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Measuring the benefits of marine protected areas in the context of EU's Natura 2000 network - scoping the methodology

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1 Introduction

The Natura 2000 network is the most extensive protected area system in the world, comprising more than 27,300 sites covering approximately 18% of the EU land area (EC 2015). It consists of Special Protection Areas (SPAs) and Special Areas of Conservation (SACs), classified under the EU Birds and Habitats Directives respectively. The SPAs and SACs, forming the Natura 2000 network, should contribute to the maintenance and restoration of favourable conservation status of the habitats and species listed in the annexes of the Habitats and Birds Directives (known together as the EU nature directives).

The Natura 2000 network also includes a growing marine protected area (MPA) network – now with over 3,000 sites covering over 318,133 km^2 (EC 2015). These areas are of importance for marine biodiversity, but also provide a range of co-benefits in the form of ecosystem services, including provisioning services (fish), regulating services (e.g. carbon storage) and cultural services (support to recreation activities and tourism). In general, ecosystem services are defined as the direct and indirect contributions of ecosystems to human wellbeing (Kumar 2010).

The aim of this paper is to provide an overview of existing analyses of the benefits provided by the EU MPAs, and to outline a possible step-wise methodology to assess the overall benefits provided by the EU marine Natura 2000 network.

Overview of the step-wise method for assessing socio-economic benefits

Developing an overall assessment of the benefits provided by the marine Natura 2000 network requires the following steps, discussed in turn below:

Step 1: Assessing the state of knowledge of MPA benefits for specific sites. This assessment needs to build on a comprehensive literature review. In the longer term, it should also comprise of new studies and/or analyses that transfer estimates of benefits from one site or area to other comparable sites or areas.

Step 2: Assessing the basis and opportunities for scaling up, including determining the scope and principles for assessment. To carry out an overall assessment of the MPA benefits, there is a need to ensure that an adequate amount of case data are available from previous analyses of protected areas to form a (sufficiently) robust basis for scaling up to the total benefits at the EU level. In order to do so, it is important to investigate whether enough evidence is available to estimate the value of the ecosystem services provided by the MPAs, or at least a subset of them, in physical and monetary terms.

→ If not enough case data are available, a synthetic analysis, building on a range of available qualitative, quantitative and monetary case insights, is the most appropriate route to take for an EU wide multiservice value assessment. More systematic (quantitative/monetary) approaches can still be attempted but for experimental purposes only.

→ If enough case data are available, further analysis should be carried out to explore whether they allow robust quantitative/monetary assessments to be carried out for a set of ecosystem services.

Step 3: Assessing the EU benefits by adopting a suitable approach. To date, there have been some experimental assessments of EU MPA network benefits that focused on a subset of services. These assessments could provide a basis for broader EU-wide aggregate assessments in the future.

Step 4: Assessing the level of robustness of the scaled-up results. Even with a sufficient amount of case data available, a range of assumptions must be made to scale up benefits to the EU level. There is a need to place the results into the context of these assumptions, taking into consideration the methods used for scaling up, data availability and all the assumptions used.

2 Step 1: Assessing the existing literature on benefits at site level

MPAs maintain and can offer the full range of ecosystem services. However, based on existing information, four types of services and related socio-economic benefits are most prominently studied:

- Provisioning services: food provision;
- Regulating services: climate regulation (carbon storage and sequestration);
- Regulating services: natural hazards control / mitigation; and
- Cultural services: recreation and ecotourism.

Food: MPAs can have positive effects on overexploited fish stocks as management measures (e.g. restricting fishing and other human activities, protecting habitats and populations) are likely to lead to a reduction of fishing pressures. This can affect fisheries' production both within sites and off-site, increasing the carrying capacities and hence potentially sustaining or increasing yields of nearby fisheries.

Climate regulation: Marine and coastal ecosystems such as saltmarshes, seagrass ecosystems and (in tropical and subtropical regions) mangroves often accumulate and store large amounts of carbon. MPAs can help protect the functioning of the ecosystems such that sequestration continues and stocks are not lost through degradation. A ban on activities such as dredging and filling contributes to the integrity of this storage. Further measures, such as controlling the quality of water inflow from land and rehabilitating drained coastal ecosystems, also support the ability of ecosystems to retain and sequester carbon.

Natural hazards control: Physically intact coastal and marine ecosystems provide a natural mechanism for protecting shorelines and coastal regions - often important areas of socio-economic activity - from natural hazards such as storm surges and coastal erosion. Extended seagrass meadows and saltmarshes can serve as a natural buffer against the impacts from the sea. The existence of these ecosystems can also reduce the need for grey infrastructure such as levees or groins. This ecosystem-based protection also has the potential to adapt naturally to environmental changes such as sea-level rise.

Recreation and ecotourism: Marine and coastal ecosystems are of high socio-economic importance as regards their recreational value. They provide opportunities for several recreational activities that depend highly on the quality of ecosystems (e.g. quality of bathing water, quality of areas for snorkelling and diving, availability of fish for recreational fishing, availability of charismatic animals for wildlife watching).

Table 1 presents the results of a brief scoping of the available analyses of the benefits provided by MPAs including both site-based and wider estimates. While illustrative only, the examples included in the table provide an idea of the current level and type of information available. The table includes studies providing information in non-monetary quantitative terms and/or in monetary terms.

