Chapter 26
The Socio-Ecological Dimension of Ocean Multi-Use Platforms

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Significance Statement A Multi-Use Platform can integrate different maritime activities into a single sea area. We propose an analytical framework to investigate the socio-ecological benefits and impacts of potential Multi-Use Platforms designs in the Mediterranean and North Sea. The framework uses a marine ecosystem services matrix that has the aim to facilitate knowledge sharing on the ecosystem goods and services a Multi-Use Platform can potentially support and interact with. The results highlight that Multi-Use Platforms provide multiple opportunities for energy generation, food provisioning (e.g. recreational fishing, extractive aquaculture) and cultural services (e.g. coastal recreation, diving, research and monitoring). Further research suggests application of quantitative socio-ecological analysis techniques to measure potential synergies and trade-offs among the multiple activities of the platform.

Keywords Ecosystem services · Blue growth · Offshore wind energy · Aquaculture · Tourism

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1 Introduction

The last two decades have seen substantial progress by the scientific community in the development of classifiers for marine ecosystem services (MES) to provide to decision-makers, planners and practitioners common standards for categorization and quantification of the ecosystem goods and services provided by the marine environment (CICES, 2018; MA, 2005). MES classification experienced a further development with the progressive implementation of the MSP Directive in European Seas starting since 2014. A stronger focus was given to the integration of the MES concept into MSP-oriented analysis (Ivarsson et al., 2017), with the aim to facilitate the integration of socio-ecological notions as sustainability principle into the planning process and the need to increase awareness of MES benefits to coastal communities and the maritime sectors commercially benefitting from MES flows (Friedrich et al., 2020). This resulted into a more diversified approaches oriented to understand the maritime sectors' benefits and trade-offs from MES, such as in relation to coastal tourism (Depellegrin et al., 2017), aquaculture (Gentry et al., 2020) or offshore wind energy (Hooper et al., 2017). Moreover, the need to enforce ecosystem-based management (EBM) into MSP, as integrated management approach to take into account full interactions within ecosystems, including humans, contributed to the evolvement of conceptual and practical techniques for the incorporation of MES into Maritime Strategy Framework Directive (MSFD) pressure assessment (Menegon et al., 2018). Most recently the EU Blue Economy Report 2020 (EC, 2020) reviewing the economic performance of Europe's Blue Economy has highlighted the need to incorporate MES notions into maritime sector analysis in order to make the Blue Economy more sustainable and resilient.

A promising development to foster Blue Growth in European Seas is the implementation of Multi-Use (MU). MU provides novel opportunities for maritime activities with potential added values for the environment and socio-economic development of the ocean space. Within the MUSES Project (Multi-Use of European Seas, Schupp et al. (2019) defined MU as "*the joint use of resources in close geographic proximity by either a single user or multiple users. It is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources and space by one or more users*". Although several studies were analysing the potentialities to MU across different sea areas (e.g. MUSES and MARIBE), none of the studies attempt to systematically account how a MU can supply and support the demand for multiple ecosystem goods and services. This chapter analyses the environmental and socio-economic benefits provided by Multi-Use Platforms (MUPs) as an example for MU. The study proposes a MUP and marine ecosystem goods and services (MES) assessment matrix (MES-MUP matrix) to address the socio-ecological relationships a MUP can disclose. The matrix is tested for two different MUP cases, namely the MWA Porto Corsini (Northern Adriatic Sea; Italy) and the FINO 3 (*Forschungsplattform Nordsee;* North Sea; Germany). An expert-based approach will be used to analyse socio-technical system components that can contribute to human-needs and welfare, the potential synergies and trade-offs emerging among MES and the potential implications of the use of socio-ecological analysis for the assessment and development of MUPs.

