can be based on classifications, descriptions and assessments from EU legislative environmental frameworks such as Birds and Habitats Directive, Water Frameworks Directive and Marine Strategy Framework Directive.

For the terrestrial environment, the Natura2000 network (as based on the Birds and Habitats Directives) is the basis for natural environment protection and conservation. For the marine environment, the legislative frameworks that apply best are those in the Water Frameworks Directive and Marine Strategy Framework Directive.

Many EU directives seem to make the link with ecosystem services through biodiversity, but, apart from the Biodiversity Strategy, do not mention ecosystem services explicitly.

There is a lack of pragmatic translation of these directives for use by Protected Area managers directly, since the directives are implemented on a national level, while many of the ecosystem services methodological frameworks mentioned above are developed at a regional or EU level. We are aware of various member states that have developed methods for assessing (mostly terrestrial) ecosystem services, but to our knowledge, these methods are far from harmonized. Protected Area managers are thus dependent on a member state-based method (if present) on if and how to incorporate ecosystem services into operational management of an area.

3.1.4 References

Alpine Convention (1992) http://www.alpconv.org/en/convention/framework/default.html
Carpathian Convention (2003) http://www.carpathianconvention.org/text-of-the-convention.html
EEA (2010) 10 messages for 2010 Mountain ecosystems, pp. 16
EEA (2013) The economic benefits of the Natura 2000 network, synthesis report, pp. 76
EU Council Directive 92/43/EEC, pp. 44
EU Directive 2009/147/EC, pp. 19
EU Directive 2008/56/EC, pp. 22
EU No 1143/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species, pp. 22

4 Summary and Recommendations

4.1 Key findings

Application of Earth Observation data and particularly as it relates to ecosystem services was more limited than might have been expected across all Protected Areas generally. Some caution is necessary, however, in drawing this conclusion as the phrasing of a questionnaire can have a big impact and the sample sizes both within and across ecosystem types were limited. We aim to follow up on the findings and determine further details in the stakeholder meeting in the spring of 2017 to clarify some of the details and better understand the situation and state of implementation. These details will aid the understanding of the scientific requirements and the role of the scientific community in supporting the Protected Area managers as well as the data access and type needs.

4.2 Recommendations

Recommendations from the work and analysis so far include better awareness of the types and functions of Protected Area data and technologies, as they can be used by Protected Area managers and, conversely, improved awareness of what managers need and can use. Manager, scientists, policy-makers and other stakeholders could all benefit from improved information flow. Such improvement can be considered and integrated from both a practical and policy perspective.

This synthesis study report is a stepping stone to further analysis and more detailed assessment but it has helped indicate where gaps exist in the transfer of knowledge and applications.

To improve the understanding of the ecosystem services framework and the application of Earth Observation, we suggest holding workshops to increase uptake and awareness of Earth Observation; publishing relevant educational leaflets and materials; presentation of other media such as video potentially; and inclusion of storylines in published material, providing contexts and details of practical situations that both scientists and Protected Area managers can relate to better their understanding.

A clearer understanding of what the Protected Areas need is required on various levels including policy and governance, management, and on the ground/stakeholder levels.

This effort has been an effective start in understanding the current situation of Earth Observation use and understanding for Protected Area managers, in particular as it relates to the inclusion of ecosystem services. More effort is needed, however, and bringing stakeholders together is most likely the most effective method to gain improved understanding. Once this happens in 2017, we will be able to better assess the situation and determine how Protected Area managers can best be assisted by the ECOPOTENTIAL project.

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5 Appendices

5.1 Appendix 1 Questionnaire for synthesis study – questions relevant to ES and EO

Integration of Earth Observation tools in decision making for Protected Areas

Selections from the Questionnaire for ECOPOTENTIAL (D 11.1 (Research outputs) 11.2 (Synthesis study)**)**

Part 1: Identifying the goals, challenges and management of the PA

1.1 Vision and purpose

1.1 What is aimed to conserve or protect at your PA?	
1	
2	
3	
4	
4	
5	
6	

1.2

1.1 Why was this area designated a PA? Can you provide the historical circumstances leading to the creation of the PA? Was there evidence provided throughout Earth Observation tools/data to support this?

