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Toward a Common Understanding of Ocean Multi-Use

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The "open ocean" has become a highly contested space as coastal populations and maritime uses soared in abundance and intensity over the last decades. Changing marine utilization patterns represent a considerable challenge to society and governments. Maritime spatial planning has emerged as one tool to manage conflicts between users and achieve societal goals for the use of marine space; however, single-sector management approaches are too often still the norm. The last decades have seen the rise of a new ocean use concept: the joint "multi-use" of ocean space. This paper aims to explain and refine the concept of ocean multi-use of space by reviewing the development and state of the art of multi-use in Europe and presenting a clear definition and a comprehensive typology for existing multi-use combinations. It builds on the connectivity of uses and users in spatial, temporal, provisional, and functional dimensions as the underlying key characteristic of multi-use dimensions. Combinations of these dimensions yield four distinct types of multi-use with little overlap between them. The diversity of types demonstrates that there is no one-size-fits-all management approach, but rather that adaptive management plans are needed, focusing on achieving the highest societal benefit while minimizing conflicts. This work will help to sharpen, refine and advance the public and academic discourse over marine spatial planning by offering a common framework to planners, researchers and users alike, when discussing multi-use and its management implications.

Keywords: multi-use of space, marine spatial planning, synergistic use, co-existence, ocean governance

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INTRODUCTION

The "open ocean" is no longer free from human use, but rather has become a highly contested space as coastal populations and maritime uses have soared in abundance and intensity over the last decades (Smith, 2000; Vermaat et al., 2005). Advancements in technology and know-how are enabling those marine uses to become more diverse, intensive, and to create more value than ever (IPOL, 2015). However, while established uses, such as shipping, fishing or resource extraction expand and intensify, new uses such as offshore aquaculture (Froehlich et al., 2017; Buck et al., 2018) or wind and wave energy generation (Perez-Collazo et al., 2015) are emerging and attempting to carve out space in an already crowded and "urbanized" sea (SAPEA, 2017). This trend is predicted to continue and even accelerate in the future, due to increases in global population, economic growth, trade, and rising income levels (Smith, 2011) Intensive anthropogenic activities can exert cumulative effects on the marine environment (Clarke Murray et al., 2015; Depellegrin et al., 2017) and be a potential source of conflicts among groups of users. The cumulative effect of the increased human activity in the marine environment leads to competition for limited marine space, increased stress on marine ecosystems and potential for conflicts amongst groups of users (Douvere and Ehler, 2008; Krause et al., 2011). Such changing marine utilization patterns represent a considerable challenge to society and governments: current widespread piecemeal governance is inadequate at supporting sustainable coastal and ocean ecosystems and human uses of the ocean (Schäfer, 2009). Different management regimes exist on geographic scales [i.e., national exclusive economic zone (EEZ) regulations, regional regulations for territorial waters, macro-regional agreements such as the Oslo-Paris Agreement (OSPAR) and Helsinki Commission (HELCOM)] and as objective-oriented management approaches such as marine conservation efforts or sectoral industry governance.

In light of these trends, maritime spatial planning (MSP) was created by the marine planning community as a tool to manage conflicts between users and achieve societal goals for the use of marine space (European Union, 2014). However, even though it is meant to be a holistic and integrated approach, too often planning decisions are made from a sectoral viewpoint. Such approaches are often not sufficient to address the contemporary increasing demands of sustainable marine resource use in highly utilized marine areas (Schäfer, 2009). Indeed, the last two decades have seen the rise of a new frontier in ocean use concepts: the joint "multi-use" of ocean space. Multi-use can be one possible favorable outcome to a structured MSP process or occur naturally through basic economic and social pressures. It differs from single-use planning outcomes in the fact that the same ocean space can be allocated to and used by multiple uses where prudent, thereby maximizing spatial efficiency and productivity. It possesses a clear focus on conflict avoidance through the fostering and exploitation of synergies between uses.

The multi-use concept emerged independently in multiple parts of the world between the 1980s, as part of the Great Barrier Reef Management Plans (GBRMP) approach to managing multiple users and uses inside a marine space (Kenchington, 1985) and the early 2000s in Germany. In the latter, the focus lay on the multi-functional or "hard" connection of offshore installations, such as offshore wind turbine foundations, with marine aquaculture installations, in order to promote the local expansion of aquaculture production (Buck, 2001, 2002). Since the development of these early instances, the multi-use concept has been widely studied and a plurality of different combinations of ocean uses have been investigated by researchers or spearheaded by industry (Michler-Cieluch and Krause, 2008).

These include for instance multi-use combinations of marine wind and wave energy generation (Perez-Collazo et al., 2015) offshore wind farms (OWF) coexisting with or actively supporting marine conservation (Lacroix and Pioch, 2011; Kyriazi et al., 2015, 2016) or local fisheries branching out into tourism, creating so called "pescatourism" (Piasecki et al., 2016) to name just a small selection of possible combinations. Recently, research has started to focus more on the interactions of marine sectors and their management (Klinger et al., 2018). To date, however, a clear distinction between the wide variety of different types and their consequences to marine planners, users, and researchers alike is missing.