Based on this scoping exercise, it appears that the availability of case data on the benefits of marine Natura 2000 sites is limited, and focused mainly on provisioning services (fish production) and recreation (e.g. diving). Only a few cases have also analysed some regulating services from certain habitats such as seagrass beds regarding coastal protection (preventing coastal erosion) and climate regulation (e.g. carbon sequestration).

This scoping study has focused on studies identifying provisioning, regulating or other services provided by marine areas. This is because information on ecosystem services and related benefits is considered a useful starting point for extrapolating site-based benefits to a wider scale.

However, it should be noted that other types of studies also exist. These studies explore the value of protecting or promoting marine and coastal biodiversity per se, with no direct link to the social or economic benefits of the protection (i.e. the ecosystem services discussed above). In terms of ecosystem services, the results of these studies can sometimes be considered as indicators for supporting services, for example the ability of ecosystems to maintain biological diversity and basic ecological processes.

Some examples of these types of studies are included in Table 1. For example, Börger et al. (2014) have recently explored the willingness of UK citizens to pay for an increase of species diversity in the Dogger Bank offshore marine area, which is protected as a Special Area of Conservation (see Table 1). In any case, it is important to note that these types of studies may significantly underestimate the value of the analysed ecosystem services, because the surveyed citizens may not be fully aware of the benefits they obtain from the supporting ecosystem services they are asked to value.

Table 1: A short scoping review of information available on the benefits of EU MPAs

Note: The table is based on a scoping exercise only and therefore not considered exhaustive.

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
Tinch, in: ten Brink et al. (2011)	EU Natura 2000	OSPAR habitats	Network		Not specified	Food provision: fisheries	€1.4-1.5 billion per year for the current area of protection (4.7% of sea area), €3-3.2 billion per year for the protection of 10% of sea area, and €6-6.5 billion per year for the protection of 20% of sea area.
Luisetti et al. (2013)	EU-27	Saltmarshes, seagrass beds	EU-27	300,000 km^2	2010, 2060 (scenario analysis)	Regulating: carbon storage and sequestration	Present value of lost carbon storage due to degradation (three scenarios developed): US$ 145,000 – 15,250,000 (optimistic scenario); US$ 153,000 – 16,500,000 (pessimistic scenario); US$ 8,790,000 – 921,000,000 (ultra-pessimistic scenario)
Halpern (2003)	Review of 89 MPAs (no-take zones) worldwide	Several	Worldwide		Not specified	Food provision: fisheries	Reserves are associated with higher values of density, biomass, organism size and diversity. On average, creating a reserve appears to double the density, nearly triple biomass, and raises organism size and diversity by 20–30% relative to the values of unprotected areas.

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
Marba et al. (2014)	Mediterranean Sea	Mediterranean seagrass beds (Posidonia oceanica)	Mediterranean		1842 - 2009	Regulating: carbon storage and sequestration	Between 13% and 50% of seagrass areal extent of P. oceanica in the Mediterranean basin appear to be lost. The remaining meadows of the Mediterranean may have thinned shoot density by 50% for the last 20 years and have become more fragmented. Considering the changes quantified in P. oceanica areal extent, cover and density, about 6.9% of the potential P. oceanica vegetation would have been lost annually over the last 50 years. The loss of P. oceanica meadows in the Mediterranean may have led to a substantial (between 11% and 52%) reduction of the capacity of this key coastal ecosystem to sequester carbon in the last 50 years, hence reducing the carbon sink capacity of the entire Mediterranean Sea.
Sumaila and Armstrong (2006)	North-east Atlantic - Barents Sea	Open ocean			Not specified	Food provision: fisheries	2.5 - 3 million tonnes on average per year NOK 30 - 46 billion total over 28 year period
Blom et al. (2012)	Belgium and the Netherlands	Tidal lake; brackish tidal marshes, salt marshes; tidal creeks	Grevelingen, Het Zwin, Waterdunen	250 ha, 183 ha (2.3 km coastline), 250 ha	Not specified	Food provision: fisheries Regulating services: carbon sequestration Recreation and ecotourism	Fishing (mainly mussels): €91 million Carbon reduction: €8 - 13 million Recreation and ecotourism: €20 million
Kosenius and Ollikainen (2011), Lindegarth et al. (2014)	Finland, Sweden, Lithuania	Coastal habitats (large vegetation and fish stocks)	Coastal regions of Finland, Sweden, Lithuania		Not specified	Food provision and recreation	Assumed 50% increase in healthy vegetation and fish stocks Finland: €359 million