1.3

What are the most damaging environmental pressures or threats to your PA?				
Environmental pressures	High pressure	Medium pressure	Low pressure	No pressure
Agriculture, please specify how:	☐	☐	☐	☐
Forestry, please specify how:	☐	☐	☐	☐
Climate change	☐	☐	☐	☐
Invasive species	☐	☐	☐	☐
Eutrophication	☐	☐	☐	☐
Tourism, please specify how:	☐	☐	☐	☐
Pollution	☐	☐	☐	☐
Hunting	☐	☐	☐	☐
Fishing	☐	☐	☐	☐
Other biological resource extraction (e.g. shells, berries), please specify:	☐	☐	☐	☐
Transport	☐	☐	☐	☐
Landscape fragmentation	☐	☐	☐	☐

Please fill in if others:	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐

Governance and funding

1.4

What type of PA management regime is in place? (e.g. government led, decentralized governance, community, private)

1.5

What is the property regime in the PA area?[4]	
	Percentage area
Private property (please specify major landholders, e.g. water companies, forestry	
Public property	
Common Property	
Open Access	
Comment: How much of the areas is openly accessible, e.g. can be visited?	

1.6

What are the sources of funding?	Total funding per source: (estimate/year)
Public funds	
Private donations	

1.7

[4] Kinds of property regimes: **Private property** occurs when the strands of the property rights bundle are held by a natural or legal person. **Common property** exists where property rights strands are shared among members of a community or association. **Public property** is established when the property is concentrated, held and managed by the government. **Open access** occurs where either no specific rights to land or natural resources have been assigned or claimed by holders.

Does the PA generate revenue? (Funds generated directly from users or beneficiaries of the PA)	Yes ☐	No ☐
If yes, how:	How much per activity:[5]	
Entry fees		
Payment for ecosystem services		
Rental of space/venues		
Extractive industries		
Visitor centres / guided tours		

1.8

What are your connections with existing networks of PAs?	
PA Networks	Member
EUROPARC	☐
Natura 2000	☐
Sub-regional networks: e.g. Carpathian Network of Protected Areas (CNPA), ALPARC Please specify:	☐
LTER Europe	☐
Others	☐
	☐
	☐

1.9

What are the policy and normative frameworks (laws and relevant policies) most relevant to the management of your PA? (Please fill in where appropriate and specify also the relevant law gazette)
Supranational: EU-level (EU-Directives, etc.)
Sub-regional (e.g. Alpine Convention, Carpathian Convention)
National level
Provincial level
Municipal / local level

[5] Please use any currency.

Other:

1.10

What are the key stakeholders you engage with in decision making processes?					
Stakeholders	Very involved	Involved	Somewhat involved	Unknown	Not relevant
Municipal government(s)	☐	☐	☐	☐	☐
Regional government(s)	☐	☐	☐	☐	☐
National government(s)	☐	☐	☐	☐	☐
Private companies	☐	☐	☐	☐	☐
Local community	☐	☐	☐	☐	☐
Visitors	☐	☐	☐	☐	☐
Downstream communities	☐	☐	☐	☐	☐
NGOs, civil society representatives	☐	☐	☐	☐	☐
Scientific institutions	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐

1.11

What are the mechanisms of exchange with stakeholders?

Ecosystem Services

Overall question for this section: What are the needs of PA managers for monitoring ecosystem services?

1.12 Ecosystem Services Card for the PA: Which ecosystem services are important?

	7. How important are the following ecosystem services to the beneficiaries of the PA? ***(Relative to the other ecosystem services, on a scale from 1 (least important) to 5 (most important) ?=unknown)***							
	Ecosystem service	1	2	3	4	5	?	#
Provisioning services	Agriculture, meat	☐	☐	☐	☐	☐	☐	1
	Agriculture , grain	☐	☐	☐	☐	☐	☐	2
	Fisheries	☐	☐	☐	☐	☐	☐	3
	Farmed sea food	☐	☐	☐	☐	☐	☐	4
	Genetic resources	☐	☐	☐	☐	☐	☐	5
	Timber	☐	☐	☐	☐	☐	☐	6
	Wild land meat	☐	☐	☐	☐	☐	☐	7
	Wild non meat food products (e.g. berries, mushrooms, kelp)	☐	☐	☐	☐	☐	☐	8
	Fresh water	☐	☐	☐	☐	☐	☐	9
	Energy production (e.g. hydropower, wind farms)	☐	☐	☐	☐	☐	☐	10
	Please fill in if others:	☐	☐	☐	☐	☐	☐	11
		☐	☐	☐	☐	☐	☐	12
		☐	☐	☐	☐	☐	☐	13
		☐	☐	☐	☐	☐	☐	14
		☐	☐	☐	☐	☐	☐	15
Regulating services	Carbon sequestration and storage	☐	☐	☐	☐	☐	☐	16
	Erosion prevention (coastal or inland)	☐	☐	☐	☐	☐	☐	17
	Lifecycle and habitat protection	☐	☐	☐	☐	☐	☐	18
	Pollination	☐	☐	☐	☐	☐	☐	19
	Pest and disease control	☐	☐	☐	☐	☐	☐	20
	Water treatment	☐	☐	☐	☐	☐	☐	21
	Flood prevention	☐	☐	☐	☐	☐	☐	22
	Please fill in if others:	☐	☐	☐	☐	☐	☐	23
		☐	☐	☐	☐	☐	☐	24
		☐	☐	☐	☐	☐	☐	25
		☐	☐	☐	☐	☐	☐	26
Cultural services	Spiritual significance	☐	☐	☐	☐	☐	☐	27
	Recreation	☐	☐	☐	☐	☐	☐	28
	Education	☐	☐	☐	☐	☐	☐	29
	Aesthetic qualities	☐	☐	☐	☐	☐	☐	30
	Research	☐	☐	☐	☐	☐	☐	31
	Please fill in if others:	☐	☐	☐	☐	☐	☐	32
		☐	☐	☐	☐	☐	☐	33
		☐	☐	☐	☐	☐	☐	34
		☐	☐	☐	☐	☐	☐	35
Other	*Please fill in if others:*	☐	☐	☐	☐	☐	☐	36
		☐	☐	☐	☐	☐	☐	37
		☐	☐	☐	☐	☐	☐	38
		☐	☐	☐	☐	☐	☐	39

