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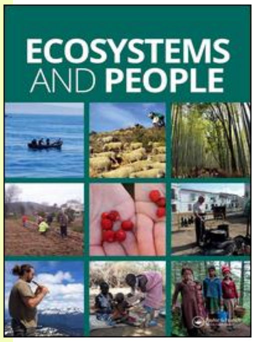

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RESEARCH

Improving ecosystem assessments in Mediterranean social-ecological systems: a DPSIR analysis

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ABSTRACT

Social-ecological systems in the Mediterranean Basin are characterised by high biodiversity and a prolonged cultural influence, leading to the co-evolution of these systems. The unique characteristics of Mediterranean social-ecological systems, current pressures leading to a decline in ecosystem services, and the need for coordinated action are recognised by policies promoting the protection and sustainable use of the region's heritage. Ecosystem assessments provide valuable information on the capacity of the Mediterranean Basin to ensure the well-being of its population. However, most assessments simplify the complexity of these systems, which may lead to inaccurate ecosystem services supply and flow estimations. This paper uses the Driver-Pressure-State-Impact-Response (DPSIR) model to guide an expert consultation that identifies the key characteristics of the Mediterranean social-ecological systems and analyses how these should be included in ecosystem assessments. Data collection was carried out through expert consultation with ecosystem services researchers. Multiple sources of complexity were identified, including the relationship between historical human activities, biodiversity spatio-temporal patterns, as well as the seasonal and long-term variability in ecosystem services. The importance of incorporating this complexity in ecosystem assessments for evidence-based decision-making is identified, suggesting that there is a need to adapt assessment approaches for the Mediterranean Basin social-ecological systems.

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1. Introduction

The Mediterranean Basin is a biodiversity hotspot, characterised by a high level of endemism and species richness (Myers et al. 2000) and, spanning a diverse range of terrestrial, freshwater and marine ecoregions (CEPF 2017). Around 10% of the world's higher plants are found in this area, which represents only 1.6% of the Earth's surface (Médail and Verlaque 1997; Médail and Quezel 1999). The region's high terrestrial biodiversity is a result of its biogeography and geological history, and its unique climatic features and interactions with human cultures over millennia (Blondel 2006). Equally, the region's coastal and marine environment significantly contributes to global biodiversity, representing an estimated 7% of the world's marine biodiversity (Coll et al. 2010). The Mediterranean Sea presents high numbers of endemic species because of its unique paleogeography and ecological characteristics that arise from a variety of existing climatic and hydrological conditions (Bianchi and Morri 2000).

The human history associated with the Mediterranean environments has led to significant transformations and the co-evolution of social-ecological systems that are rich in biodiversity, provide a wide range of ecosystem services and represent a diverse cultural heritage (Catsadorakis 2007; Blondel et al. 2010; Martín-López et al. 2016).

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However, the relationships between biodiversity, ecosystem services and human society in co-evolved social-ecological systems are complex and multi-layered, creating challenges to understand, use and, even more difficult, to predict how the processes and interactions may change in the future due to a complex suite of drivers acting at different scales (Mace et al. 2012).

Existing literature shows that biodiversity, ecological functions and related ecosystem services in the Mediterranean Basin terrestrial (Bangash et al. 2013; Doblas-Miranda et al., 2015; Thom and Seidl 2016), freshwater (Mediterranean Wetland Observatory 2018) and marine ecosystems (Coll et al. 2010, 2012; Piroddi et al. 2017) are often threatened by a series of indirect drivers and direct pressures, which may lead to a decline in the capacity of ecosystems to provide services (Bangash et al. 2013; Piroddi et al. 2017). Recent changes within the Mediterranean Basin such as the abandonment of agrosilvopastoral practices, the intensification of primary sector activities (e.g. the use of more intensive agricultural, fishing practices and increased demand for energy wood), as well as an increase in urban development, have been suggested to lead to the loss of biodiversity and lower ecosystem services supply (Liquete et al. 2016; García-Nieto et al. 2018).

Coordinated action to address common drivers, the protection of the region's heritage and promotion of the sustainable use of ecosystems are some of the key objectives of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean[1] adopted in 1995. The Mediterranean Strategy for Sustainable Development[2] recognises the multiple long-term anthropogenic pressures acting on this region and calls for coordinated policy and management responses to halt the degradation of Mediterranean ecosystems (UNEP/MAP 2016). Policy and management responses based on scientific evidence, such as that emanating from ecosystem assessments (Maes and Jacobs 2017), allow for a better exploration of scenarios and management alternatives (Maes et al. 2012). However, important methodological choices simplify the shared natural and cultural heritage, and the challenges faced by Mediterranean social-ecological systems, to the extent that obtained results represent a limited integrated understanding of the region (e.g. for Mediterranean wetlands (Perennou et al. 2018)). The Mediterranean Basin is generally divided into separate studies, such as is the case in the regional assessments for Europe, Africa and Asia of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[3] and the EU Mapping and Assessment of Ecosystem Services (MAES)[4] initiative for European countries. There are, however, a few initiatives that undertake assessments at national scales (e.g. Spain,[5] Portugal,[6] France[7] and Israel[8]) and others that are currently in the process of developing national assessments (e.g. Dimopoulos et al. 2017; Balzan et al. 2018).

Ecosystem assessments need to be feasible while incorporating a sufficient level of complexity to ensure that they represent the different patterns and processes acting within the region's social-ecological systems. This paper identifies the key characteristics of Mediterranean social-ecological systems that should be represented in ecosystem assessments to support evidence-based policy and management actions. Therefore, the objectives of this work are to (a) identify the specific elements and characteristics of Mediterranean social-ecological systems that uniquely shape ecosystem services flows, and that are at risk of not being adequately captured by existing ecosystem services assessments; and (b) propose how common and shared ecosystem services assessment methods could better take these elements into account.

2. Methods

2.1. Conceptual framework

The identification of the key characteristics of Mediterranean social-ecological systems followed the DPSIR (Driver-Pressure-State-Impact-Response) framework (Smeets and Weterings 1999; OECD 2003). This well-established framework provides a coherent structure for the integration of information of biophysical and socio-economic interactions across spatio-temporal scales (Pinto et al. 2013; Vidal-Abarca et al. 2014; Díaz et al. 2018). It has been applied in terrestrial and aquatic ecosystem assessments due to its ability to improve communication and facilitate collaborative interactions between policymakers, stakeholders and scientists thereby contributing to science-based resource management decisions (Grunewald and Bastian 2015; Xue et al. 2015; Patrício et al. 2016). The DPSIR approach has received some criticism for its hierarchical structure (Svarstad et al. 2008) and its limited grasp of complex interrelationships between different types of indicators (Niemeijer and De Groot 2008). Tscherning et al. (2012) highlighted that even though the DPSIR framework is an effective approach to provide information and allow consultation for the formulation of policy, only few DPSIR studies integrated end users into the participative process which impaired the reality of the representation of the social-ecological systems.