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
Sweeting and Polunin (2005)	United Kingdom	Inshore: sand, gravel, mud	Southwest Isle of Man Scallop Research Closures	2 km^2	Not specified	Food provision: fisheries	Increases in both the number and size of individuals led to 12.5 times greater reproductive biomass and 11 times greater exploitable biomass.
Sweeting and Polunin (2005)	United Kingdom	Inshore: rocky reef habitat	Lundy Island Marine Nature Reserve	3.3 km^2	Not specified	Food provision: fisheries	After 18 months, the number of landable lobsters in the zone increased 3 fold. Lobsters were also on average 6 mm bigger than those outside the nature reserve.
Kenter et al. (2013)	United Kingdom	Numerous (inshore and offshore)	Networks of sites in England, Scotland and Wales		2012-2013	Recreation: diving and angling Non-use values (to divers and anglers)	Additional use value from additional MPAs: England: £20 - 34 million (divers); £190 - 340 million (anglers) Scotland: £5-8 million (divers); £6-10 million (anglers) Wales: £1-2 million (divers); £10-18 million (anglers). Non-use value that would result from additional MPAs: Divers: England: £100 - 170 million; Scotland: £20-33 million; Wales: £10-16 million Anglers: England: £630 – 1,100 million; Scotland: £100 – 190 million; Wales: £56 - 97 million
Álvarez-García et al. (2012)	United Kingdom	Numerous (inshore and offshore)	Network of sites in Scotland (different scenarios)	Different scenarios: 76,900 km^2 102,400 km^2 96,100 km^2	Not specified	Use and non-use values	Overall on-site benefits of designating a Scottish network of MPAs range between £6.3 billion and £10 billion. Of this use values amount to: between £5.5 billion and £8.9 billion

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
Fletcher et al. (2012)	United Kingdom		Holderness Inshore, Torbay Kingmere	Sites between 19.9 and 307 km^2	2010-2012	Food provision: fisheries Regulating: carbon sequestration (only for Torbay)	Three sites proposed as MPAs provide benefits for a range of services; per hectare estimates for fisheries range between £400 and £5,200. In the Torbay case, carbon sequestration benefits are estimated to range between £1.5-5/ha with traded carbon value and £6-18/ha with non-traded carbon value respectively.
Börger et al. (2014)	United Kingdom	Offshore sandbank	Dogger Bank	17,600 km^2 (UK share 8,600 km^2)	2013	Supporting services / maintenance of biodiversity: species diversity	10% increase in diversity Willingness to pay (WTP): £5.70/ha
McVittie and Moran (2010)	United Kingdom	Marine conservation zones (UK territorial and offshore waters)	UK wide	125,700 / 156,000 / 147,200 km^2 (different scenarios)	Not specified	Supporting services / maintenance of biodiversity: marine biodiversity	Halt loss of biodiversity Willingness to pay (WTP): £70/ha. Total £1700 million
Goñi et al. (2010)	Spain	Spiny lobster	Columbretes Islands	5,493 ha (MPA)	1997-2007	Food provision: fisheries	Spiny lobster in the reserve increased by 41% over the 10 years of study. Mean annual catch: 11,000 lobster (6,000 kg). Mean spillover of lobsters originating from the MPA was 2,000 lobsters/year (estimated value of over €120,000)
García Charton et al. (2013)	Spain	Several (Epinephelus marginatus, Dicentrarchus labrax, etc.)	Cabo de Palos – Islas Hormigas	1,931 ha (MPA)	1996-2013	Food provision: fisheries Recreation: diving	Increase in catches (from 6,000 kg in 1995 to close to 40,000 kg in 2012). Total income (2001-2012) was more than €2.1 million. The catches of grouper have increased from 140 kg in 1999 to 300 kg in 2012. The number of dives has increased by 225% between 1998 and 2010, from 8,100 dives recorded in 1998 to more than 26,000 in 2010.

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
Alban et al. (2008)	Spain and other EU countries	Numerous (inshore and offshore) – rocky habitats, Posidonia, etc.	Cabo de Palos – Islas Hormigas – and other MPA	1,931 ha (MPA)	2005-2006	Food provision: fisheries Recreation: diving	Mean value of landings per boat is €50,000/year so currently the average income of the fleet (7 boats) can be estimated around €350,000/year. Local added value due to the expenditure of non-resident MPA recreational users: scuba divers with 140 dives/year, €870,000, 20 local jobs.
Junta de Andalucía (2014); Díaz-Almela, (2014)	Spain	Seagrass meadows (Posidonia oceanica)	Several (12 sites in Andalusia)	6,739 ha – surface of seagrass meadows (90% in Natura 2000)	2013	Regulating: carbon storage and sequestration Food provision: fisheries Recreation Regulating: natural hazards control / mitigation	Carbon sink: Seagrass meadows of Andalusia sequester 31,500 tonnes of CO_2/year. In addition, these meadows contain a stock of organic carbon sequestered in the long-term, estimated at 24,700,000 tonnes of CO_2. The non-release of this carbon to the atmosphere would be valued in the voluntary carbon market as €83,800,000. Fish catches in seagrass areas: 17,300 kg with a total value of €63,000/year. Income from tourists that visit the areas with seagrass beds: around €124 million/year. Coast protection: the replacement costs (maintenance and regeneration) of 80 km of beaches in seagrass areas would be €96 million. The economic valuation of these different ecosystems services and benefits provided by seagrass meadows in Andalusia amount to over €300 million / year.