		☐	☐	☐	☐	☐	☐	40
		☐	☐	☐	☐	☐	☐	41
		☐	☐	☐	☐	☐	☐	42
		☐	☐	☐	☐	☐	☐	43
		☐	☐	☐	☐	☐	☐	44

1.13

Is a ecosystem service framework used in the management of your PA?	Yes ☐	No ☐

If no, why not? And if yes, why?

1.14

Who are the main beneficiaries (direct and indirect) of the PA ecosystem services? And how do these groups benefit from the PA?	
Stakeholders	Which ecosystem services benefit the stakeholders? (use numbers from ES list, from 1.12)
Local communities	
Downstream communities	
Government	
Local farmers	
Other private industries (please specify)	
Others please specify:	

Part 2: Data collection practices and needs – Earth Observation(EO) and other research

Overall question: *What is the current use of EO data, research practices and research needs?*

2.1

Which quantitative or qualitative indicators are used to monitor progress towards the main goals of the PA listed above (question 1.1)? (e.g. habitat mapping using aerial photographs, bird surveys, water quality, visitor counts - if none, please indicate NA)	
1	
2	
3	
4	
4	
5	
6	

2.2

What environmental and socio economic data is /has been collected in situ?
Environmental data:

Socio economic data:

2.3

Do you use modelling? Please list and briefly describe most used models.

2.4

Do you need further modelling? If so, please list and describe modelling needs.

2.5

Please list reports or publications based on data from the PA:

2.6

Do you use the above collected data to quantify ecosystem services? If yes, please specify which ecosystem services.

2.7

Would you like to further monitor ecosystem services? If yes, please specify which.

2.8

To which Earth Observation (EO) data sources do you have access?	
Radar images	☐
Satellite images/optical	☐
Plane images	☐
Drone images	☐
Airborne platforms	☐
Buoy based instruments	☐
Snow gauge	☐
Wind gauge	☐
Others, please specify:	☐
	☐
	☐
	☐
	☐

2.9

Which EO-resources and tools are currently in use for the management of your PA?

2.10

Are further EO resources or tools needed for the management of your PA?

2.11

What hardware and/or software do you employ to collect and analyse EO data?

2.12

How many staff members use EO data?		
Do you have specific staff members working mainly with monitoring?	Yes ☐	No ☐
What skills do they have specific to EO data collection, analysis and application?		

2.13

How are EO data and/or models used to inform the following processes in your PA:
Indicators, assessments and reporting obligations
Policy frameworks
Management (including elaboration and revision of management plans) and decision making

2.14

What are the challenges you face with respect to EO data/tools in decision making?

2.15

How could ECOPOTENTIAL or other potential science projects help to tackle the challenges above (question 2.14)? *We cannot guarantee to follow all suggestions within ECOPOTENTIAL but where applicable we can aim to adjust the planned work programme.*

2.16

Are there EO science policy interface dialogues happening in your PA (and if so what types)?

3: Collaborating with ECOPOTENTIAL and communicating results

Collaborating with ECOPOTENTIAL

3.5

What kind of training/capacity building workshops for the use of ECOPOTENTIAL data and toolkits do you think would be most useful to the PA staff? Kind of training	Yes	No	Maybe
Software training	☐	☐	☐
Training in collecting EO data *in situ (in the office, in the field)*	☐	☐	☐
Training in collecting EO data online	☐	☐	☐
Training in analysing and processing EO data	☐	☐	☐
Other please specify:	☐	☐	☐
	☐	☐	☐
	☐	☐	☐
	☒	☐	☐
	☐	☐	☐
Who should be trained?			