2 Data & Methods

2.1 Analytical Framework

The analytical framework that defines the five methodological steps for the analysis of MUP from a socio-ecological perspective is presented in Fig. 26.1. The framework is composed by five steps: (1) review of MES typologies applicable in Blue Growth contexts; (2) definition and review of MUP case studies to be analysed; (3) the definition of the socio-technical systems (STS) composing the MUP, (4) the design of a MES-MUP assessment matrix through literature and (5) the expert based evaluation of results in terms of MES provision by MUPs and potential MES synergies-trade-offs emerging from MUPs. In the following paragraphs a detailed rational for each step will be provided.

2.2 Step 1: MES Typologies for MUP Analysis

We analysed existing marine ecosystem services classification schemes relevant for the marine realm and Blue Growth (EU, 2020; Hattam et al., 2015; Lillebø et al., 2017) through a structured literature review. In order to be operational, MES identification was firstly performed considering the maritime sectors that MUP can potentially aggregate. A typical example of a MUP can refer to offshore wind turbines combined with aquaculture cages that can function as an energy-food

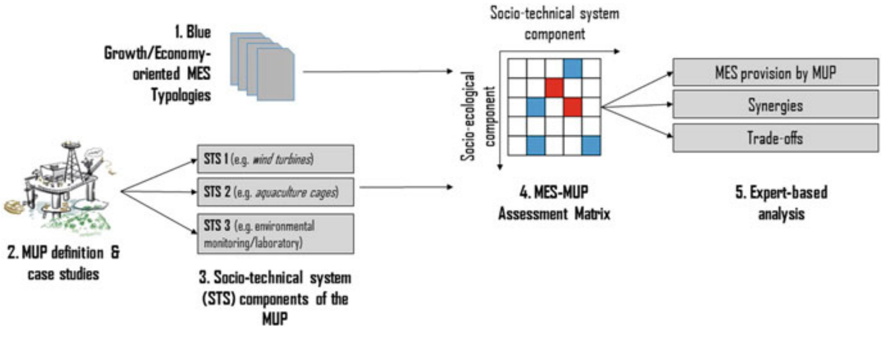

Fig. 26.1 Framework applied for the analysis of socio-ecological dimension of MUPs.

production installation (e.g. van den Burg et al., 2020) or marine renewable energy devices combined with a desalination device for a water-energy production infrastructure (e.g. Schupp et al., 2019).

2.3 Step 2: Characterization of MUP Case Studies

We analyzed the results from two EU funded projects on MU, to identify MUP case studies to be tested: The MARIBE Project (Marine Investment for the Blue Economy; www.maribe.eu) explored cooperation opportunities for companies that combine different Blue Growth/Economy sectors. The MUSES project (Multi-Use in European Seas; www.muses-project.com) explored the opportunities and barriers for MU in European Seas across five EU sea basins (Baltic Sea, North Sea, Mediterranean Sea, Black Sea and Eastern Atlantic). Both projects provided material to characterize MUPs and supported experts in the analysis of MES. According to van den Burg et al. (2020), MUPs are physical structures hosting multiple activities. MUPs are central to achieving EU's Blue Growth targets and can contribute to the implementation of several Sea basin Strategies as a central component to boost ocean sustainability. To test our hypothesis we selected two well studied MUP cases (Table 26.1 and Fig. 26.2), the MWA Porto Corsini MWA (Adriatic Sea, Italy; Depellegrin et al., 2019) and the FINO 3 Platform (*Forschungsplattform Nordsee,* North Sea, Germany; Viertl, 2006; UNITED Project, 2020).