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
García-Rubies A. (2013)	Spain	Several fish species	Medes Islands	1,944.4 ha	19 years	Supporting services / maintenance of biodiversity: marine biodiversity	On average, the number of species observed per census was three times higher in the reserve, while overall abundance was 5 to 6 times higher and biomass 13 to 19 times higher inside the reserve.
WWF (2014)	Spain	Numerous (inshore and offshore)	10 marine Natura 2000 sites		2014	Food provision: fishing Recreation and ecotourism	Identification of ecosystems services provided in each area, and overall estimate of benefits from all the areas based on the estimates proposed in the Marine Bill in the UK: €302 million for all marine Natura 2000 sites.
De Stephanis and Gimeno (2000)	Spain	Cetaceans	Estrecho Occidental	10,527,000 ha	2000	Ecotourism (whale watching)	Seven vessels with capacity for three hundred people. €3 million revenue from the sale of tickets annually.
García Allut and Vázquez Portela (2012)	Spain	Coastal and offshore	Lira-Os Miñarzos	2,162 ha	2007-2012	Food provision: fishing Social acceptance, improved governance (fishermen participating in management of the reserve)	Increase in barnacle production within the MPA: 200% biomass increase in 5 years (2007-2012), increase in catches. Sea urchin also increased from previous years. Increase in gatherers of shellfish (4 new jobs)
Tubio et al. (2010)	Spain	Numerous (inshore and offshore)	Cedeira	720 ha	2008-2010	Food provision: fishing Habitat recovery Social acceptance, improved governance (fishermen participating in management of the reserve)	Increased populations of octopus and of the size of other commercial species.

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
López-Ornat et al. (2014)	Spain	Numerous (inshore and offshore)	Several Natura 2000 sites (also declared Marine reserves under Fisheries law)		Several (from different authors)	Fishing and recreation (recreational fishing, scuba diving) Other socio-economic benefits: improved governance. Biodiversity and habitats recovery	The report provides quantitative valuations from different marine reserves (based on a compilation of published studies), including increase in fish catches, biomass and spillover, increases in the number and average size of fish. Increase in number of divers and income generated by diving. Increase in recreational fishing and income generated.
González Lorenzo et al. (2010)	Spain	Commercial fish species and various habitats	La Restinga	1,180 ha Marine reserve and Natura 2000 site	2006-2010	Food provision: fishing	Increase in abundance and biomass of fish species of economic interest both in the area of the reserve and beyond. Slowing down the process of abandoning traditional fishing activity, emergence of new business opportunities such as ‘fishing-tourism’, and agreement with recreational fishers.
Martín-Sosa and Falcón, (2011); Sangil et al. (2009)	Spain	Commercial fish species and various habitats	La Palma	3,455 ha Marine reserve and Natura 2000 site	2004-2010	Food provision: fishing Habitats recovery	Improvement in the populations and sizes of three commercial fish species*: Cretan Sparisoma, Serranus atricauda* and *Gymnothorax polygonius*, and other species (snappers, moray eels, roosters and sunfish). Recovery of benthic communities
Martín-Sosa and Falcón (2011)	Spain	Commercial fish species and various habitats	La Graciosa Island and Islets of Noth Lanzarote	70,439 ha Marine reserve and Natura 2000 site	2007-2010	Food provision: fishing Habitats recovery	Fishing effort and catches of 2010 were significantly higher than in 2007, 2008 and 2009, particularly for hake and grouper. Reduction of invasive species, recovery of algae species
Guidetti and Ciccolella (2008)	Italy	Coastal zone	Torre Guaceto	2,227 ha	2008	Food provision: fishing	Fish catches: 25-30 kg/1,000 m fishing net inside the reserve, 10 kg outside the reserve
Morandi and Usai (2011)	Italy	Coastal and offshore	Tavolara - Punta Coda Cavallo Natura	16,005 ha	2008, 2011	Recreation and ecotourism	Economic income from diving and ecotourism (Travel Cost Method): 11,000 visitors (2011), €14 million income from diving, €24 million for the whole holiday industry in Sardinia

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
Vasallo et al. (2013)	Italy	Seagrass meadows (Posidonia oceanica)	Bergeggi Island	260 ha	Not specified	Provisioning and regulating services	Economic value of the habitat calculated (Pulselli et al. 2011): €172/m^2/year
Sweeting and Polunin (2005)	Italy	Inshore: sand and mud	Gulf of Castellammare No-trawl Area	200 km^2	Not specified		4 years after closure, total biomass of catch had increased eight fold
Blasi (2009)	Italy	Seagrass meadows (Posidonia oceanica)			2009	Food provision: fishing Regulating: coastal protection, carbon fixation	Oxygen production: €14/m2/year Carbon fixation: €0.01/m2/year Prevention of coastal erosion: €309/m2/year Refuge for fish species: €1.7/metre trammel Primary production (5% discount rate for 40 years): €1.7/m2. Supporting service of the meadow for other coastal ecosystems: €0.8/m2.
Batista et al. (2011)	Portugal	Coastal habitats	Arrábida MPA	53 km^2 (with different levels of protection)	2004-2008	Set of indicators (ecological, economic, social, management and governance) comparing situation before and after MPA	All ecological, management and governance indicators show an improvement; the economic indicators for fisheries are mixed, with lower income. The social indicators show mostly a decline.
Batel et al. (2013)	Croatia	Bottlenose dolphin (Tursios truncatus)	Cres-Lošinj		Not specified	Marine conservation (general)	Over 80% of interviewees were willing to pay more for their holiday in support of marine conservation. The average WTP was 6–10% higher than the average daily expenditure per person. This resulted in a potential ecological tax of approximately €1 per person per day, and an overall estimated increase of seasonal income of between €2.4 million and €9.9 million.