The basic idea behind the DPSIR framework is that social, demographic and economic (indirect) *drivers* exert *pressures* (also termed direct drivers, in the Millennium Ecosystem Assessment; Nelson et al. 2005) on the environment, thereby changing its *state* and the associated flow of ecosystem services. Whilst drivers are the underlying cause of change, pressures are the actual stimulus that through alterations of the state of the system can ultimately have an *impact* on human well-being. The impacts of changes on the state of the system trigger societal *responses* in the form of human actions implemented by society and governments (Müller and Burkhard 2012; Nassl and Löffler 2015). These *responses* include the formulation of, for instance, new laws, management plans or economic and planning instruments, and reflect decisions based on people's perception of ecosystem services, the state of the environment and acting pressures and drivers (Kelble et al. 2013; Villamagna et al. 2013; Nassl and Löffler 2015). This DPSIR process is not linear but has inherent feedback loops and reciprocity. We have used an adapted DPSIR framework (Figure 1), based on the contributions of Müller and Burkhard (2012) and Xue et al. (2015), to identify key characteristics of Mediterranean social-ecological systems and their associated ecosystem services, and how those key aspects need to be captured through ecosystem assessments to inform evidence-based policy and management decisions. In addition to the causal pathway normally considered using the DPSIR frameworks, and to avoid the pitfalls of the DPSIR framework associated with the compartmentalisation of indicators (Niemeijer and De Groot 2008; Svarstad et al. 2008), we also considered potential interactions between different types of indicators and ecosystem services, as these have been recognised to be important for effective decision-making (Nassl and Löffler 2015; Xue et al. 2015).

The analysis of ecosystem services using a DPSIR framework makes it possible to move towards more proactive and integrative interventions rather than reactive mechanisms to protect ecosystems from human impacts (Kelble et al. 2013). Elements of the DPSIR framework have also been widely used in conceptual frameworks for ecosystem assessments, including the Millennium Ecosystem Assessment (MA 2005) and The Economics of Ecosystems & Biodiversity (de Groot et al. 2010), and more recently, the Common International Classification of Ecosystem Services (Haines-Young and Potschin 2018) and the IPBES conceptual framework (Díaz et al. 2015). Various remaining structural mismatches between ecosystem assessments and DPSIR frameworks exist, and by addressing these it is possible to analyse societal trade-offs in the formulation of management goals (Nassl and Löffler 2015).

2.2. Data collection

This work builds on the expertise of members of the Ecosystem Services Partnership (ESP) Mediterranean Working Group,[9] an interdisciplinary network of ecosystem services scientists and practitioners working in the Mediterranean region. ESP[10] is a global network of researchers, academia and conservation organisations, policymakers and practitioners dedicated to the advancement and promotion of the concept of ecosystem services in policy making and management of natural areas and natural resources. The Mediterranean Working Group comprises members who work across a wide range of scientific and applied disciplines (e.g. ecology, social sciences, planning and management, land use policy, ecological economics) in terrestrial (including urban and agricultural systems), freshwater and marine and coastal Mediterranean social-ecological systems. The group members use a wide variety of approaches and tools in ecosystem assessments and practice, and work at different spatial and temporal scales within the region.

The key characteristics of Mediterranean social-ecological systems, ranging from the supply and flow of

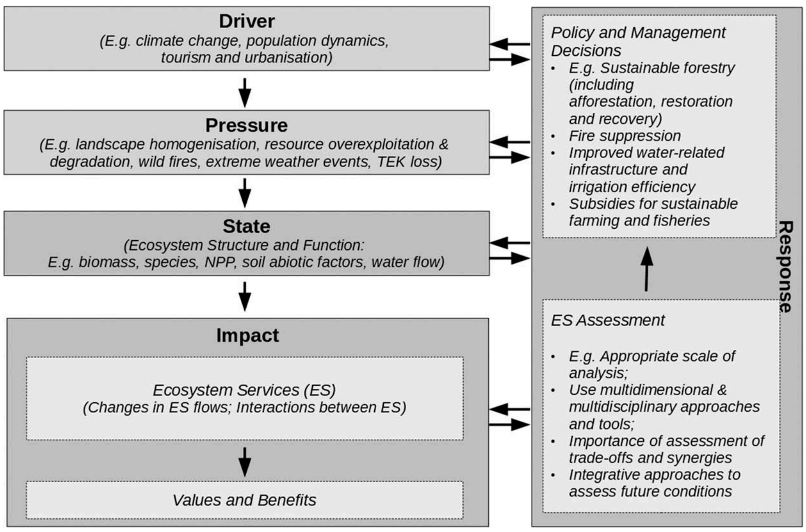

Figure 1. DPSIR framework for ecosystem and ecosystem services assessments in a rapidly changing Mediterranean Basin. Arrows indicate causal relationships between driver, pressure, state, impact and response (ES: Ecosystem Services; TEK: Traditional Ecological Knowledge; NPP: Net Primary Productivity) (Adapted from Müller and Burkhard 2012; Xue et al. 2015).

ecosystem services to the benefits and value to society, were identified using iterative expert consultation. The expert consultation adopted a three-step process (Figure 2). In the first step, a workshop was organised at the ESP conference in Antwerp in September 2016. The workshop in Antwerp was open to anyone interested in ecosystem services, but experts from the Mediterranean working group were explicitly invited to participate, as well as key European and Mediterranean scientific networks working on ecosystem assessment. Invitations were sent to the ESMERALDA,[11] OPERAs,[12] Open NESS,[13] EU BON[14] and ECOPOTENTIAL[15] Seventh (FP7) and Horizon 2020 Framework Programmes project consortia, coordination and supporting action project partners, the Mediterranean scientific network BIODIVMEX[16] and the policy stakeholders from the Mediterranean Basin. A total of 19 participants attended the workshop. Participants were presented with conceptual frameworks of a range of ecosystem services (Ericksen 2008; Power 2010; Church et al. 2014; Guerra et al. 2014; Stevens 2014; Sánchez-Espinosa et al. 2016), while also being offered the option to freely choose other ecosystem services frameworks. Visualisations of ecosystem service flows were used to identify particularities of Mediterranean ecosystems, as well as the challenges encountered when attempting to quantify these services. Each workshop participant contributed to a round-table discussion in line with their expertise and their perceived importance of these ecosystem services in terms of the key benefits provided to society. These were subsequently discussed in plenary with the whole group. The studied ecosystem services were food production, soil erosion regulation, carbon sequestration and water supply ecosystem services, and an aggregation of cultural ecosystem services. The choice to focus on cultural ecosystem services was made during the workshop to focus on what cultural ecosystem services had in common as key characteristics and, given the strong dependence on personal and social driving forces (Hernández-Morcillo et al. 2013), attempts to avoid national or cultural differences between the use and appreciation of cultural ecosystem services between countries and areas in the Mediterranean Basin.

After a thematic analysis, the results from the first workshop were complemented in a second round of expert consultation by the workshop participants and the members of the ESP Mediterranean Working Group through an online working document. The results were shared in the form of a manuscript outline and a preliminary table identifying key elements from the DPSIR framework for the five selected ecosystem services (Figure 1). At this stage, participants identified relevant peer-reviewed and grey literature for the Mediterranean Basin and for the topics identified during the expert consultation.

