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Incorporating principles of reconciliation ecology to achieve ecosystem-based marine spatial planning

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ABSTRACT

Intense human activity in the marine environment poses a threat to marine ecosystem. The ecosystem-based planning and management approach has developed over the past decades with the goal of reducing this threat by defining planning and management of uses in a way that mitigates negative effects on ecosystem structure and function. For oceans and coasts, marine spatial planning (MSP) can further aid the implementation of ecosystem-based management, a widely accepted tenet of planning for the marine environment. It can do so by allocating different uses of space in a way that reduces conflicts for the benefit of the environment. Here, we propose an approach to MSP that incorporates principles of reconciliation ecology for the planning of marine (nearshore) enclosures. The approach supports conservation within and around anthropogenic elements outside of marine protected areas. Since human activity typically involves some damage to natural ecosystem, this research contributes by proposing a way to incorporate ecosystem modeling for MSP that includes human activity. Examining areas of human activity under different management scenarios allows identification of possible trends in human-natural ecosystem interactions. Using such an approach increases marine conservation opportunities, and directs educated and cautious MSP in ways that allow implementation of an ecosystem-based approach.

1. Introduction

Increased human utilization of marine resources is a major threat to the conservation of marine environments (Douvere and Ehler, 2009; Portman, 2011). However, and somewhat counter-intuitively, marine areas dedicated to human activity can be beneficial for conservation (Bulleri and Chapman, 2010; Dyson and Yocom, 2015; García-Gómez et al., 2015) and in some situations, can be part of the solution rather than the problem.

Marine spatial planning (MSP) is a comprehensive framework which allows the integration of such conservation opportunities (Table 1). MSP facilitates integrated strategic and comprehensive planning of multiple uses in the marine environment in ways that can mitigate the impacts of development on the marine environment and can promote conservation while doing so. Some MSP initiatives focus on economically efficient use of an area (e.g., Plasman and Van Hessche, 2004). Here, we are consider MSP, as a tool for achieving ecosystem-based management (e.g., Douvere and Ehler, 2009). The latter is a holistic management strategy for systems (rather than individual components) that considers humans as an integral part of the ecosystem (COMPASS, 2005). As such, it aims to maintain the diversity, productivity, and resilience of the ecosystem. Mengerink et al. (2009) discuss five aspects of ecosystem-based management which are necessary for its implementation. The first two aspects are the development of an ecosystem-based vision and plan, and incorporation of science into management decisions. For the remainder of this paper the use of term ecosystem-based management (EBM) refers exclusively to these two aspects.

The coupling of MSP and EBM produces different outcomes based on the planning objectives. In a review of ecosystem-based marine spatial planning and management initiatives, Katsanevakis et al. (2011) and Collie et al. (2013) found that various plans that differ in their scope, implementation methods, and legislative support, do share a general common notion of aiming for sustainable development and conservation of marine biodiversity. Despite the different outcomes and emphases in each of these plans, they all share the intention of marine ecosystem protection.

Marine protected areas are a well-known conservation tool and their designation is often part of MSP (Arkema et al., 2006; Douvere, 2008; Leathwick et al., 2008). There are currently several initiatives that promote the establishment of marine protected areas and suggest MSP as a tool for improving management of the marine environment, mainly

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Table 1
Applying reconciliation ecology to MSP to enhance EBM and overall conservation in the marine environment.

	Reconciliation ecology	MSP	Reconciliation approach for MSP
What is it	A conservation approach which aspires to establishing or maintaining habitats in areas of residence, industry and recreation to conserve species within them.	A process of allocating spatial and temporal distribution of all human activities in the marine environment.	Spatial and temporal allocation of uses considering the ability of the use to reconcile primary activities with ecosystem needs.
Advantages for conservation	Enhancing conservation opportunities by recognizing multiple areas in which it can take place.	Enhancing conservation by spatially allocating uses and separating them, if needed.	Integrating conservation approaches into the planning of the marine environment. Implementing MSP which enhance EBM.
Possible Impediments	Implementation focuses on discrete conservation initiatives at a local level and is absent from planning practices at various scales. Means of implementation (even conservation initiatives at a local scale) is unclear.	Does not readily use or integrate conservation approaches.	The outcomes of the integration between human activity and conservation are hard to predict. The integrated nature of the approach may be difficult to communicate; conservationists and developers tend to occupy opposing camps with each viewing the use of the approach as selling out to the other 'side'.
How can impediments be addressed	Integrating the approach into planning by considering opportunities to enhance conservation at all areas during the planning process and later in management of the areas, while constantly examining the compatibility with conservation goals.	Including a consideration of integrative conservation approaches and on updated ecological data related to conservation objects in a way which aligns with planning approaches.	The integration could be examined using ecosystem modelling and management scenarios at the planning stage. In addition, integration opportunities should be examined using surveys and experiments in the field. Communicating the integrated approach to conservationists and planners using practical examples rather than just theoretical concepts.

by reducing conflicts (such as habitat degradation and pollution), between human uses and marine ecosystem (e.g., Barcelona Convention, 1995; IUCN, 2008). However, designation of conservation actions through planning, in addition to allocation of marine protected areas, may be required in order to bring about the desired results of implementing ecosystem-based approach to marine planning (e.g., De Santo, 2011).