This rush of research into new and promising multi-use combinations, by actors across Europe and the world, produced and continues to produce a wealth of knowledge on interrelationships between stakeholders, uses, and the environment. Much of this knowledge does not fit into existing ontologies of marine management and has stakeholders and regulators alike struggling to decipher management implications of different combinations. This becomes especially apparent when delving into the plurality of terms established for slightly different, yet often overlapping multi-use combinations. Terms such as multi-functional, co-existence, co-use, multi-purpose and others, each conveying a meaning, which may differ based on the recipient's own understanding of the whole subject. Furthermore, behind each of these terms stands a highly complex multi-actor social-ecological system prone to suffer from user conflicts and conflicts with the environment. In order to manage a multi-use ocean, accurately capturing and describing a multitude of possible combinations of uses is important. In response to this problem this paper aims to generate a common language and typology for current multi-uses, thereby creating a starting ground for a more conceptual study of this field.

Toward this goal, the paper starts from a Europe-centric approach to conceptualizing multi-use. Focusing on a case study area such as Europe allowed the necessary detail to be developed in the findings of conceptualizing multi-use projects. It builds on an extensive review of primary, secondary and gray literature on multi-use developments, as well as the multi-use research conducted under the analytical framework of the H2020 project MUSES (Multi-Use in European Seas) (Zaucha et al., 2017) and the 10 case studies examined as part of it. These activities identified a total of 16 relevant multi-use combinations spanning five major European sea basins on the case study level, as well as recommendations for their optimization or implementation (Bocci et al., 2018).

The identified combinations served as a pool of examples of possible multi-use cases. Drawing from these different data sources, this paper aims to refine and explain the concept of multi-use of ocean space by reviewing the development and state of the art of multi-use in Europe before presenting a clear definition and a comprehensive typology for existing and future multi-use combinations. The typology and the associated recommendations will help decision-makers and planners to update existing as well as design new policy and marine management approaches that are fit to purpose for the different types of multi-uses and their specific challenges and opportunities.

BACKGROUND

Multi-use of space is not a novel concept. Indeed, it can be observed as a matter of course in the natural world on a daily basis. Various ecological multi-uses have developed during the course of evolution and have existed for millions of years under the guise of "symbiosis." The concept of symbiosis was first coined by German botanist Heinrich Anton de Bary in 1879 and was used to describe the "living together of different species," excluding short-term connections (Douglas, 1994). It can describe a variety of structures of benefits and trade-offs between the different parties involved (Savada et al., 2008). In biology, recognizing and defining the concept have sparked exploration, discussions, and ultimately helped to shape and affirm a common understanding of the underlying processes.

Working from this definition, we can find analogs in terrestrial land-use planning and zoning approaches employed by town and regional planners. Various land planning concepts have developed over the years, focusing on space-saving by intensification and combination of uses. These include Multifunctional Land Use (Wiggering et al., 2006; Mander et al., 2007), New Urbanism and Smart Growth (Grant, 2009) and the Compact City Concept (Burton, 2000; Van Der Waals, 2000), to name a few. However, these concepts have different focuses in terms of creation of synergies and attention to resource conservation toward sustainability. To date, multi-use of ocean space has perhaps its closest terrestrial equivalent in Multifunctional Land Use, which differs from other mixed land use planning concepts in its clear focus on the creation of synergies, which may arise due to the interactions between uses and users. The major strategies of this concept are to increase density and diversity of land use functions in order to create those synergies (Rodenburg et al., 2003). Such synergies are also at the center of the Urban Nexus concept. It is based on linkages, interconnectivity and interdependencies in urban systems (energy, water and food as well as material provisioning systems) and the need for integrated holistic approaches across these sectors (Bazilian et al., 2011).

In the maritime realm, governance of sectors, such as maritime transport, fishing, tourism, energy, marine research and protection of the marine environment, has developed on oftentimes parallel, yet separate, tracks (European Commission, 2007; Harte et al., 2010). Issues arising between uses, users and the environment were, and often still are, approached from a single sector viewpoint. Such "fragmented decision-making" can lead to negative impacts on the marine environment and conflicts between competing uses, thereby reducing their potential for Blue Growth and innovation (Schäfer, 2009; Holm et al., 2017). To this end, MSP was created by marine planners as a tool for improved decision-making that can be used to avoid or manage conflicts between maritime uses and foster more efficient and sustainable use of maritime spaces and resources (Foley et al., 2010). The development of MSP in member states of the European Union was largely sparked by the Union's Integrated Maritime Policy (IMP) (European Commission, 2007). This also sparked the subsequent adoption of Blue Growth as one goal of this Policy (European Commission, 2012).