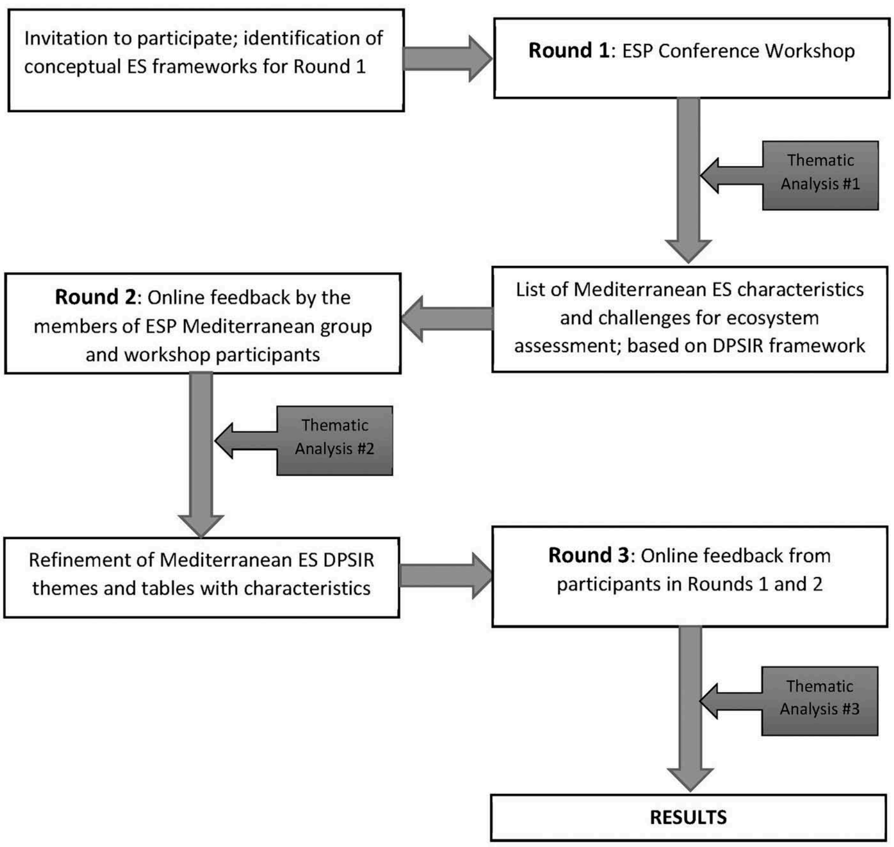

Figure 2. Flowchart showing the implementation of the collaborative research process (ES = Ecosystem Services; DPSIR = Driver-Pressure -State-Impact-Response).

In the third round of expert consultation, the refined Mediterranean ecosystem services DPSIR framework (Figure 1), themes and key characteristics were shared with the experts who had participated in rounds 1 and 2 to provide feedback on the synthesis of previous contributions. These steps allowed for the engagement of a total of 28 scientists and practitioners in total (including the authors of this article). The experts have worked in terrestrial, freshwater and marine ecosystems, in a gradient of natural to artificialised ecosystems and in policy processes (Supplementary Figure 1). The experts have worked in a total of 11 Mediterranean Basin countries with some of the experts working at a more regional Mediterranean Basin (n = 6) and European Union (n = 5) level (Supplementary Figure 2). Based on the expert consultation, a comprehensive list of key aspects of (a) the particularities of Mediterranean ecosystems and their services (Table 1), and (b) those aspects which are at risk of not being adequately captured by existing ecosystem service assessments was developed.

3. Results and discussion

3.1. Drivers and pressures

Demography and economic drivers, including human population growth and increased demand for goods and services, urbanisation and industrialisation patterns were identified as being important drivers of change within the region. Changes in land use management, the degradation and loss of habitats, overexploitation of terrestrial, coastal and marine resources, introduction of alien species, and regional climatic change were considered as key direct pressures acting on Mediterranean ecosystems (Table 1). Drivers and pressures often act synergistically (Doblas-Miranda et al. 2016) and not linearly, thus increasing the complexity in determining the impact on ecosystems. Therefore, whilst the high level of vulnerability of the Mediterranean Basin to global environmental change can threaten future ecosystem services supply (Schröter et al. 2005; Hoff 2012), projections of ecosystem services supply patterns show high levels of uncertainty (Cramer et al. 2018). For example, while forest cover areas and biomass storage in forest ecosystems are predicted to increase thereby increasing carbon sequestration (Vilà-Cabrera et al. 2017), seagrass meadows are predicted to decline in coverage and associated carbon sequestration capacity (Jordà et al. 2012). Droughts are predicted to further impact the Mediterranean Basin through increased mortality of plants, reduced quality of surface water, lower levels of ecosystems productivity, and pest and disease outbreak (Palacio et al. 2012; Vayreda et al. 2012; Mediterranean Wetland Observatory 2018).

In terms of land use management changes, the strong links between socio-economic factors and Mediterranean landscapes are particularly evident in agricultural abandonment. The loss of traditional management is associated with the progressive loss of terraces and the erosion of fertile soils (Cyffka and Bock 2008). The expansion of forest ecosystems regions of land abandonment impacts on ecosystem services in yet another way (Aretano et al. 2013; Fuchs et al. 2016). A contemporary phenomenon is the intensification of agricultural production and the loss of diversified agroecosystems, affecting many areas in Mediterranean EU countries (Debolini et al. 2018). The homogenisation of the landscape over vast areas (Nogués-Bravo 2006) results in the loss of agrobiodiversity (José-María et al. 2010; Tsiafouli et al. 2015), and associated ecosystem services (Raudsepp-Hearne et al. 2010; also see 3.5. Impact – Interactions between ecosystem services, and arising benefits and values).

Freshwater resources within the region are threatened by multiple pressures. These have led to the degradation and fragmentation of freshwater ecosystems, impacting significantly on their biodiversity (Skoulikidis et al. 2011, 2017; Mediterranean Wetland Observatory 2018). Irrigation demand increases rapidly with the intensification of agricultural practices while surface and groundwater bodies are often sinks of pollution arising from sources within catchment areas (CEPF 2017). The combination of increasing temperatures, decreased precipitation, particularly in the southern part of the Mediterranean Basin (Mariotti et al. 2015; Polade et al. 2017), and urbanisation and increased water demand (e.g. Malek and Verburg 2017; Skoulikidis et al. 2017) contributes to the degradation of land and water resources, through aridification, salinisation and desertification, especially in the southern parts of the Mediterranean Basin (Souissi et al. 2018). Climatic extremes, especially droughts, exacerbate the impact on ecosystem services supply, amongst others, due to significantly lower freshwater availability (Terrado et al. 2014). The counterpart to agriculture in marine systems is reflected on the long fishing tradition, and the Mediterranean Sea has been exploited by humans since the prehistoric era and fishing is one of the activities with the longest tradition (Cortés-Sánchez et al. 2011). Historically, fishing was mainly performed through artisanal methods and was restricted to coastal areas. However, artisanal fishing has over the last 50 years been relegated to a marginal role (Gaudin and De Young 2007) and has been gradually replaced by heavy towed gear capable of operating at greater depths. The introduction of new technologies led to an increase in fishing capacity and catchability, which has further increased the pressure on marine ecosystems. Additionally, there is growing concern for the damages on benthic habitats caused by towed

Table 1. Drivers and pressures acting on Mediterranean socio-ecological systems and ecosystem services capacities and flows.