Study	Country	Habitat(s) / Species assessed	Site name	Site characteristics	Year of estimate	What services were looked at / assessed	Value in physical and economic terms (Estimates from the studies rounded up for the purpose of this scoping study)
Săseanu et al. (2010)	Romania	Coastal zone, Danube delta and Black Sea littoral	Vama Veche, Danube Delta Biosphere Reservation, Black Sea littoral (Eforie, Mangalia)		2001 and 2007	Recreation and eco-tourism (incl. health/spa tourism)	Danube delta: tourist arrivals (number of tourists) in 2001 (5,500) and 2007 (20,400). Overnight stays in 2001 (13,500) and 2007 (33,600). Black Sea littoral: tourist arrivals in 2001 (44,400) and 2007 (58,200). Overnight stays in 2001 (373,000) and 2007 (347,000)
Nicolae et al. (2011)	Romania		Danube Delta Marine area, Submerged beach Eforie Nord – Sud, Marine area from Tuzla Cape, Sulphurous springs from Mangalia, Vama Veche – 2 Mai.		2004 - 2009	Commercial, recreational and subsistence fishing	Commercial fishing: of the total registered boats, about 64% operating within marine Natura 2000 sites.

3 Step 2: Assessing the basis and opportunities for scaling up

Bottom-up versus top-down scaling

Step 2 aims at assessing whether there is enough data on the benefits provided by MPAs to allow for a scaling up of benefits to the European level, for all or at least some ecosystem services, both in quantitative and monetary terms.

The value of individual ecosystem services can be estimated in quantitative terms (e.g. tonnes of fish caught by fishermen, tonnes of carbon stored in saltmarshes or mangroves), and also in monetary terms. The latter can be done either by multiplying a quantitative estimate of the services by a market price (e.g. the price of fish or the price of carbon in carbon markets) when a market price is available, or by employing monetary valuation methodologies based on costs, stated or revealed preferences.

The methodologies based on costs estimate the value of ecosystem services using avoided costs (e.g. economic damage by flooding or wave action/erosion avoided due to the natural protection by coastal ecosystems), replacement cost (e.g. the cost of infrastructure to replace the natural protection by ecosystems) or restoration costs (i.e. the cost of restoring a degraded marine or coastal ecosystem).

The methodologies based on revealed preferences estimate the value attached by individuals to ecosystem services by analysing their actual behaviour (e.g. the Travel Cost Method analyses the costs people pay to visit a protected area). The methodologies based on stated preferences estimate the value of ecosystem services using surveys aimed at investigating people's willingness to pay for improved environmental conditions or their willingness to accept compensation for a reduction in environmental quality. A wider discussion on characteristics, advantages and problems related to all these methodologies can be found in White et al. (2011) and Pascual et al. (2010).

Different approaches can be used to derive an aggregate quantitative or monetary estimate of benefits covering multiple sites. The most frequently used approach is the <u>bottom-up approach</u>, which scales up the estimated value of ecosystem services and related goods from a set of individual sites to a wider set of sites. This generally builds on scaling up per-hectare values from a set of sites for which data are available and extrapolating to the wider study area (ten Brink et al. 2011). A sufficient number of base sites and an understanding of the ecological and socio-economic characteristics of the site and beneficiaries can form the basis for a meta-analysis covering a whole range of similar sites. For example, a relationship (e.g. taking the form of a mathematical production function) could be derived between the benefits generated and the different factors that contribute to these benefits (de Groot et al. 2012).

However, for this kind of analysis to be robust, a large number of base studies is required; as a general rule, 20 sites are required per key variable driving the benefits (see Annex 2). Below that threshold, an assessment should be considered as illustrative or experimental, depending on the number of available studies and their quality. While the application of benefit production functions is foreseen to be an important tool in the future, few studies are yet available (Annex 2).

The second approach is the top-down approach, which builds on detailed, region wide and spatially explicit geo- and bio-physical data to derive aggregate values. One example is determining the carbon capture and storage services of marine and coastal ecosystems (Barbier et al. 2011, Duarte et al. 2013, Marba et al. 2015). Spatially explicit maps of the distribution of seagrass meadows and saltmarshes can help determine the quantity of carbon stored and sequestered in these ecosystems (see Box 1). For an analysis of potential future developments, ecological models can provide scenarios of carbon capture and storage services. This quantitative information can then be multiplied by a carbon price (as observed in carbon markets or based on other considerations) to arrive at a monetary value of these services.

Box 1: Estimating the economic value of Blue Carbon in Europe

Luisetti et al. (2013) provide an estimate of the loss of value due to the loss of carbon storage and sequestration services of saltmarshes and seagrass beds in the EU-27 due to environmental degradation. First, the authors collect available data on the distribution of these ecosystems across Europe and the corresponding carbon quantities. In a second step, Luisetti et al. estimate the monetary value of these services in a series of scenario analyses.

The economic valuation requires choosing an appropriate carbon price, for example based on actual prices observed in carbon markets, or damage costs of carbon emissions, or marginal abatement costs. The choice of an appropriate carbon price influences the estimates markedly. For example, in an optimistic scenario with relatively small losses of saltmarshes and seagrass beds between 2010 and 2060, the corresponding present values of losses range between US$ 145,000 and US$ 15,254,000. This wide range shows that the results of monetary valuation need to be carefully interpreted, with a transparent presentation of the assumptions underlying the calculations.