The report of the First International Workshop on Marine Spatial Planning (Ehler and Douvere, 2007) provides one of the most widely used definitions of MSP. It defines MSP as "a process of analyzing and allocating parts of three-dimensional marine spaces to specific uses, to achieve ecological, economic, and social objectives that are usually specified through the political process." The European Commission (2008) expands on this definition by postulating that MSP "optimizes the use of marine space to benefit economic development and the marine environment." It also represents an adaptive management process that constantly monitors and evaluates its approaches (Douvere, 2008; Foley et al., 2010). However, this role of MSP is slowly changing to also address the identification and promotion of synergies between marine uses (ICES, 2012, 2016, 2018). It has been realized that as long as maritime industries and the exploitation of marine resources are perceived as individual and separate activities, approaches to their development remain limited in terms of spatial efficiency and do not allow for identification of environmental, economic and social synergies (Lukic et al., 2018). Hence, marine planners, researchers, and the business community alike are starting to consider novel and sustainable concepts that foster synergies between sectors, improve operational and spatial efficiency, and enable co-existence, such as the multi-use concept (Lukic et al., 2018). However, it is also important to consider that no management approach can eradicate all conflicts. But while there will always be conflicts between maritime users with competing claims, stemming from either historical uses or new societal benefits (see Arbo and Thủy, 2016 for oil versus fisheries), MSP can minimize and manage such conflicts between actors and sectors. Either through single-use zoning, or, where it is beneficial to society, through a focus on the multi-use of ocean space and the fostering of synergies between users and uses.

The multi-use of ocean space, has been under scientific investigation since the early 2000s, with some of the earliest identified multi-use combinations being the spatial, structural, or operational connections of offshore wind farms with marine aquaculture in the German Bight (Buck, 2001; Buck et al., 2008). Another early instance of the topic being picked up by the academic community is the Report of the First International Workshop on Marine Spatial Planning's discussion on multiple use marine protected areas (Ehler and Douvere, 2007). To date, the main drivers behind the development of specific multi-use combinations or the concept as a whole have been academia and policy makers.

Building on much of this early momentum and experience, another key international initiative in this context has been the launch of the European Union's The Ocean of Tomorrow cross-thematic calls (2010–2013) in FP7-OCEAN (European Commission, 2014). The resulting large-scale collaborative projects, namely TROPOS, MERMAID and H2Ocean, have provided promising designs, technological solutions and models for combining activities in terms of economic potential and environmental impact (Quevedo et al., 2013; Brito, 2015). Following FP7, the Horizon 2020 research and innovation program continued the policy driven academic investigation of the multi-use concept in order to further promote economic growth and sustainable development (IPOL, 2015). Most recently the MARIBE project focused on analyzing and developing business cases for a selection of most promising multi-use combinations (Johnson et al., 2018).

The aforementioned experiences have provided a good basis for multi-use implementation, but its realization is, in many aspects, still in its infancy, and being stalled by a wide variety of factors. In 2016, the H2020 MUSES project set out to analyze the current state of multi-use development across Europe and highlight drivers, barriers, added values, and possible negative impacts. It builds on the data collected by these international and national projects as well as many national level initiatives across the European Union while engaging relevant sectoral and regulatory stakeholders in order to provide a clear overview of compatibility, regulatory, environmental, safety, societal, and legal issues on multi-use (Zaucha et al., 2017). The work of the MUSES project has highlighted the plurality of possible combinations of uses as well as the corresponding terminology currently in use in different sectors, groups and research fields. A comprehensive understanding of environmental, spatial, economic and societal benefits of multi-use for offshore and near-shore activities, at sea basin (Przedrzymirska et al., 2018) and case study level (Bocci et al., 2018) have been created out of this work. The collection of data and wide-reaching stakeholder engagement have made the development of a joint typology of ocean multi-use possible and necessary.

TYPOLOGY

Typologies, or organized systems of types, are valuable tools while exploring new concepts. They can assist with everything from concept formation to drawing out underlying dimensions and classification (Collier et al., 2012). The MUSES project has, as a first step, defined multi-use as "different users operating side by side, sharing the same resource" (Zaucha et al., 2017). This first working definition allowed for a unified methodological approach to the analysis of multi-use to be developed. However, as any definition is subject to changes as the understanding of the subject matter morphs and evolves, so too has the definition of multi-use. The following definition serves as the cornerstone of the typology presented here:

> *Ocean multi-use is 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.*

Following the definition of the concept of multi-use, we followed the four steps laid out by Kluge (2000) in order to arrive at this typology: Development of relevant analyzing dimensions; Grouping the cases and analysis of empirical regularities; Analysis of meaningful relationships and type construction; Characterization of the constructed types.