	Erosion control	Carbon sequestration	Food Production (Agriculture)	Cultural	Water supply
Drivers and Pressures	• Agricultural abandonment • Abandonment of agricultural use in steep areas • Loss of grazing • Climatic change – increased duration of drought period; role of extreme rainfall events • Intensification, increased mechanisation, irrigation, dependence on agro-chemicals • Negative effect on erosion regulation of larger wildfires • Natural succession, afforestation and restoration in some areas. But concurrent biodiversity loss in other areas • Coastline artificialisation • Commercial fishing practices • Nutrient run-off into coastal waters (fertilisers, sewage…) • Increasing numbers of recreational boats and yachts affecting marine habitats (e.g. *Posidonia oceanica*) through anchoring	• Agricultural abandonment and decreased human use of forests during last decades. Natural succession, afforestation and restoration in some areas. • Change in fire occurrence and intensity • Coastal and urban development • Direct negative impacts of climate change on forest C storage and sequestration • Role of pest outbreaks leading to reduced tree growth and C stock accumulation rate • Urbanisation and industrialisation; loss of traditional agroforestry systems • Pollution from nutrient run-off • Increasing numbers of recreational boats and yachts affecting marine habitats (e.g. *Posidonia oceanica*) through anchoring	• Recent agricultural intensification and concentration, including increased use of agro-chemicals, irrigation. • Loss of heterogeneous rural landscapes and crop/agro-biodiversity • Disconnection between agriculture, forest and the use of animals have led to an unbalanced fuel load favouring rural fires • Agricultural fragmentation • Urbanisation • Climate change is likely to increase dependence on food imports • In certain parts, exhaustion of freshwater reserves leads to abandonment and soil salinisation. • Local, national and regional (e.g. EC) agricultural policies. Agriculture in the Southern Mediterranean Basin as being particularly susceptible to market and price fluctuations; • Land use and climate change have an impact on wild food production	• Climate change • Tourism in islands leading to agricultural abandonment and more urbanisation; • Urbanisation and industrialisation • Political and economic instability impact negatively on tourism in affected regions but potentially further causing a concentration of tourists in northern Mediterranean countries; • Impact of loss of traditional practices and associated elements from the landscapes on cultural identity and heritage • Lack of regulations or otherwise lax enforcement	• Climate change – the most important driver affecting water supply in the Mediterranean Basin. Scenarios indicate increased demand for domestic water and irrigation • Land cover change affect water supply by extra water demanding crops; • Changes in permeability of surfaces due to urbanisation. • Pollution affecting the quality dimension of water supply; • Invasion of non-native species affecting water availability dynamics • Loss of keystone marine species with high cultural values for local population (e.g. dolphins, sea turtles, monk seals). • Highly prone to invasive species (e.g. *Acacia, Arundo, Eucalyptus spp.*)

fishing gears (e.g. de Juan et al. 2007). This increase in fishing pressure has led to the over-exploitation of fish stocks and a shift in community structures (Coll et al. 2010; Piroddi et al. 2017).

The Mediterranean Sea has many entry routes for exotic species due to the opening of the Suez Canal, high maritime traffic and aquaculture activity (Katsanevakis et al. 2014; Mačić et al. 2018). Additionally, high coastal population densities, impacts from agriculture run-off and insufficient level of sewage treatment combined with the fact that the Mediterranean is a semi-enclosed sea with little water exchange with the open ocean, make the Mediterranean Sea particularly sensitive to pollution, posing an important threat to marine biodiversity (Micheli et al. 2013). Maritime traffic has been a major source of pollution in the Mediterranean Sea (Abdul Malak et al. 2015) whilst the extremely busy shipping routes increase the already high mortality rates of endangered species like marine mammals through ship collisions (Vaes and Druon 2013). These shipping routes are also a major source of underwater noise which has harmful impacts on marine biodiversity (Aguilar Soto et al. 2006). Given the strategic location of the Mediterranean Basin, these shipping routes are crucial for the financial well-being of its adjacent countries, generating conflicts among biodiversity protection and human well-being. Microplastic pollution is also a major driver of biodiversity loss within the Mediterranean Sea (e.g., Fossi et al. 2017; Casini et al. 2018).

Widespread urbanisation trends in the Mediterranean Basin are associated with persistent rural-urban migrations, endogenous urban growth, and increasing tourist influx. Between 1970 and 2010, the urbanisation rate around the Mediterranean increased from 54% to 66%, whilst it is estimated that by 2025 72% of the Mediterranean population will live in urban areas (Masad 2016). By 2030, the Mediterranean Basin may have become the global biodiversity hotspot with the highest percentage (5%) of urban land (Elmqvist et al. 2013). Cities play an important role in economic growth and development, but have increasingly promoted rural-urban migration and are a source of impacts on biodiversity (Masad 2016; Mediterranean Wetland Observatory 2018), and on coastal and insular ecosystems because of a strong tourist influx to these environments (Tzanopoulos and Vogiatzakis 2011; Aretano et al. 2013). With 33% of the Mediterranean Basin population residing in coastal areas, coastal ecosystems are highly threatened by the overexploitation of natural resources and the conversion of natural ecosystems into urban areas with a direct impact on ecosystem service supply (CEPF 2017; Balzan et al. 2018; García-Nieto et al. 2018), further pressure is added as these areas are becoming hotspots for ecosystem services demand (Baró et al. 2017). On the marine and coastal realm, the unplanned and exacerbated transformation and use of the coast has impacts at various ecosystem levels, from meiofauna to vertebrates, including marine mammals, due to stressors such as pollution, exploitation and biological invasion among others (Defeo et al. 2009). Coastal development has, for example, been associated with strong declines of Mediterranean seagrass *Posidonia oceanica* beds, with negative impacts on its food web components (Giakoumi et al. 2015; Holon et al. 2015). The loss of traditional cultural elements and endemic ecosystem is also associated with the loss of local knowledge, cultural heritage (Morán-Ordóñez et al. 2013; Stara et al. 2015), and other cultural ecosystem services (Martín-López et al. 2016).