Table 26.1 Overview of MUP types analysed

MUPs type	Geographic Area	Socio-technical system of the MUP	Development stage	Reference
MWA Porto Corsini Platform	Emilia-Romagna region Northern Adriatic Sea, Italy (Mediterranean Sea)	1. Extractive aquaculture 2. Nautical tourism 3. Diving 4. Recreational fishing 5. Research & monitoring laboratory	The platform needs to be decommissioned by 2021 and conceptual design for re-purposing the platform was developed by several stakeholders	Depellegrin et al. (2019)
FINO[1,2,3]	Southern North Sea, German bight, EEZ	1. Research & monitoring laboratory 2. Offshore test site 3. Extractive aquaculture	The platform is currently in use as a multi-use research station with future aspirations to include more economic activities such as extractive aquaculture	Viertel (2006), FINO 3 (2020) and UNITED Project (2020)

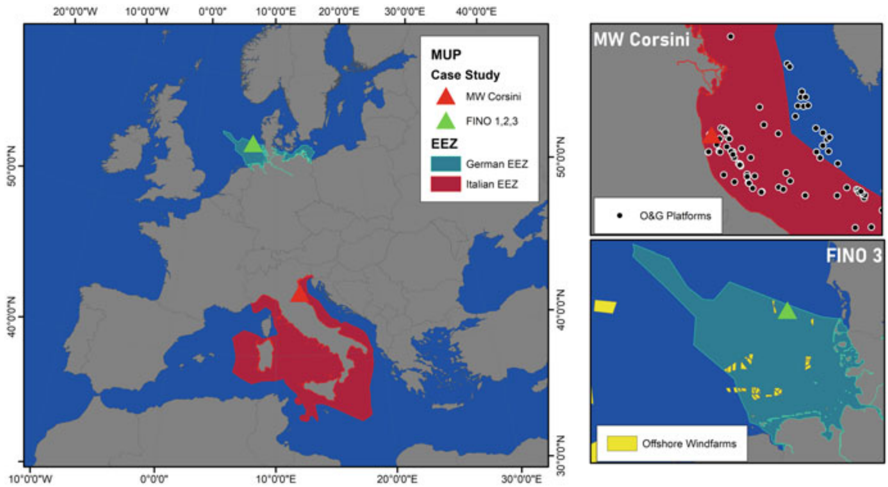

Fig. 26.2 MUP case studies. (For further graphical visualizations on the MUP design we refer to Castellani et al., 2017 (MWA Porto Corsini) and FINO 3, 2020)

Case 1 – MWA Porto Corsini Platform The twelve-legged Gas platform was constructed in 1968 operated by the energy company ENI and located in the Emilia-Romagna coasts (Italy) in the Northern Adriatic Sea (UN-MIG, 2017). The main driver for the potential conversion of the Platform to a MUP is the need for decommissioning in 2021. According to Italian Ministry of Economic Development (DGSUNMIG; Grandi, 2017) at least 20 offshore platforms (mainly extracting natural gas in shallow waters) will come to end of their production lifetime between 2017 and 2021. The need for decommissioning of O & G marine platforms has induced several pilot studies in diverse conceptual designs for the re-purposing of the platform as an alternative to a full or partial removal. The proximity to the coast line (7 km from coastline) and the intensive coastal tourism activity and infrastructure of the *riviera* suggest a re-purposing of the platform as a tourism and recreational attraction centre. Conceptual designs identified include the use of the platform as an anchoring support for aquaculture cages, the use of the site for nautical tourism purposes. Recreational activities such as diving and recreational fishing were planned as additional activity to be performed along with a marine research and monitoring laboratory (Depellegrin et al., 2019).

Case 2 – FINO 3 Platform The FINO 3 platform is part of a series of three offshore research platforms in Germany's North Sea and Baltic EEZ. They were constructed in the 2000s as part of the German federal government's newly developed offshore wind energy strategy and were erected in areas of immediate suitability for future offshore wind energy projects (Viertl, 2006). The FINO 3 platform is located roughly 80 km west of the island of Sylt and is made up of a 13 × 13 m work deck and a helipad roughly 22 m over sea level on a 4.7 m monopile foundation, topped with a 105 m tall lattice mast. It is situated in immediate vicinity if multiple active offshore wind farms (FINO 3, 2020). The platform is meant to provide a continuous monitoring station for meteorological, oceanological and ecological data as well as to serve as a test bed for new offshore technologies, training and construction methods (IEA Wind, 2011). While the FINO platforms have always acted as MU research platforms, FINO 3's sister platform in the North Sea, FINO 1, has previously also been investigated for its potential to host marine aquaculture installations (Buck et al., 2017). More recent investigations into the suitability of FINO 3 MU scenarios, as part of the EU H2020 BG5 Project "UNITED", have focussed on realising a combination of the research platform with extractive mussel and seaweed aquaculture in close vicinity to offshore wind farms (UNITED Project, 2020). The platform could potentially serve as a logistical hub, data centre or central monitoring station for connected mussel or seaweed aquaculture installations.