Similar analyses are possible for other ecosystem services such as food provision through models that depict fish stocks, or the distribution of seagrass meadows, saltmarshes or wetlands and their contribution to coastal protection (Barbier et al. 2013). For this approach, the quality of maps and other related data is crucial. Over recent years, this data basis has improved gradually and the potential for a wider use of this approach is rising.

Both bottom-up and top-down methods require good data based on primary research in marine protected areas or from other sources such as remote sensing. In either case, a number of assumptions are necessary to arrive at benefit estimates on a larger scale, beyond individual sites or specific MPAs.

Where the base data proves sufficient to develop both a scaled up and a top down estimate for a service, comparing the values obtained with these two approaches can be helpful; this could form the upper and lower bounds of a benefits range.

Total benefits versus incremental benefits

A further key methodological issue to be decided is whether to look at the total value or the incremental value of the Natura 2000 network. For example, a marine area can produce a certain quantity of fish and store a certain quantity of carbon with or without a protected area status. However, protection measures may help increase the fish provision and carbon sequestration and/or avoid loss of these ecosystem services because of outside pressures.

In addition, protection measures can be driven by different policies, including for example Natura 2000 management measures, measures implementing the Common Fisheries Policy (CFP) or upstream pollution prevention measures under the Water Framework Directive (WFD). This raises the additional challenge of allocating benefits to specific measures when there are multiple, often interconnected, drivers of change.

Complementarity and/or competition between benefits[1]

Further to the set of methodological issues to be considered, aggregation of benefits needs to consider the complementarity and/or competition between benefits across multiple sites (ten Brink and Kettunen, 2013). While a subset of benefits can be added across sites and/or scaled up directly, not all benefits that accrue on a site level will lead to a simple 'summed-up' total benefit at the level of multiple sites. There can be complementarity and/or competition between benefits associated with different ecosystem services and related goods.

When the benefits from different sites are complementary (non-rival), it is possible to sum up the estimated value of current and future benefits across multiple sites (ten Brink and Kettunen, 2013). In other cases, the assessment of benefits from multiple sites can be a type of zero sum game where foreseen site-specific increases in benefits cannot be added across several sites in a region. In yet other cases, markets and/or demand for a benefit might be growing, leading to (partial) complementary effects across sites (see Table 2). Consequently, one should not take for granted that the socio-economic importance of, and obtained values for, different benefits can be simply added up across sites. The more sites there are in the area the greater the risk of individual sites 'competing' over the provisioning of some ecosystem services and related goods. In general, when the availability of a certain potential benefit exceeds demand, one site can affect the socio-economic value of benefits on another site. As a general rule, if the 'demand for' a service or benefit is larger than the potential supply from multiple sites, it is possible to add up the values of the benefits across sites.

[1] Directly as from Kettunen and ten Brink (2013)

Table 2: General socio-economic linkages between benefits provided by multiple protected areas (PAs)
Source: Kettunen and ten Brink (2013)

Benefit	Socio-economic value in the case of multiple sites	Explanation
Provisioning services and related goods	Possibly competitive	In economic terms, increased availability of a resource generally diminishes its relative value. On the other hand, increased availability helps to reduce pressure and guarantee that a resource (e.g. fish stock) can be used in a sustainable manner. Development and branding of 'PA friendly' products might diminish the market share of similar products produced on other sites in the same region. On the other hand, having a critical mass of products from across sites in the same region can help increase overall brand recognition and demand.
Regulating services and related goods	Likely to be complementary, with few possible exceptions	Regulating services and related goods (pollination, regulation of water quality and flow, mitigation of natural hazards) are relatively fixed spatially (i.e. dependent on the ecological characteristics and hydrology of the site). Therefore, they also have spatially fixed sets of beneficiaries and are less likely to suffer from competition with similar services at other sites. However, if there is more capacity than demand (for example enough wetland area to maintain water quality or mitigate flooding) then the marginal value of an additional hectare of land providing regulating services can decrease. As for climate change mitigation, any local addition to carbon stock and/or sequestration complements the overall national and global carbon stock.
Cultural: recreation and tourism	Complementary and/or competitive	Encouraging ecotourism and recreation at one site may reduce visitors and the value of ecotourism at a neighbouring site. On the other hand, increasing tourism and recreational opportunities at multiple sites within the same region might attract more tourism to the area as a whole (seen as an opportunity to enjoy several sites during one visit).
Cultural: broader cultural benefits	Complementary and/or competitive	As above
Broader local / regional socio-economic benefits	Possibly competitive and/or complementary	Multiple sites might face competition in terms of available investments. However, multiple PAs might also be a factor drawing in further investment that would be an advantage for a region.
Long-term resilience / insurance	Complementary	Multiple PAs increase biodiversity and the quality of ecosystems at the regional level, increasing overall resilience.

4 Step 3: Assessing benefits at the EU level

To date there have been some experimental assessments of EU MPA network benefits that focus on a subset of ecosystem services (see Box 2). There has also been increasing interest in modelling marine ecosystems and developing marine accounts (e.g. in the UK) to help better measure this part of natural heritage. These experimental assessments can provide a basis for a wider, robust EU-level assessment in the future. Such assessments can derive quantitative or monetary estimates of the services provided.