The single unique characteristic of ocean multi-use, which sets it apart from other systems of marine resource use, is the degree of connectedness between uses and users alike. The concept of connectedness or connectivity is more commonly associated with mathematical or technological dimensions but is increasingly being explored as a tool to describe social systems (Kolb, 2008). It is used as the core concept underlying this typology. Examining ocean multi-use using the connectivity of uses and users in a series of dimensions as the underlying key characteristic yields four major types of multi-use with little overlap between them (see **Table 1**).

The connectivity of uses and users has been analyzed in a set of four dimensions: the *spatial*, *temporal*, *provisioning*, and *functional* dimensions. While these are by far not the only dimensions of human use at and with the sea (e.g., Krause and Mikkelsen, 2017), they are the most fundamental underlying connected dimensions of all analyzed multi-use scenarios. Other possible dimensions can include, for example, Ownership or Resources. The four dimensions underlying this typology are defined as follows:

Spatial Dimension

The *Spatial Dimension* refers to the three-dimensional sea space, which can be occupied by a given use at sea (e.g., space taken up by offshore structures, including safety or exclusion zones, space used by marine fisheries or as transport corridors). A connection of uses in this dimension (i.e., "close geographic proximity") is intrinsic to all multi-use scenarios by the definition set forth in this paper. Two uses are seen as connected when the occupied spaces overlap.

Temporal Dimension

The *Temporal Dimension* refers to the timeframe in which the uses in question take place. Two or more uses connected in this dimension take place at the same time, while uses taking place subsequently, with no aspect of operational overlap, show a clear break in that connection.

Provisioning Dimension

The *Provisioning Dimension* encompasses all activities and processes servicing and supporting the main function of a use (e.g., monitoring of environmental data, providing safety and rescue chains, marketing, etc.). A connection of uses in this dimension usually takes the form of sharing of those services or their associated costs in order to reduce the financial burden of operating in a marine environment. Such a sharing of services can also represent a trade-off for one or both users in that it can potentially limit other activities.

Functional Dimension

The *Functional Dimension* refers to the main function of a use (e.g., power production and transmission for offshore renewables or seafood production for marine aquaculture or passive fisheries). A connection of uses in this dimension implies a direct linkage of one use function to the other. This can take the form of shared infrastructure, e.g., multi-purpose platforms designed to accommodate different uses and users, or the sharing of multi-purpose vessels directly involved in the main functions or others. Its clear distinction from the *Provisional Dimension* requires a clear understanding of the operations of each use.

In the following section, each type of multi-use is described and explained with a clear focus on the differences in connectivity in key dimensions. In addition, the plurality of the terminology commonly used to describe each type is showcased in order to aid stakeholders in identifying their own situation. Finally, key recommendations for each type of multi-use are presented that will support development and management of such scenarios. Recommendations are presented per type with one key recommendation singled out for each group of actors from Policy, Regulation, Industry, and Research (see **Table 2**). These four fields encompass different levels, from regional to national and international. Which recommendation is prudent at which level can only be decided on a case specific basis. Combination specific actions can be found in the MUSES Multi-Use Action Plan (Schultz-Zehden et al., 2018).

Types

Type 1: Multi-Purpose/Multi-Functional

The first type of identified multi-uses is characterized by the highest level of connectivity between the involved uses and users. A Type 1 multi-use shows a connection between use, user or both in all four identified dimensions. This means the uses share the same space, occur at the same time, share provisioning services and, setting it apart from the other types, their main functions are intrinsically connected (see **Table 1**).

The most prominent examples are multi-use platforms as developed as part of the TROPOS Project designed to serve as multi-purpose marine platforms (Quevedo et al., 2013; Brito, 2015), the floating power plant combining multiple marine renewable energies from wind to tidal and wave power (FPP) (Kafas, 2017) and other platform solutions as are currently under development in the Space@Sea Project (Space@Sea, 2018). Such platforms are specifically designed to house or support multiple uses from transport, energy, aquaculture to leisure (Pérez et al., 2014). Even before these modern approaches, the "Forschungsplattform Nordsee" (1974) and the FINO Platforms (2002) provided the first multi-purpose offshore platforms for a variety of different public and private users and uses (Buck and Langan, 2017).

A strong connection exists between the main functions of the different uses, in order to profit from enhancing synergistic effects. Such effects can include the sharing of costs such as those related to personnel, platform maintenance, safety, logistics, or energy. Another example of uses connected in the functional dimensions are proposed offshore aquaculture devices which could be structurally connected to offshore wind turbines as reviewed by Buck and Langan (2017). Even though less apparent, the two main functions are so closely connected that at least one could not function without the other. This scenario has to be clearly separated from cases where offshore aquaculture is located in the area of OWFs but no infrastructure directly related to the main functions is shared (i.e., no use of multi-purpose harvesting/transport vessels, no structural connection between facilities). Such scenarios are part of a less connected type of multi-use. The terminology used by the specialized literature for these kinds of connections spans from multi-purpose (Pérez et al., 2014) in relation to ships and

TABLE 1 | Typology of ocean multi-use with descriptions and examples given for each identified type.