Drivers and pressures do not act in isolation, but they interact within landscapes. Fires are a common feature of the Mediterranean landscapes and its determinants are rapidly modified by changes in the landscape, climate and socio-economic factors (Brotons et al. 2013). Traditionally, the deliberate burning of woodlands by rural populations for improving ranges for grazing animals has been a cause of forest fires in the region (Meddour-Sahar et al. 2013). The increasing frequency and intensity of large wildfires in the last decades, in particular in the Western Europe, is caused by several factors including the strong decline in rural populations; the replacement of agricultural ecosystems with scrubland and forests by secondary succession, and the homogenisation of traditional landscape mosaics with subsequent loss of cultivated fields and meadows (Badia et al. 2002; García-Ruiz et al. 2013; Nunes and Lourenço 2017). The changing dynamics of wildfires also has a strong impact on the ecosystem services supply (Thom and Seidl 2016) and whilst abandonment and secondary succession may be associated with improved biodiversity conservation in some cases (Plieninger et al. 2014), enhanced erosion regulation (García-Ruiz et al. 2013) and carbon sequestration (Vilà-Cabrera et al. 2017) or increased eco-tourism potential (Aretano et al. 2013), these may be negated quickly by wildfires (Moreira et al. 2011; Peñuelas et al. 2017).

3.2. State – ecosystem structure and condition

Mediterranean social-ecological systems are a complex mixture of elements (Table 2). The rich biodiversity within the region has played a critical role in human prosperity and well-being for millennia as ecosystems were modified and transformed to provide a wide range of ecosystem services. Together with the climatic and environmental variability, human activities strongly influence and shape the spatio-temporal heterogeneity in biodiversity and ecosystem services supply. The key characteristics identified across the five selected ecosystem services were the (1) impacts of historical changes to ecosystems and human inputs, (2) the significant role of indigenous biodiversity and endemic species, and (3)

Table 2. State of Mediterranean social-ecological systems as a consequence of human input and temporal (intra-annual and long-term) variability (ES: Ecosystem services).

		Erosion control	Carbon sequestration	Food Production (Agriculture)	Cultural	Water supply
State – Ecosystem structure and condition (including spatial variability)	***Human input and influence on ecosystem services structure and condition***	• Historical changes and continuous human input shaping landscapes and contributing to erosion reduction ES; • Role of traditional elements of Mediterranean landscapes (extensive terracing/ditches/field margins, open-forest/agroforestry systems). These patches provide vegetation cover. • Role of human-induced disturbances e.g. traditional grazing activity, fires and fire suppression • Negative role from the intensification of agriculture and forest activities, in particular mechanisation • Intense use of coastal waters and excessive nutrient input leading to seagrass habitat erosion	• Historical deforestation and more recent abandonment and afforestation including policies (since mid-twentieth century) at national level • Decreased human use of forests during the last decades • Important role of traditional farming and agroforestry/landscape elements (as dehesas or montados) in relation with this ES and the potential effect of the decline by land abandonment and fire impact • Dense coastal population and intensive use of coastal waters affecting the abundance and quality of seagrass habitats and hence sequestration capacity	• Heterogeneous landscapes due to historical and present changes, farming practices moulding the landscape, and driven by natural and socio-economic factors • Dependence on importation of food • (Fishing) Commercial fishing practices (e.g. trawling) affecting the structure of marine habitats and associated production	• Many traditional farming and fishing practices associated with cultural heritage and ES; • Human input plays an important role in shaping terrestrial landscapes and coastal areas • Anthropogenic vegetation disturbance regimes sustaining culturally modified habitat types, and associated species assemblages of high conservation value	• Intense human impact; historical human modification of ecosystems to ensure rain-water harvesting • Dependence on both ecosystems and water infrastructures to support freshwater provisioning ES.
	Biodiversity patterns underpinning ecosystem services	• Traditional agricultural management associated with high biodiversity and heterogeneous landscape patterns, multiple ES. • Role of native flora and ecosystems (e.g. forests) • Resistance of scrublands to grazing	• Importance of endemic species: e.g. *Posidonia oceanica* has a high C sequestration capacity • Local-scale heterogeneity of ecosystems and regional spatial trends • Important role of forest species and structural richness	• Traditional agricultural management associated with high biodiversity, multiple ES. • Nutrient deficient soils	• High level of biodiversity; characterised by a patchy mosaic of different types of ecosystems, including herbaceous, shrub and tree cover • Protected areas are often located in cultural landscapes that also provide many cultural ecosystem services • Important role of sites with high biodiversity, coastal areas and heterogeneous landscapes • Importance of key species in eco-tourism/part of the cultural heritage	• Critical role of ecosystems in ensuring groundwater recharge • vegetation traits – ecosystems/plants are adapted to drought during Summer –
State – Temporal Variability	***Intra-annual variability***	• Dry periods with reduced vegetation cover and lower ES delivery. In particular, directly after the summer period the soil is most vulnerable to erosion due to reduced cover. • Periods with strong rainfall trigger soil erosion	• Primary production is highly dependent on water availability – service flow varies between the seasons. E.g. in wetlands, where in dry period there is a net emission of carbon	• Seasonality of agricultural production • Fallow land during drier months	• Temporal variation in tourist visitation or use of coastal ecosystems, and arising pressures • Given the strong intra-annual variability, dynamic management of natural resources & socio-ecological systems is required	• Precipitation in Mediterranean Basin is seasonal, associated with high inter-annual variation, which affects ecosystems integrity and the provision of water supply • Surface water often greatly reduced during dry seasons/intermittent
	Inter-annual variability	• long(er)-term changes in ecosystems as a consequence of agricultural abandonment and intensification; • changing disturbance regimes e.g. fire and fire suppression policies (prescribed fires) impacting on erosion regulating ES	• Increased tree density and biomass of Mediterranean forests during last decades due to reduced human use • Abandonment giving rise to 'new forests' which provide faster growth rates and carbon sequestration • Changes on forest dynamics and composition. Some species are replaced by other less sensitive to environmental variability	• Inter-annual variability of weather conditions affects food production • Impacts of climate change • Areas sensitive to drought effects often show abandonment of crops	• ES delivery dependent on weather conditions in a particular year. • Changing weather patterns e.g. extended summer and severe droughts;	• Reservoirs and land management role in interannual variability • Increasing value of water due to climate change, scarcity and dependence on grey infrastructure. • Increased frequency of drought episodes.

strong seasonal, interannual, long-term and spatial variation in ecosystem services supply creating trade-offs and synergies between ecosystem services.

Land use land cover patterns, arising from historical modifications of the landscapes, and particularly in agricultural, coastal and island environments, have a long-lasting impact which is still influencing current ecosystem services supply (Baró et al. 2016; Balzan et al. 2018). For example, forest clearing has traditionally been a requirement for agricultural production systems in many parts of the Mediterranean. This land use change had profound effects on the region's biodiversity and involved a reduction in forest-related ecosystem service supply like firewood or soil erosion control (Blondel et al. 2010). Agricultural legacies may continue to prevail in the long-term through their impact on biodiversity and ecosystem services as demonstrated by forests growth and carbon sequestration. Forest attributes vary with environmental conditions that remain influenced by past decisions on the allocation and use of land for agriculture (Vilà-Cabrera et al. 2017).