To develop a comprehensive assessment of EU wide MPA benefits two main bottom-up approaches are available in theory:

Site-based approach - extrapolating data from a small and disparate sample of Natura 2000 sites. This procedure calculates the average per hectare value of the site (i.e. aggregating across services), compiling a list of sites with a range of per hectare values and then extrapolating to all EU sites using the average per hectare value from the data available. In practice, one would use both the mean and the median of the range to arrive at two estimates. In the case of monetary estimates, one can also scale up by adjusting for GDP to consider the location - at least with respect to services where income is relevant (e.g. recreation and tourism).

Habitat-based approaches – different habitats can also be used as the basis for estimating the value of benefits of the MPAs. This approach is based on the assumption that the value of services varies by habitat, as similar habitats can be expected to deliver similar ecosystem services. The approach is similar to the site-based scaling up, but using different habitats with 'sub-ranges' and habitat specific means and medians. The advantage is that there is likely to be a better representation of habitat values where there is base data; the weakness is that habitats that have not yet been studied will not be included. However, when applying this approach one needs to be aware that the estimated value may also depend on factors other than habitat type, such as its abundance and vicinity to human settlements.

Both approaches above would be strengthened through additional site-based benefits valuations, allowing a wider 'meta-analysis' to be carried out. This could be done by the simple scaling approach noted above. However, better yet would be the development of benefits production functions or value transfer functions (as explained under Step 2) that would help to identify and characterise key factors driving the benefits. This kind of calculation is useful to obtain an indication of the benefits provided by ecosystems in areas where fieldwork has not been carried out. However, such results need to be interpreted with caution because the provisioning of ecosystem services – including the ecological factors underpinning the supply or services - is often location-specific.

The opportunities for aggregating site- or habitat-based results are also dependent on the different methodologies used in individual valuations. For example if, in the case of monetary estimates, the available estimates are calculated based on different valuation methodologies (e.g. cost-based approaches vs. stated or revealed preferences) these values may not be fully comparable or able to be aggregated.

Finally, spatial models with detailed representation of fish stocks and reproduction, as well as the spatial distribution of fishing effort, could help assess the overall benefits from MPAs – both at the level of individual sites and moving towards aggregation. One such example is the 'Ecopath with Ecosim' model (www.ecopath.org) for marine systems (Tinch, in: ten Brink et al. 2011).

Box 2: Examples of experimental aggregate assessments of marine ecosystem services

Tinch et al. (in: ten Brink et al. 2011) calculate the net present value of ecosystem service conservation for EU marine and coastal waters as an experimental assessment. The results are summarised in the table below.

Table 3: Present values over 20 years of increase in ecosystem services arising from conserving 10% of assessed waters with different levels of protection.

Ecosystem Service	Highly restrictive	Less restrictive
Nutrient recycling [2]	€4.69 bn	€2.38 bn
Gas and climate regulation	€26.79 bn	€14.59 bn
Leisure and recreation	€5.26 bn	€4.78 bn
Food provision	€0.43 bn	€2.59 bn
Raw materials	€0.07 bn	€0.49 bn
Disturbance prevention and alleviation	€0.23 bn	€0.23 bn
Cognitive values	€1.87 bn	€1.68 bn
Total	€39.34 bn	€26.73 bn

Source: Tinch et al. 2011, calculations extrapolating from values in UK Marine Bill studies

Mangos et al. (2010) present an attempt at evaluating the benefits related to the provision of food resources by five main marine habitats in the Mediterranean Sea, including seagrass meadows (Posidonia), soft and hard substrate areas, Corallogenic areas and open water. Table 4 presents the main findings.

Table 4: Value of the benefits relating to the provision of food resources (fishery resources) by ecosystems

		Total	Posidonia meadows areas	Soft substrate areas	Hard substrate areas	Corallogenic areas	Open water
A	Catches (in t)	1,070,993	27,210	133,746	48,003	37,483	710,542
B	Catch distribution (in %)	100%	3%	14%	5%	4%	74%
C	Value of the benefits (in millions of Euros) (total benefits*B)	2,871	83	399	144	112	2,133
D	Area covered (km²)	2,500,000	35,000	217,000	108,500	108,500	2,031,000
E	Area distribution (%)	100%	1%	9%	4%	4%	81%
F	Value of benefits per unit of area covered (in €/km²) (C/D)	1,148	2,379	1,839	1,323	1,032	1,050
G	Quantitative productivity (t/Km²) (A/D)	0.4	0.8	0.6	0.4	0.3	0.3
H	Economic productivity (€/km²) (C/D)	1.1	2.4	1.8	1.3	1	1.1

Source: Adapted from Mangos et al. (2010)

[2] Nutrient recycling is a supporting service and care is needed to avoid double counting. Only those aspects of the value that are not captured by final ecosystem services and benefits should be included. See original text for how potential overlaps were addressed.