Type	Dimensions				Description	Examples
	Spatial	Temporal	Provisioning	Functional		
Type 1: Multi-purpose/multi-functional	✓	✓	✓	✓	Takes place in the same area, at the same time, with shared services and core infrastructure	Marine renewable energy sources and desalination (Maniopoulou et al., 2017), Scottish Floating Power Plant Design (FPP) (Kafas, 2017)
Type 2: Symbiotic use	✓	✓	✓		Takes place in the same area, at the same time, and peripheral infrastructure or services on sea or land are shared	Proposed aquaculture in OWF in Germany (Buck et al., 2017), combination of Wave Energy generation and aquaculture (Onyango and Papaioannou, 2017)
Type 3: Co-existence/co-location	✓	✓			Takes place in the same place and at the same time	Fisheries in OWF proposed in the United Kingdom (Kafas, 2017) and Germany (Schupp and Buck, 2017)
Type 4: Subsequent use/repurposing	✓				Takes place in the same ocean space but subsequently	Repurposing of offshore structures for new uses like recreational fishing, tourism, aquaculture, or environmental conservation (e.g., Italy) (Ponti et al., 2002; Depellegrin et al., 2019)

Types are ordered by decreasing degree of connectivity between uses and users. Connectivity in any given dimension is symbolized by "✓" in the respective field for each type.

platforms to multifunctional (Buck et al., 2008) or simply multi-use (Zanuttigh et al., 2016; Buck et al., 2017).

Recommendations

Multi-use combinations of this type often times rely on deploying investment-heavy new technology or infrastructure in new and challenging environments. Policy makers can promote the most promising new combinations by creating a positive investment climate for developers willing to bear the associated risk (Johnson et al., 2018) (see **Table 2**). The nature of the high degree of connectedness of both users and uses in this type of multi-use scenario brings with it the need for clear structures (regulatory, economic and social) for the sharing of both benefits and responsibilities. A number of so-called "modes of cooperation," from legislated to negotiated have been proposed to order such relationships (Krause et al., 2011) and could help shape future policy and regulatory approaches. Research gaps are largely related to safety of operations, benefits and drawbacks of multiple tightly interconnected uses. Additionally, joint pilot cases between research and industry actors are needed to generate and disperse such knowledge and address all perceived or real knowledge gaps. Finally, any multi-use scenarios with this degree of connection have to be based on an inclusive planning and joint licensing procedure, from start to finish, in order to account for every individual user's needs, rights, and finally responsibilities in regards to any joint assets (Maniopoulou et al., 2017; Schultz-Zehden et al., 2018). This type is heavily characterized by its need for such joint development processes.

Type 2: Symbiotic Use

A Type 2 multi-use is characterized by connections in the spatial, temporal, and provisional dimensions. There is no direct linkage of one use's core function to the other (**Table 1**). This case appears when uses operate in the same zone (i.e., a connection exists in the spatial dimension) but in contrast to Type 1 they do not share the same core infrastructure, such as foundations or other (floating) platforms.

The most prevalent characteristic of a Type 2 multi-use is the connection of the provisioning services such as, for example shared crew transports, harbors, or monitoring data. The exploitation of a used area created by a fixed infrastructure (for instance OWFs) by other uses such as aquaculture cages, marine protected areas (MPAs) and compatible touristic activities (Christie et al., 2014), requires active cooperation of the different users and can benefit from the sharing of supporting services. This can occur when a zone is already in use and an additional use is derived later based on apparent synergies or when two new uses cooperate to exploit a new area together. One example is the mussel aquaculture in between offshore wind turbines in the North Sea as examined in the framework of the MERMAID project (He et al., 2014; Röckmann et al., 2015). Other examples include: touristic visits of OWFs in the North Sea (e.g., United Kingdom, Germany), combinations of tourism and aquaculture as exist in Malta, Greece, and Italy (Castellani et al., 2017); pesca-tourism, the combination of small scale fisheries with touristic offers, across the Mediterranean (Piasecki et al., 2016). This Type 2 multi-use can create a number of benefits. For instance, when aquaculture can be conducted within the exclusion zones of OWFs, the overall spatial footprint of the two activities is reduced and the cost for supporting services can be shared (MMO [Marine Management Organisation], 2013).

Recommendations

Similarly to heavily connected Type 1 multi-use combinations, Type 2 can benefit from joint development procedures, especially

TABLE 2 | Key recommendations for each identified type of ocean multi-use pertaining to Actors from: Policy; Regulation; Research; Industry.