2.4 Step 3: Definition of Socio-Technical System Components (STS) constituting the MUP

The STS can be defined as systems designed to meet societal needs and generate benefits and value for markets, policy, behaviour, technology, science, industry, business, etc.. . . (EEA, 2020). Maritime activities such as ocean energy devices, aquaculture or port facilities are STS that can compose the MUP and that require access/alter/protect/exploit of marine ecosystem good and service due to a specific human demand. STS require continuous inputs from marine biotic and abiotic ecosystem services. STS could refer to traditional (e.g. shipping, coastal tourism or Oil & Gas extraction) but also combine emerging maritime sectors (e.g. marine aquaculture, ocean energy, marine biotechnology sampling sites). In addition, the operation of STS can cause adverse environmental effects on marine ecosystems responsible for the MES delivery, such, as pollution, marine litter or underwater noise.

2.5 Step 4: Design of the MES-MUP Assessment Matrix

This step includes the design of the MES-MUP assessment matrix. The matrix cross-links the socio-ecological components in form of MES and the STS components of the MUP that are responsible for MES flows. The matrix consists in the *x-axes* of the MUP types identified and the STSs features composing the MUP. The *y-axes* is composed of the MES category, the intermediate MES and the final MES. Intermediate ecosystem goods and services are services that offer humans indirect benefit (e.g. CO_2 storage, waste and pollution removal). Final ecosystem goods and services are the directly enjoyed, consumed or used by humans and so make a direct contribution to welfare (Boyd & Banzhaf, 2007; 619). The matrix (see Table 26.3) is composed by seventeen MES grouped into four categories: provisioning services (e.g. food provisioning and water storage), regulating & maintenance services (e.g. water purification, climate regulation or coastal protection), cultural MES (e.g. effects on tourism or recreational activities) and MES produced by abiotic means (Alexander et al., 2016) that refer to non-living components (e.g. water temperature) of the marine environment and by non-living processes (wind, wave and tidal motion).

2.6 Step 5: Expert-Based Compilation of the MES-MUP Matrix

The MES-MUP assessment matrix is compiled and evaluated by a dedicated expert group with experience in the MUP evaluation and MES assessment. Experts were asked to assess the direct and indirect linkages among the MUP based on the key concepts presented in Table 26.2.

3 Results & Discussion

3.1 MES Provision by MUP

Table 26.3 presents the MES-MUP assessment matrix for the two MUP cases. In the *x-axes* the socio-technical system components of the MUP were defined and the *y-axes* presents the socio-ecological components in form of MES. For example the

Table 26.2 Terms and definitions composing the MES-MUP matrix

Term	Definition	Reference
Social-technical systems	Systems designed to meet societal needs and generate benefits and value for markets, policy, behaviour, technology, science, industry, business, etc...	EEA (2020)
MES use	The access/alteration/management or protection of an ecosystem being due to ES demand	Turkelboom et al. (2018)
Direct MES use	The goods or benefits derived from the services provided by an ecosystem that are used directly by an economic agent. These include consumptive uses (e.g., harvesting goods) and non-consumptive uses (e.g., enjoyment of scenic beauty)	Openness (2020)
Indirect MES use	The benefits derived from the goods and services provided by an ecosystem that are used indirectly by an economic agent. The indirect use of the MES from an actor or entity outside the MUP is omitted from this definition	Openness (2020)
MES synergies	The simultaneous enhancement of multiple services through the use of an ES.	Spake et al. (2017)
MES trade-offs	The reduction of the provision of a service as a consequence of increased use of another.	Spake et al. (2017)