Massive changes in human societies and cultural practices have strongly affected biodiversity. Despite these changes, the region's social-ecological systems have continued to support a high level of biodiversity (Médail and Quezel 1999; Myers et al. 2000; Allen 2003), which underpins the capacity of ecosystems to provide services (Vlami et al. 2017). Scrubland and forest adapted to the Mediterranean weather, fire regimes and grazing dynamics, are important for the supply of food (including for example wild fruits or mushrooms) and materials (e.g. cork, timber), the regulation of freshwater quantity and quality, and of soil erosion whilst contributing to carbon sequestration (Roces-Díaz et al. 2018a). Mediterranean wetlands ensure a buffering role to absorb water during floods and provide freshwater during droughts while sequestering carbon and providing nursery habitats for many endemic species (Mediterranean Wetland Observatory 2018). Similarly, *Posidonia oceanica* meadows, an endemic Mediterranean species, do not only play a key role for carbon sequestration in coastal environments but also provides multiple ecosystem services (Campagne et al. 2015) such as the protection of the gene pool, habitat provision for multiple species, provision of food, maintenance of water quality, the prevention of coastal erosion and the use of beaches and coastal waters for recreation and tourism (Vassallo et al. 2013; Ruiz-Frau et al. 2018). The Mediterranean Sea is also home to emblematic marine species, like whales, dolphins and sea turtles (Panigada and Notarbartolo Di Sciara 2012).

3.3. State – intra-annual variability

The sources of temporal variation in ecosystem characteristics and in the supply of ecosystem services were identified to arise from the (a) strong seasonal changes in ecosystems and (b) the longer-term interannual changes in ecosystems. Across the annual cycle, seasonal variation is particularly expressed in cultural ecosystem service supply and flows, whereas temporal availability of water determines many provisioning and regulating ecosystem services (Terrado et al. 2014). Dry periods are associated with reduced primary production, vegetation cover or with plant dormancy (Volaire and Norton 2006; Volaire et al. 2009), and therefore in addition to lower freshwater supply, these drier periods are also associated with lower erosion regulation, carbon sequestration and food production. Seasonality in food provisioning from marine systems is mainly determined by the life cycle of those species of commercial interest such as deep-sea prawns (Guijarro et al. 2009). This biological seasonality is generally coupled with seasonal fishing regulations aimed at protecting the stocks. Seasonal variability is also visible in ecosystem services demand which follows the peaks of tourist visitation patterns. The high recreation and tourism services' flows coincide with high demands for water during the warmer months (Mediterranean Wetland Observatory 2018).

3.4. State – inter-annual and long-term variability

Longer term changes in ecosystems and their services are strongly determined by human activities and are mainly associated with land use and climate change. Long-term variability arises for the concurrent agricultural abandonment and intensification of agriculture and tourism-related activities (Aretano et al. 2013), changes in fire occurrence, and the decreased use of forests leading to recovery and increased tree species diversity (Vilà-Cabrera et al. 2017). Climate change has been associated with significant negative impacts on regional biodiversity and ecosystem services (Schröter et al. 2005), including the decline of some types of forest ecosystems (Vidal-Macua et al. 2017), wetlands (Mediterranean Wetland Observatory 2018), and impact on crop production (Olesen et al. 2011; Vidal-Macua et al. 2018) flood protection (Mediterranean Wetland Observatory 2018), and forest carbon sequestration (Seidl et al. 2014). With a projected decrease in annual precipitation and increase in extended summer droughts (Mariotti et al. 2015), it is expected that climate change will lead to a lower capacity of ecosystems to supply freshwater whereas the demand for this ecosystem service, especially from cities, agriculture and industries, is expected to increase.

Climate change is considered one of the main drivers of change for Mediterranean terrestrial, freshwater, coastal and marine ecosystems. Forecasted scenarios for Mediterranean areas envisage decreases in rainfall and wind, warmer surface waters and prolonged water stratification periods (Calvo et al. 2011; Mariotti et al. 2015). The Mediterranean Sea is warming two to three times faster than the global ocean (Marbà et al. 2015). The effects of these changes are likely to be reflected in the meridionalisation of species, mortality events of coralligenous communities due to anomalous warm water temperatures; increases in the smallest phytoplankton due to longer water stratification periods; proliferation of gelatinous carnivores and a faster acidification of seawater compared to the global oceans (Calvo et al. 2011). Furthermore, it has been predicted that the seagrass, *Posidonia oceanica* could reach functional extinction under warming scenarios predicted in the western Mediterranean (Jordà et al. 2012; Telesca et al. 2015).

A recent assessment of periurban land around 12 Mediterranean cities (eight European and four North-African), shows that the capacity of these important areas in terms of ecosystem services supply has generally reduced over the last 20–30 years due to urbanisation dynamics (García-Nieto et al. 2018). However, it also shows some increases in the supply of certain forest-related ecosystem services, such as air quality regulation, timber, and fuelwood provision. Studies have demonstrated that agricultural abandonment followed by secondary succession may indeed lead to increased canopy cover, increasing ecosystem services supply (Padilla et al. 2010; Tzanopoulos and Vogiatzakis 2011; Aretano et al. 2013). However, these long-term changes may also give rise to reduced species diversity, increased wildfire risk and the loss of crop production systems and associated cultural ecosystem services (CEPF 2017).

3.5. Impact – interactions between ecosystem services, and arising benefits and values

Several ecosystem service interactions, in the form of synergies and trade-offs, were identified by the experts (Table 3). Fisheries and agricultural food provisioning ecosystem services were identified to be strongly associated with cultural heritage and identity, recreation and tourism (Holmlund and Hammer 1999; Zasada 2011). Similarly, freshwater provisioning is a key ecosystem service that is threatened by overexploitation and the impacts of a changing climate, potentially impacting on food security and other benefits arising from ecosystems such as reduced carbon storage and local and global climate regulation (Hoff 2012). Increased demand for food and freshwater provisioning ecosystem services and increased tourist influx, support economic growth within the region but also significantly impact the Mediterranean ecosystems which causes a general reduction in natural capital (CEPF 2017). Similar decreasing trends in the natural capacity of ecosystem to provide ecosystem services have been observed for the Mediterranean wetlands, coastal and marine ecosystems (Liquete et al. 2016; Mediterranean Wetland Observatory 2018).

3.6. Response – challenges in the implementation of ecosystem assessments

The experts have identified several key characteristics that are currently no well captured in ecosystem assessments due to the inherent complexity of the Mediterranean social-ecological systems (Table 4). This information can serve to identify meaningful management or policy actions to sustainably manage ecosystems and their services within the region. The key challenges in the implementation of ecosystem assessments for the social-ecological systems of the Mediterranean Basin are presented in more detail below:

(1) *Appropriateness of spatial and temporal scale*: experts identified relevant pressures acting at varying spatial and temporal scales which drive intra- and inter-annual variation in ecosystem structure, ecosystem services supply and socio-economic conditions that are often inadequately represented in ecosystem assessments. The assessment of ecosystem condition is considered as an important challenge due to existing inter and intra annual variability of climate and related biophysical processes. This variability is, however, only rarely sufficiently covered by ecosystem assessments (e.g. for Mediterranean wetlands (Perennou et al. 2018)).