Recommendations for	Type 1: Multi-purpose/multi-functional	Type 2: Symbiotic use	Type 3: Co-existence/o-location	Type 4: Subsequent use/repurposing
Policy (macro-regions/nations/regions)	Provide financial incentives and sureties for development of new technologies and combinations	Mainstream and include multi-use concept on all relevant policy levels	Clarify rights and responsibilities of different users to ocean space	Adopt clear legal frameworks and clarify liability rules (between current and future platform users), allowing for better management of expectations and predictability
Regulation (nations/regions)	Develop and deploy joint licensing procedures for multi-use development throughout entire life cycles	Identify and apply site selection criteria to establish viable multi-use sites in managed waters	Ensure that effective cooperation and mediation mechanisms are in place between representatives of all sectors (i.e., working groups)	Develop general suitability criteria as to which sites and types of installations are suitable, for which type of reuse
Research (academia/industry)	Identify and address gaps in current knowledge about safety, benefits and drawbacks and create decision support systems	Identify operational overlaps allowing for the sharing of cost for supporting services and infrastructure	Gather and communicate data about compatibility of uses	Carry on time series research about long-term local impacts of maritime infrastructure and installations to ecosystems
Industry (corporations/associations)	Develop pilot sites to showcase and advance new technology in the field	Formulate exemplary benefit and cost sharing agreements between involved actors	Facilitate industry wide capacity building regarding opportunities and operations	Suggest suitable investment mechanisms to facilitate re-use of installations after initial lifespan

Recommendations are derived from analysis of the MUSES Ocean Multi-Use Action Plan (Schultz-Zehden et al., 2018).

when it comes to the sharing of provisioning services. Such consideration for which services can be shared with which actors at what cost may require a negotiation process between the parties involved that should lead to an agreement on what supporting services and infrastructure can be shared and under what conditions, as well as who will bear the possible cost of negative externalities that may result from combinations with new uses. Exemplary cost sharing and cooperation agreements need to be developed by industry players in a bottom-up approach so as to account for each combinations intrinsic differences. The top-down creation of such cooperation agreements can best be achieved by including multi-use considerations into planning provisions made at the policy and regulatory level for all prospective new users of the sea (Kyriazi et al., 2016; Kyriazi, 2018). Regulators can best support these developments by identifying areas and uses where multi-use makes sense and through the creation of a societal cost-benefit analysis for multi-use. On the research level, both academic and industry driven research need to analyze operational overlaps which might allow for the sharing of costs and increase of efficiency of operations for each possible combination.

Type 3: Co-existence/Co-location

A Type 3 multi-use is characterized by a moderate to low degree of connectivity between the involved uses. A clear connection can only be found in the spatial and temporal dimensions. This 2D connection implies that uses share the same space and occur at the same time. However, the sharing of provisioning services and connection of the core functions is absent. There is no clear focus on cooperation and creating synergies between users and uses like in a Type 2 multi-use. The lack of connectedness on the third and fourth dimensions suggests an incidental overlap and a degree of involuntary combination between the marine uses. Incidental overlap occurs when involved uses target the same sea areas, each for accommodating their own needs, but taking no particular account for each other's selection criteria to shape their own agenda. However, users need to work together and actively facilitate the presence of one another, in order to align with planning goals and strategies.

One example of a Type 3 multi-use identified within the scope of this review, is the occurrence of commercial fisheries within areas occupied by offshore wind farms, without any further interaction between the two uses. Most utility-scale offshore wind developments across Europe are traditionally bottom-fixed, and use mono-pile, tri-pile, gravity-based, or jacket foundations (Wind Europe, 2018). The current foundation types have created a unique dynamic with other traditional maritime users, such as commercial fisheries, sharing the same spatial requirements (e.g., shallow areas, specific depth ranges, sediment types, proximity to coast, etc.). Access to the same locations, often leads users to compete. Sometimes, incompatibility between competing maritime uses results in claims for exclusive access to space. The terminology used by the specialized literature for this kind of connection spans from cooperation (SeaPlan, 2015), and co-existence (e.g., de Groot et al., 2014; FLOWW, 2015; ICES, 2016), to co-location (e.g., Catherall and Kaiser, 2014; Stelzenmuller et al., 2016; Roach et al., 2018).

Recommendations

The low degree of connectedness between the uses in this type of multi-use scenario highlights the need for legislated relationships in order to facilitate a free and equitable flow of information about best available technologies, risks, and opportunities between all levels of users and regulators (Krause and Stead, 2017). This requires policy to clearly reflect the responsibilities and rights of each user of the sea in order to facilitate such passive "co-existence" of users. Such clarifications can serve to address power imbalances between different stakeholder groups and sectors (Lukic et al., 2018). The roles of both researchers and industry in fostering Type 3 multi-use revolve around the gathering and communicating of data about the compatibility of uses. The communication of data within the relevant industries should rest on the shoulders of industry wide associations that can initiate capacity building for multi-use operation. Within this type of multi-use, a clear distinction has to be made when describing commercial large scale fisheries and recreational or artisanal fisheries. These types of fisheries have highly different impacts on surrounding uses and the environment and can require different regulatory considerations, especially in regulating the possible risk they pose to other users and uses.