Table 26.3 MES-MUP assessment matrix. MES included in the matrix were retrieved from the following documentation: EU (2020), Lillebø et al. (2017), Hattam et al. (2015). Note: P-Provisioning ES; R-Regulating ES, C-Cultural ES; A-Abiotic ES.

ES category	*Ecosystem Service*	**MWA Porto Corsini Platform**						**Fino 3**	
		Decommissioned Oil & Gas infrastructure	*Extractive Aquaculture*	*Nautical Tourism*	*Diving*	*Recreational fishing*	*Research Facility*	*Research & Monitoring*	*Extractive Aquaculture*
P1. Food provisioning	Commercial fisheries								
	Aquaculture production		D						D
P2. Water storage & provision	Water for human consumption								
P3. Biotic material & biofuels	Biomass production for non-food purpose		D						D
R1. Water quality regulation	Bio and physicochemical processes for waste and pollution removal	D	I		I	I	D		I/D
R2. Air quality regulation	Air pollution concentration in the lower atmosphere						D		
R3. Coastal protection	Erosion prevention, protection against floods, hurricanes								
R4. Climate regulation	Greenhouse gases: uptake, storage and sequestration of CO2		D						D
R5. Weather regulation abiotic	Influence on local weather conditions as thermo regulator and humidity		I				D		I
R6. Life cycle maintenance	Biological and physical support for habitat maintenance and nursery	D	D		D	I	D	D	D
R7. Biological regulation	Biological control of pests may affect commercial activities and human health		I			I	D		I
C1. Symbolic & aesthetic values	Recreational services based on hunting, observation of species living in the wild			D	D				D
C2. Recreation & Tourism	Recreational fisheries					D			D
	Opportunities for nature-based relaxation and amusements			D					D
C3. Cognitive effects	Marine research, monitoring and education				D		D	D	D
A1. Abiotic mean	Provisioning of marine energy (wind, wave, tidal)								
	Creation of space for other uses to exist	D						D	

Direct Use/"MUP impacts" (blue, D)
Indirect Use/"MUP relies on" (red, I)

six STS composing the MWA Porto Corsini are, the decommissioned Oil & Gas infrastructure itself, extractive aquaculture, nautical tourism, diving, recreational fishing and a research facility. In the case of the MWA Porto Corsini, provisioning MES are supported through food provisioning by extractive aquaculture activities. In fact, also Emilia-Romagna Region belongs to the important mussel aquaculture producers in Italy (Castellani et al., 2017). The MWA Porto Corsini would be a donor of space for food provisioning through aquaculture in an area that is usually restricted, as the O & G platforms have a safety area of 500 meters (UNCLOS, 1992; *Article 60 - Artificial islands, installations and structures in the EEZ*). In terms of regulating and maintenance MES provide an indirect benefit to the food provisioning as they refer to the bio-physical processes of the marine environment that usually sustain the aquaculture production, this includes waste and pollution removal, suitable weather conditions for harvesting and operations in the aquaculture sites, suitable marine habitats and the pest control. The other four STS components identified would provide direct benefit to society through cultural MES. Adequate anchoring systems would provide opportunity for nautical tourism facilities through the establishment of marinas with multiple recreational opportunities for nature-based relaxation and the enjoyment of seascape and marine habitats. Especially maritime recreation activities such as diving and recreational fishing would directly benefit from a MUP, as hard substrate. The decommissioned oil and gas infrastructure can act as hard substrate that could enhance biodiversity, also known as rig-to-reef (RTR) effect (Ounanian et al., 2020; Macreadie et al., 2011). A concrete example of a reef-to-rig effect is the *Paguro* submerged O & G platform that sank after a fire in 1965 off the coasts of Emilia-Romagna Region (Castellani et al., 2017). Nowadays the *Paguro* is a NATURA 2000 Network (SIC-IT4070026; Regione Emilia Romagna, 2013).