(2) *Multidisciplinary approaches are required given the complexity of social-ecological systems in the Mediterranean Basin*: the use of adapted methods is crucial in the assessment of changes in ecosystem services flows and the arising socio-economic benefits (IPBES 2016). The complexity of Mediterranean social-ecological systems suggests that multidimensional tools and methods are required to assess changes in Mediterranean ecosystem services. This is required to allow for a meaningful connection between changes in the supply, use and, demand of ecosystem services and different beneficiary groups (Geijzendorffer et al. 2015).

(3) *Representativeness*: Existing methods are often adapted from different social-ecological systems that may not be characterised by the high levels of diversity present in heterogeneous landscapes and the non-linear importance of certain ecosystems

Table 3. Impacts on ecosystem services and the benefits humans gain from Mediterranean social-ecological systems (ES: Ecosystem services).

	Erosion control	Carbon sequestration	Food Production (Agriculture)	Cultural	Water supply
Impact – Interaction with other ecosystem services (synergies and trade-offs)	• Synergy between erosion regulation and provisioning, regulating and cultural ES capacity and flow (e.g. on crops, C sequestration; nursery habitats); • Silting of waterbodies is associated with reduced flood prevention ES.	• Synergies with local and global climate regulation, and other regulating ES such as erosion control. • Synergy with gene pool protection ES, e.g. through a positive association with tree diversity.	• Synergies with regulating ES e.g. erosion regulation, air and water quality regulation. But depends on the intensity of management, and can lead to trade-offs with these services in intensive cultivation. • Synergies with gene pool protection ES (in the case of low input/several traditional agricultural practices); Some food-systems rely on landscape and biodiversity attributes • Intensive farming leading to a land sparing dynamic but intensification in some areas is not balanced by better environmental conditions of extensively managed areas. • Importance of intermediate ES (pollination, nutrient cycling, pest control) for food production	• Different forms of tourism creating synergies between multiple ES; strong links between traditional food production and cultural ES • Trade-offs caused by high tourist influx. E.g. concerns of locals related to tourism pressure in some areas. • Trade-offs with food provisioning ES (particularly on islands) • Trade-offs between benefits and nuisances (e.g. perceived nuisance of seagrass beach cast vs. seagrass benefits) • Relevant gradient of demand of cultural ES from urban to rural areas • Multifunctionality of coastal ecosystems: provide recreation, tourism, high educational, scientific, aesthetic and inspirational value.	• Water supply may have a trade-off with food production (agriculture); • Water availability important for vegetation cover, leading to synergies with cultural, carbon sequestration and erosion regulation services.
Impact – Benefits and Values	• Several indirect benefits, through for example food provisioning • Erosion prevention ES improves water quality downstream • Avoided siltation of dams and aquatic habitats • Erosion prevention in coastal habitats improves coastal waters' quality and transparency	• Part of climate change mitigation within the Mediterranean Basin	• Important role in cultural heritage, recreation and tourism; • Low environmental impact agriculture can act as important fire breaks and limit the spread of wildfires • Intensification of management leads to soil erosion, loss of agrobiodiversity • Abandonment may have a positive impact on other items of wild food production such as game meat – e.g. populations of wild boar, roe deer and others are increasing in many areas partly as a consequence of decreased traditional agricultural and forest activities	• Traditional farming practices part of the cultural heritage • Feeling of sense-of-place and distinct identity • Artisanal fishing part of cultural heritage and related to identity values • Protected areas/coastal areas/sites with high biodiversity important for recreation, ecotourism, and aesthetics. • Spiritual and inspirational values related to cultural landscape forms (landscape character). • Inspiration gained from wilderness attribute of landscapes. • Tourism – consumed by many visitors; strong direct and indirect contribution to economic growth; • Positive impacts on human health of recreational and sport activities; • Leisure, recreation, environmental education & awareness, tradition	• Freshwater supply (aquifers, surface water) as a highly valued benefit, and often scarce ecosystem good, necessary for human well-being and important for crop provisioning within the region; • Source of renewable energy

Table 4. Challenges in the implementation of ecosystem assessment within Mediterranean socio-ecological systems.

Ecosystem service	Ecosystem Service specific challenges	Common challenges
Erosion regulation	• Erosion regulation ecosystem services strongly linked to ecosystem condition. The assessment of ecosystem condition presents several challenges in heterogeneous Mediterranean landscapes; • Data availability on effectiveness of measures or ecosystems for erosion mitigation is often limited;	• Uncertainty of future climate, land cover and associated ecosystem processes (e.g. wildfires) scenarios • Data availability for ecosystem structure, condition, function and services; • Empirical data relating to biophysical characteristics (at species, ecosystem level), and obtained from field trials and empirical studies, for specific ecosystem services is often limited. • Capturing the inter-annual variability in ecosystem services capacity and flow; • Discerning between the importance of human input and semi-/natural ecosystems in ecosystem services delivery; • Importance of considering Mediterranean as 'social-ecological ecosystem structures' that co-produce ecosystem services; this must be reflected in the choice of assessment methods; • Assessment of synergies and trade-offs is likely to hampered by the relative inavailability of data at adequate spatial scales (e.g contribution of traditional small-scale farming practices to carbon sequestration, erosion regulation and cultural heritage);
Carbon sequestration	• Empirical data about species or functional group cover, carbon storage and sequestration is normally limited and based on multiple assumptions; • Empirical data from field and long-term trials are strongly required to assess ecosystem services and their dynamics;	
Food production (agriculture)	• Challenges associated with the assessment of food production due to high diversity of farming systems; • The presence of small-scale agricultural activities (e.g. subsistence agriculture), having important socio-cultural and economic functions, may not be adequately captured in existing assessments carried out at national or regional scale;	
Cultural	• Cultural services may be provided by different ecosystems e.g. important role of semi-natural ecosystems for aesthetic/inspirational value but strong contribution of green urban areas for recreation; • Importance of focusing more on relational values and the socio-cultural significance of ecosystems. The assessment of perception and use by society of different cultural services, and their change in the future requires locally adapted approaches and stakeholder and expert participation. • Scale of ecosystem assessments: often difficult to value cultural benefits generated by a specific ecosystem or specific species (e.g. dolphins or sea turtles).	
Freshwater supply	• Water quantity, quality and demand data availability • Implementation of ecosystem assessment to combine conservation of freshwater resources with biodiversity conservation and restoration practices within watersheds; • Ecosystem assessments can provide the basis for the implementation of nature-based solutions that enhance ecosystem capacity to provide freshwater but also conserve biodiversity and create synergies with other ecosystem services (e.g. food provisioning, erosion regulation, aesthetic)	

for the wider supply of ecosystem services. For instance, wetlands and sandy beaches in small Mediterranean islands contribute to a higher ecosystem services flow relative to their surface in comparison to other ecosystems (e.g. Zedler and Kercher 2005; Togridou et al. 2006; Katselidis et al. 2013).