Type 4: Subsequent Use/Repurposing

A Type 4 multi-use shows only a connection in the spatial dimension and a clear break in the temporal dimension. The two uses are, however, still connected in the spatial dimension, meaning the previous use is still occupying the space and hindering other uses. This can occur with cases where the permanent installation of a maritime use (e.g., oil and gas, offshore wind) remains in place after end of its lifetime and is repurposed for another maritime use. This sort of repurposing of marine infrastructures can only be considered when the production lifecycle is concluded and potential new uses of the platform and its restriction zone can be considered. The decommissioning process can be defined as the cessation of operations and the controlled process of safely retiring a facility from service. Specific decommissioning activities are employed to ensure safety and the reduction of health risks to the general public and the environment (Castellani et al., 2017).

The repurposing of decommissioned oil and gas installations into a new use, in the multi-use framework, can include: (1) repurposing of the installation for recreational activities (e.g., recreational fishing, diving, gastronomic experiences, marina establishment); (2) conversion into monitoring, observation and research stations; (3) structural and logistic support for different sea uses (e.g., aquaculture); (4) structural support and/or temporary energy storage facility for renewable energy devices (e.g., wave and wind energy); or (5) the reuse of the installation as an artificial reef in a so-called of Rigs-to-Reef (RTR) system, while keeping it in the same space (Fowler et al., 2014; Depellegrin et al., 2019).

Several conceptual designs for the repurposing of oil and gas platforms already exist in the Mediterranean Sea in the form of "Ocean Awareness Destinations" connecting in the spatial dimension of multiple recreational opportunities, environmental protection and possible research and monitoring stations. The identified areas for this multi-use include platforms to be decommissioned in sea areas of Emilia Romagna Region (Northern Adriatic Sea) (Barbanti et al., 2017). An existing example of RTR is the Paguro relict, a wreck of a gas platform collapsed after an explosion occurred in 1965, located 12 miles off Marina di Ravenna located in the Italian Northern Adriatic Sea (Barbanti et al., 2017). The newly formed habitat was colonized by marine species and an MPA was established around it in 1995. In 2012, the European Union established the area as a Site of Community Importance (SCI), attracting large numbers of diving excursions per year (Iperbaricoravenna, 2013). Such decommissioned oil and gas infrastructures can be beneficial for the development of marine habitats (Macreadie et al., 2011; Claisse et al., 2014; Jagerroos and Krause, 2016) and commercially valuable fish species (Love et al., 2006).

Recommendations

The multi-use scenario of repurposing maritime installations and infrastructures after their envisioned life span faces relevant responsibility and liability issues. It is also facing ever evolving national and international legal constraints addressing the opportunities for repurposing of, e.g., oil and gas infrastructure (Jørgensen, 2012). These uncertainties combined create a low degree of financial security for investors. Any such multi-use endeavors need a clear legal and regulatory framework governing rights and responsibilities of all involved parties. Especially international organizations such as OSPAR and the European Union need to give clear guidance and impulses to national law makers and regulators on how such multi-uses can fit into existing national and international agreements. Regulators then, in turn, may create guidelines as to which structures can be re-used to what degree and how rights and responsibilities may be best structured at the national level. These guidelines need to be informed by relevant time-series research about local and ecosystem impacts of removal and re-using of infrastructures. Such data on the impacts of marine infrastructure often times already exists but is locked behind non-disclosure agreements. It can also help to quantify any potential environmental impact of excluding or combining uses. Additionally, this multi-use requires an accurate cost-benefit analysis to better understand and valorize its economic and social value chain (e.g., research and innovation, new job profiles, diversification of the tourism sector) and make informed decisions as to its benefit for society and the environment. Industry actors can support this multi-use by proposing possible investment mechanisms to facilitate the re-use of installations from a legal, environmental, and economical perspective.

CONCLUSION

This typology and the derived recommendations were created based on a collection of European examples of multi-use. However, limiting the scope of the analyzed multi-use scenarios used in creating this typology served to create a conceptual approach to the topic, which can serve as a starting point for future discourse on global multi-use developments, as the recommended actions possess a high degree of transferability.

Those recommended key actions are meant to help create a more encouraging regulatory environment for each type of multi-use. Some key pieces are already in place, for example, in the form of the European Union's MSP Directive, directly promoting multi-use (European Union, 2014), and just need to be adapted into national frameworks and policies. In fact, the practice of MSP as a whole is an important corner stone of multi-use development across all types as it provides an opportunity to foster and influence interactions between users (Schultz-Zehden et al., 2018).

The multi-use of marine space can take a multitude of forms and offer a wide variety of benefits to users, society and the environment alike. Analyzing the interactions of uses and users in the four presented dimensions yields four distinct types of multi-use, each encompassing multiple different use combinations. Each of the four identified types of multi-use are distinct from the others in not only their degrees of connectedness, but also in the implications they carry in regards to required regulation, technological and legal considerations as well as their possible need for mediation between users. The use of a joint typology and clear terminology is therefore paramount to the continued discourse on ocean multi-use.