Transitioning the FINO 3 research platform into a MUP includes two STS components: the maritime and marine research and monitoring operations as well as the extractive aquaculture operations. The primary component is the existing research platform which hosts a variety of different efforts for marine and maritime research. This component provides the platform and, thereby creates a space and opportunity for the second component, extractive aquaculture operations, to take place. The extractive mussel aquaculture would potentially supplement natural food provision from the marine ecosystem by providing food for human consumption. If macroalgae aquaculture were to be integrated into a system, it could also provide biomass for other non-food purposes and supplement harvests from wild stock. Non-food biotic materials harvested could potentially serve to capture carbon from the marine environment. Extractive aquaculture heavily relies on the natural water quality regulation services of the host-ecosystem while also positively impacting the water quality by removing dissolved or particulate nutrients from the water column. It also relies on other natural regulating services such as the provision of a stable ecosystem, biological pest control and others.

3.2 MES Synergy and Trade-Offs within a MUP

The MWA Porto Corsini Platform as MUP is a donor of space, infrastructure, logistic support and hard substrate. There is a high synergy of the MUP with all the cultural ecosystem services, as it would provide the necessary structure to support diving (recreational and scientific), recreational fishing and nautical tourism. Potential trade-offs are related to aquaculture activities that could result into marine pollution phenomena to the marine environment (e.g. production of waste, anoxic conditions of sediments or the release of medicines or chemicals) that could affect the overall ecological status of the sea area surrounding the MUP (Farella et al., 2020). Also a MUP could be associated with an increase of maritime traffic activities from nautical tourism, small scale fishery and diving operators that could cause additional stress to the marine environment or spatial conflicts with other activities not directly associated with the MUP, such as commercial fishery or shipping traffic related to port activities in proximity of Ravenna port.

Similarly to the MWA Porto Corsini Platform, the FINO 3 platform is a donor of space. It creates space and opportunities for other STS components, such as extractive aquaculture, to exist within an otherwise crowded coastal sea. The introduction of new system components into a MUP will inevitably increase the possible risks to either component. Traffic from either component can increase the shared and individual infrastructures while also potentially introducing environmental trade-offs as far as contaminants may affect either aquaculture or research and monitoring activities. The platform foundations provide a hard substrate habitat for a variety of benthic species while the floating aquaculture installations provide food, shelter and nursery grounds largely for pelagic species. However, these same habitats may potentially also serve as stepping stones for invasive species and disease vectors.

4 Conclusions

MUP can have several effects on surrounding marine sea areas through the enhancement of the socio-ecological benefits to coastal communities, such as artificial reef effect, fish food yielding or support to scientific knowledge through environmental monitoring devices or laboratories. The presented matrix can be used to screen which MES are used by a MUP and how they can support human wellbeing. The benefit of this matrix-based approach is that it combines socio-ecological knowledge and indicators and allows the STS components to be analysed in a multi-use setting. This is crucial information for understanding the impacts of MUPs. The advantage of the matrix approach is that also other MUP based on other STS components can be analysed (e.g. offshore wind energy in combination with aquaculture or desalination plants), or MU combination based on soft uses, such as for instance *pescatourism*, that refers to small scale fishery with tourism activities. Moreover a socio-ecological analysis can facilitate communication with non-scientific stakeholders on the benefits to welfare provided to coastal communities and society at large. In future the matrix could be extended through a synergy-tradeoff analysis of the MES that could contribute to the design of MUPs and better understand eventual environmental and socio-economic conflicts rising from MUP realization.

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