(4) *Data availability, national and institutional fragmentation* – The detection of trends to make robust inference across the region requires a significant amount of data, to guarantee the coverage of the large spatial, intra- and interannual variability of Mediterranean social-ecological systems. The fragmentation of data between regions, countries, and often local authorities, creates a strong element of heterogeneity in data availability and characteristics which often constitutes a source of uncertainty in ecosystem assessments. Ecosystem assessments for the Mediterranean Basin have been carried out at national or local scales (Martín-López et al. 2016) but a regional assessment remains unavailable, even though several drivers and pressures act at a regional scale. Earth observation methods provide the means to fill a limited number of data gaps relating to the biophysical assessment of ecosystems and their services across the region (e.g. Hardin and Jensen 2011; Perennou et al. 2018). Meanwhile permanent networks of surveying plots, such as those derived from National Forest Inventories or long-term ecological research, provide an opportunity to develop regional studies about ecosystem structure and functions and to study temporal changes of relevant ecosystem services (e.g., Vayreda et al. 2012) at multiple spatial scales (Roces-Díaz et al. 2018b). Given these gaps, and the extensive data requirement for ecosystem assessments at varying scales, the consultation with experts and stakeholders can improve the understanding of the ecosystem services flows (Campagne and Roche 2018). An important challenge also remains for the collection of comparable information on socio-economic data, with data availability often being biased towards the European Mediterranean countries and much less available for North Africa and Eastern Mediterranean countries (García-Nieto et al. 2018; Malek et al. 2018).

(5) *Operationalisation of ecosystem assessments and projections*: Process-based approaches incorporate explicit representations of geochemical, physical and biotic processes underpinning ecosystem functioning (Lavorel et al. 2017), and can make projections on ecosystem services flow (Wolff et al. 2015). The application of such approaches for the Mediterranean Basin social-ecological systems remain limited and only a few examples are available (but see Schröter et al. 2005; Liquete et al. 2016; Piroddi et al. 2017). To adequately capture future changes in ecosystem services, assessments should be able to incorporate human-inputs and disturbance processes across the terrestrial-coastal-marine continuum. Within a context of the environmental and socio-economic changes within the Mediterranean Basin, the assessment of trends in ecosystem services flows is considered as being particularly important for policy and decision-making relating to land and resource use but this aspect is the least covered by existing data and indicators (Maes et al. 2012; Geijzendorffer et al. 2017). Projections are considered a critical tool for evidence-based decision-making on adaptation and mitigation actions to avoid, to the maximum possible extent, future negative impacts on ecosystems and undesirable trade-offs. Scenario-based approaches for the Mediterranean Basin can provide an opportunity to explore the uncertainty around the relationships and feedbacks between the different elements of the ecosystem services chain. (e.g. Malek et al. 2018). The challenge for scenarios of Mediterranean systems is to incorporate the multiplicity of factors influencing Mediterranean social-ecological systems whereas most projections tend to be monospecific, for example focusing on only one key driver such in climate change, land use, future projections on fish stocks and sea level change scenarios (Morán-Ordóñez et al. 2019). Results from scenarios can be used to coordinate environmental and other sectoral (e.g. agricultural, tourism, economic) policies to enhance adaptation and steer management towards sustainability (Khabarov et al. 2014; Malek et al. 2018). However, such approaches need to be multidimensional (Carpenter et al. 2009) and should capture the ecological and social processes operating at multiple spatio-temporal scales.

3.7. Response – implications for policy and management

Mediterranean Basin social-ecological systems are highly dynamic and continuously evolve due to new drivers and pressures whilst at the same time demonstrating a legacy of historical changes and patterns. The use of the modified DPSIR framework allowed us to conceptualise the dynamic nature of the Mediterranean social-ecological systems. By highlighting ecosystem service flows, the DPSIR framework enabled a focus on the management of ecosystems and their ecosystem service flows. It can be a useful tool in the identification of management approaches that integrate drivers of change with ecosystem service capacities and flow, and their spatial interactions and dynamics. This is in contrast with more traditional approaches to biodiversity management, which tend to be reactive in nature, focusing on the protection of ecosystems from human impact (Kelble et al. 2013). The use of the modified DPSIR conceptual framework integrating ecosystem services facilitates the identification of policies and management that improve the capacity and flow of ecosystem services and which evolved both with changes in the biocapacity of ecosystems to provide services as well as with changing demands for ecosystem goods and services by modern societies.

Mediterranean social-ecological systems are inherently complex, and oversimplifications in ecosystem assessments may arise from an inadequate representation of the relationship between historical and present human activities, biodiversity and ecosystem services spatial patterns, as well as the seasonal and long-term variability in ecosystem services supply, flow and demand. Multidisciplinary approaches are required to incorporate this complexity in ecosystem assessments for improved relevance to decision-making. Whereas the development of process-based approaches is generally considered an important tool to quantify ecosystem service flows, the integration of multiple ecosystem assessment methods remains a necessity to cover the wide variety of social and environmental indicators. The extent to which assessments can incorporate this complexity depends on the availability of data, with several gaps and opportunities for filling these through the use of satellite imagery, ecological methods, and social and economic assessment methods, at relevant spatial and temporal scales. This is without a doubt a challenge but information on ecosystem services is a crucial asset for evidence-based policy and management responses.

4. Conclusions

The use of ecosystem assessments to understand ecosystems' contribution to human well-being and to inform policy and management has become increasingly popular within the Mediterranean Basin. However, despite the shared natural and cultural heritage and the common threats, adaptations of assessment approach methods to the specific context of Mediterranean social-ecological systems are rare. In this work we have identified key characteristics of the Mediterranean social-ecological systems using the DPSIR framework, and have highlighted aspects that are currently oversimplified, leading to a potential bias in policy and management decisions. We have identified a number of challenges in the implementation of ecosystem assessment in the Mediterranean Basin associated with the integration of drivers and pressures in ecosystem assessments, the availability of empirical data about ecosystems, functions and ecosystem service flows and demand at the right scale, and the assessment of synergies and trade-offs between ecosystem services. Finally, we evaluate the potential application of DPSIR frameworks and multidisciplinary approaches, which are based on empirical data at relevant spatio-temporal scales, in developing more dynamic and evidence-based management practices for the Mediterranean Basin.

Notes

1. http://ec.europa.eu/environment/marine/international-cooperation/regional-sea-conventions/barcelona-convention/index_en.htm .
2. http://www.un.org/esa/sustdev/natlinfo/indicators/egmIndicators/MSSD_latest_eng.pdf .
3. https://www.ipbes.net/deliverables/2b-regional-assessments .
4. https://biodiversity.europa.eu/maes .
5. http://www.ecomilenio.es/ .
6. https://www.millenniumassessment.org/en/SGA.Portugal.html .
7. https://www.ecologique-solidaire.gouv.fr/levaluation-francaise-des-ecosystemes-et-des-services-ecosystemiques.
8. http://www.hamaarag.org.il/en/content/inner/ecosystem-services .
9. https://www.es-partnership.org/community/workings-groups/biome-working-groups/bwg-5-mediterranean-systems/ .
10. https://www.es-partnership.org/ .
11. http://www.esmeralda-project.eu/ .
12. http://www.operas-project.eu/ .
13. http://www.openness-project.eu/ .
14. http://www.eubon.eu/show/project_2731/ .
15. http://www.ecopotential-project.eu/ .
16. http://biodivmex.imbe.fr/?lang=en .

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