Assigning a use combination to a distinct type requires an in-depth understanding of the interrelationships between the different uses and users. Similar use combinations are often times envisioned more or less connected by different stakeholders (e.g., marine aquaculture and offshore wind farms) and can thus be categorized into different types based on the respective scenario. Other uses, such as fisheries for instance, have a high spatial variability and can vary highly in their intensity from commercial bottom trawling or pelagic fisheries to artisanal, recreational or passive fisheries. A clear understanding of the proposed multi-uses parameters is therefore paramount to the use of a joint typology. Furthermore, these differences highlight the importance of creating a set of shared values, a shared meaning and a culture of practice for multi-use in the marine environment (Gazzola and Onyango, 2018). Such a culture of practice will help to shape and inform the adaptive management processes of MSP and allow it to better manage arising multi-use possibilities.

The recommendations presented showcase some requirements for the development and management of each type. They are not always exclusive to one type but rather represent key actions required in order to promote each individual type of multi-use. This typology represents a first important step in creating and operationalizing a conceptual understanding of ocean multi-use and will help guide both private and public stakeholders while promoting public discourse and knowledge exchange at the same time. The typology, as well as the recommendations derived from their study, are based on the concept of connectivity of uses and users. Another viewpoint to consider is the concept of conflicts between users or the distinction between intended and unintended multi-uses. The latter becoming potentially important when analyzing the de-facto marine protected areas that are created by exclusion zones around maritime infrastructures. Changing the focal point of the analysis may change the resulting structure of recommendations but will most likely result in very similar recommendations.

Irrespective of the specific type of multi-use in question, the plurality of possible scenarios presented within the different types is bound to overload any existing systems of reference, nomenclature, and by extension, the terminologies for discourse and ocean use management developed from a single sector viewpoint. Each presented example of ocean multi-use represents a highly complex multi-actor social-ecological system. This makes understanding the societal, economic, and environmental context of each proposed combination all the more important. Trying to weigh, promote, regulate, and monitor multiple ocean uses in the same space therefore requires a departure from previous systems and the adaptation of new, responsive, and inclusive systems of governance. Such a system should strive to maximize societies' social and economic benefit from the sea while always trying to minimize its negative impact on the environment. That being said, it may not always be possible to achieve multi-use of marine space in any instance, either due to technical, operational, or social incompatibilities or because it runs contrary to societal management goals.

MULTI-USE PRINCIPLES

In order to help promote the systemic change necessary to foster multi-use development, parallels need to be drawn and lessons learned from multi-use land-use concepts, which have successfully fostered beneficial multi-use scenarios on land for decades. However, as Borgese (1998) has noted, "The law of the land cannot swim." Most human societies are intrinsically connected to the land and our notions of ownership and systems of governance denote that connection down to their very foundations. Today's society as a whole still lacks the close relationship with and the understanding of the ocean on a broader scale that we have developed for the land.

In order to further develop and strengthen the multi-use idea in the marine realm, we wish to create a wider public discourse on the topic of multi-use. Toward this end, we postulate the following three guiding principles which we believe will aid the creation of a multi-use system of resource use. These three overarching themes stood out from the analysis of a wide variety of European multi-use scenarios and their underlying socio-ecological systems. We invite every interested actor to reflect on them and start a global conversation:

(1) *Future multi-use governance should be based on a foundation of knowledge* about the effects of our cumulative actions on the ocean and the services it provides us. The creation, aggregation, and communication of this knowledge-base to all involved stakeholders of the process is the task of the academic community. The creation and analysis of functioning pilots of different types of multi-use as public showcases must be a top priority toward this goal.

(2) However, *academia should not be charged with being the sole advocate of multi-use development*. This has and will continue to create situations where technological development will outpace market readiness. If there is a clear policy goal toward the adoption of multi-use, it is the responsibility of policy makers, planners, and regulators alike to create a market environment were such technologies could take hold.

(3) Lastly, a *social responsibility lays on the shoulders of every user of the sea*, from small-scale fishermen to multi-national corporations, to consider the feasibility of multi-use in their specific circumstances. Only with such concerted efforts on all levels and including all relevant stakeholders will future multi-use development take place.

AUTHOR CONTRIBUTIONS

MS is lead author, conceived and designed the study, wrote and reviewed the manuscript, and prepared the manuscript for submission. MB, DD, AK, ZK, and IL provided input to background and type characterizations and reviewed the manuscript. AS-Z provided input to background and reviewed the manuscript. GK and VO provided input to introduction, background, typology, and discussion, and reviewed the manuscript. BB conceived the study, provided input to introduction, typology, and discussion, and reviewed the manuscript.

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