5 Step 4: Putting the results in perspective

Even with a sufficient amount of case data available, scaling up benefits to the EU level requires a range of assumptions. There is therefore always a need to place the results into the context of these assumptions, taking into consideration the methods used for scaling up, data availability and scenario assumptions. The question of robustness must be seen in the context of the question being explored. For example, providing a range estimate may be robust enough for some purposes (e.g. capturing and communicating the order of magnitude) but not for others (e.g. when there is a need for an exact estimate for damage to a site's status, ecosystem services and related benefits).

A range of factors determines the robustness of both site-specific and aggregate estimates, including the quality of data, scope of assessment, methodology used and assumptions made (Kettunen and ten Brink 2013). For example, low quality or out-of-date data can undermine any assessment. It is also important to reflect whether the estimated values can be attributed to the site itself or whether they also require the presence of a wider non-protected seascape and/or some man-made infrastructure (e.g. artificial spawning closures). Finally, future projections incorporating any changes to status quo will need to explain what changes have been factored into an assessment and what the rationale and data sources are behind the choice assumptions (population growth, income changes, GDP growth, carbon values etc.).

Currently there are a small but growing number of site-specific assessments of the benefits of MPAs, both in physical and in monetary terms. As regards EU-wide assessments, these are generally experiments, with very large ranges. When considering the utility of the studies, it is important to see the level of robustness in the context of the use made of these numbers - as some may be fit-for-purpose to communicate that an issue is important, but not fit-for-purpose as estimates of e.g. the value of natural capital per se to include in national accounts.

6 Conclusions

At present, there are too few site-based MPA case studies for a comprehensive (quantitative) bottom-up assessment to be developed at the EU level. At this stage, it is therefore recommended to develop a synthetic picture of benefits by combining case study information and also looking to see where top-down methods could offer complementary (if still experimental or ecosystem service-specific) routes. While a number of studies have looked at different aspects of marine ecosystem services in Europe, the number of studies that explicitly look at the effects of MPAs is still sparse. More focused research targeted at MPAs, including Natura 2000 sites, should be encouraged.

Therefore, the best approach to developing a synthesis of the benefits of MPAs in the Natura 2000 network is to continue combining insights from case studies and developing a series of narratives around specific ecosystem service values to illustrate and communicate the importance of MPAs. This approach can use case numbers and, in certain contexts, ranges. For a subset of issues, EU wide aggregate numbers can be useful (e.g. on EU MPA carbon stocks). These should be interpreted as indicative estimates, and should be updated in light of evolving estimates e.g. for carbon prices.

In parallel, additional efforts are worthwhile in the area of marine accounts for carbon and fish stocks, the former linked to spatial data that maps marine ecosystem types and the latter linked to fisheries models. For carbon storage and sequestration, more site 'calibration' will be useful to fine-tune the associated values used in the maps and hence help this top down approach realise its potential. More analysis is also needed on the utility of fisheries models for ecosystem services estimates of EU MPAs. In this scoping exercise, it has not been possible to look at whether the fisheries models allow distinction between MPAs and non-MPA fisheries. This merits further attention and assessment as to what level of 'accuracy' would be feasible in these models, given designation and allocation issues, and which ecosystem services these models could eventually cover beyond food provision. Finally, fisheries models should not be used to overemphasise the role of MPAs for fish production, and commercial fisheries in particular, without due consideration of the other benefits associated with protecting marine areas.

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Annex 1 Benefit production function

An increasing number of comparable, site-based benefits valuation for PAs allows a 'meta-analysis' to be carried out, forming a basis for deriving a 'benefits production function' that shows the relationship between the estimated socio-economic value and site variables affecting the value (see list below). The benefit production function could then be used as a 'value transfer function' to extrapolate to other existing PAs in the region for which no site-specific valuation has been done. In practice, separate benefits production functions would need to be developed for terrestrial sites and for marine sites, given their different drivers of value. Separate functions could also be usefully developed for different subcategories of ecosystems, such as done for inland wetlands by de Groot et al. (2012). A benefits production function can also be adapted from one region to another if the contexts are largely comparable.

The wide variation of per hectare values by site, while affected by different methodological approaches used and the scope of the assessment, can be driven by the key factors presented below. These key factors also need to be taken into account to develop benefit production functions:

- Habitat type and species, related to their impact on ecosystem functions;
- Area, due to its potential impact on the extent of ecosystem services such as carbon capture and storage or flood control;
- Conservation status, as a reflection of ecosystem health and linked to resilience;
- Uniqueness/rarity, which can influence the scientific value, potential for bioprospecting and tourism/recreation;
- Spatial relation to key resources and their abundance, determining the perceived scarcity/abundance of substitutes for ecosystem services as well as potential for benefits ;
- Proximity to population and accessibility and population density around sites, as the proximity of beneficiaries can impact the perceived benefits;
- Income, linked to ability/willingness to pay;
- Prices, to calculate monetary benefits for ecosystem services such as carbon sequestration.

A statistically significant benefit production function requires a certain level of site-specific data. While geographic scale influences the level of studies needed (i.e. more needed for larger/more diverse area), a fair basis for analysis would encompass at least 20 quality studies per key factor driving benefits. The required data sources would be less for assessments focusing on only one region or one ecosystem type in similar climatic and socio-economic setting. As temporal and spatial conditions are important and methods for economic valuation are evolving, some past studies will not be useable, and new studies will be needed in the future to allow the development and application of robust benefit production functions.

Source: Case study example from Kettunen and ten Brink (2013)