5.2 Appendix 2 Questionnaire Respondents – Details

Name	ES Type	Country	Partner	Type of Protection	Role of respondent at PA
Wadden Sea and Dutch Delta	Coastal and Marine Ecosystems	The Netherlands	Koninklijk Nederlands Instituut voor Onderzoek der Zee	UNESCO Biosphere Reserve (World Heritage)	NA
Danube Delta	Coastal and Marine Ecosystems	Romania	University of Bucharest	UNESCO Biosphere Reserve (World Heritage) Ramsar site, NATURA 2000 site	Contact person for PA in the ECOPOTENTIAL Project
Curonian Lagoon	Coastal and Marine Ecosystems	Lithuania	Klaipeda University	NATURA 2000 site, Curonian Spit cultural landscape is on UNESCO World Heritage List since 1999 Baltic Sea Protected territory by HELCOM	Vice director
Curonian Lagoon	Coastal and Marine Ecosystems	Lithuania	Klaipeda University	NATURA 2000 site, Curonian Spit cultural landscape is on UNESCO World Heritage List since 1999 Baltic Sea Protected territory by HELCOM	Environmental specialists
LME2: Mediterranean	Coastal and Marine Ecosystems	transnational	United Nations Educational, Scientific and Cultural Organization	Marine Protected Areas	Scientific Support (TETHYS Institute)
Doñana National Park	Coastal and Marine Ecosystems	Spain	Doñana National Park	National Park	Conservation Director of PA
Camargue	Coastal and Marine Ecosystems /Wetlands	France	Tour du Valat	UNESCO Biosphere Reserve, Regional Park, Natura 2000, Ramsar site	GIS Officer
Gran Paradiso	Mountain Ecosystem	Italy	Consiglio Nazionale delle Ricerche	National Park; Special Protection Area (Birds Directive); Site of Community Importance (Habitat Directive)	Biologist
Lakes Ohrid/Prespa	Mountain Ecosystem	Former Yugoslav Republic of Macedonia	PSI Hydrobiological Institute, Ohrid	UNESCO world heritage site / Ramsar site and Monument of Nature	Researcher

Continued next page

Name (cont)	ES Type	Country	Partner	Type of Protection	Role of respondent at PA
Lakes Ohrid/Prespa	Mountain Ecosystem	Former Yugoslav Republic of Macedonia	PSI Hydrobiological Institute, Ohrid	UNESCO world heritage site / Ramsar site and Monument of Nature	Environment Sector, Department for water and natural resources, project coordinator of the project for Restoration and management of Prespa Lake,
La Palma Island	Mountain Ecosystem	Spain	University of Bayreuth	Biosphere Reserve (whole island), including a national park (Caldera de Taburiente), UNESCO starlight reserve,	Director of National Park
La Palma Island	Mountain Ecosystem	Spain	University of Bayreuth	Biosphere Reserve (whole island), including a national park (Caldera de Taburiente), UNESCO starlight reserve,	Biologist
Samaria	Mountain Ecosystem, Water-limited Ecosystems	Greece	FORTH - Foundation for Research and Technology - Hellas	UNESCO Biosphere Reserve (World Heritage), National Park, Natura 2000 site	Project Coordinator
Northern Limestone NP	Mountain Ecosystems	Austria	European Environment Agency	National park (IUCN Cat II); Natura 2000	Geoinformatic and IT
High Tatra Mts.	Mountain Ecosystems	Poland/Slovakia	United Nations Environment Programme	UNESCO Biosphere Reserve / national parks / N2000 (both SCIs and SPAs	Spatial Data Management Specialist
Hardangervidda	Mountain Ecosystems	Norway	University of Bergen	NATIONAL park (IUCN Cat. II) , and adjacent landscape protected area (IUCN Cat. V)	Post-doc on the Hardangervidda National Park part of the ECOPOTENTIAL project
Swiss National Park	Mountain Ecosystems	Switzerland	ETH Zürich	National park (IUCN Cat. Ia); UNESCO Biosphere Reserve	Researcher
Har HaNegev	Water-limited Ecosystems	Israel	Ben Gurion University	Natural reserve; UNESCO World Heritage site.	Researcher
Kruger National Park	Water-limited Ecosystems	South Africa	Council for Scientific and Industrial Research (CSIR)	National Park	Scientist