Actions supporting EBM are needed to successfully integrate anthropogenic elements with conservation goals, in order to reduce the pressure on the natural environment and to integrate existing anthropogenic elements for marine conservation needs (Arkema et al., 2006; Douvere, 2008; Gilliland and Laffoley, 2008; Katsanevakis et al., 2011). Such actions or measures may consist of establishing additional marine protected areas and ensuring that they are effective. However, in most cases setting aside marine protected areas alone is insufficient for achieving conservation goals, (Agardy et al., 2011; Mora and Sale, 2011; Roff and Zacharias, 2011). EBM should account also for the conservation value of the areas outside marine protected areas.

The idea of extending conservation measures beyond defined conservation areas, and particularly into areas of human activity, was suggested by Rosenzweig (2003 p.7) as the *reconciliation ecology approach*: "the science of inventing, establishing and maintaining new habitats to conserve species diversity in places where people live, work, or play." Although some species may exist only in protected areas, there are many more species that could and should exist within areas of intense and dominant human activity. Therefore, conservation should take place in areas beyond those declared as 'protected areas'. In such "non-protected" areas people should use the sea in a way that reconciles their needs with conservation goals; thus, some level of wildlife protection could be achieved even in areas dedicated to industry and infrastructure (Table 1).

In the current study, our goal is to develop a planning framework that integrates planning and conservation biology, and by doing so, operationalizes marine conservation approaches and enhances EBM. This requires that the planning process is based on well-defined conservation goals. By adopting this framework, planners involved in MSP can aim to reconcile human activity with conservation of the marine environment while taking advantage of new types of areas where conservation could take place to enhance overall marine conservation. One specific type of area includes those where human activity is significantly restricted (hereafter: enclosures). Here we focus on the use of marine enclosures as a type of protected areas; our approach can be used as part of an experimental process for identifying conservation opportunities related to existing enclosures but our approach could also be used for large scale conservation through an MSP process.

2. Using reconciliation ecology to enhance ecosystem-based planning

Conservation-oriented marine planning involves designing and allocating marine protected areas. However, conservation planning could account broadly for allocating all uses and needs. This may shift the focus away from an emphasis on the transfer of benefits from nature to humans (ecosystem services), to an emphasis on the relationships between humans and nature, and could therefore consider benefits for the natural environment as well as for humans (Table 1).

The concept of reconciliation ecology can help to identify anthropogenic elements that conserve wild species. It can also help to enhance conservation in areas which have been degraded by providing guidance on the most suitable management methods for wildlife conservation purpose (Chapman and Underwood, 2011; Francis and Lorimer, 2011; Lundholm and Richardson, 2010; Moyle et al., 2012). For example, Dyson and Yocom (2015) conclude that integrating ecological design for new or modified marine infrastructures may lead to improvement in the quality of urban ecosystem function and provide suitable habitats for many marine species. They also suggest that the daily operation of the area in the vicinity of the infrastructure protects the ecosystem within it.

Here, we propose to enhance the potential of anthropogenic environments to support the natural ecosystem and to form broad conservation networks. Specifically, we propose to integrate the concept of reconciliation ecology into planning at multiple scales. In terrestrial environments, anthropogenic elements have been incorporated in conservation networks for urban planning and implemented through various approaches, including reconciliation ecology (Colding, 2007; Francis and Lorimer, 2011). In contrast, for planning of the marine environment the inclusion of anthropogenic elements in conservation networks is missing and reconciliation ecology has not yet been incorporated for marine planning. Instead, initiatives have focused on local management of areas which were found to be valuable (e.g., Bulleri and Chapman, 2010; Dyson and Yocom, 2015). In order to realize the potential of reconciliation ecology to enhance EBM, planners need to consider marine species and communities as one of the aspects which are accounted for in the planning process among social, political, and economic aspects.

3. Marine enclosures

Some human activity in the marine environment occur within areas where public access is limited or prohibited due to safety or security concerns. Such areas include fire ranges, borders in conflicted areas, military ports, oil and gas platforms, wind farms, and power stations. The activity which occurs in the enclosures is often thought to negatively affect the marine environment (e.g., gas and oil platforms, power plants). In an MSP process, such activities are therefore likely to be identified as conflicting with marine conservation goals (Blæsbjerg et al., 2009; Ehler, 2011; SEYMSP, 2014). However, these enclosures may also have certain benefits for conservation, especially through restricting fishing in their territory and sometimes in the surrounding area (e.g., safety zones around gas and oil platforms where unauthorized presence is prohibited up to 500 m from the platform according to the UN Convention on the Law of the Sea). Application of the reconciliation ecology approach would view such enclosures as an opportunity, rather than as a threat for conservation of marine environments.

Similar types of conservation opportunities have been identified in conflict areas and war zones in terrestrial ecosystem worldwide. For example, McNeely (2003) concluded that among the positive impacts that war may have on biodiversity is the creation of areas that are off limit. A well-known effect occurs in the 1000 km^2 demilitarized zone of the Korean Peninsula, which is under the control of the military and to which access is therefore prohibited. This area provides a sanctuary for a wide and diverse range of native Korean species that are rare elsewhere (Kim, 1997). In addition, numerous studies have demonstrated higher species diversity on military training lands and fire zones than on their surroundings (e.g. Cizek et al., 2013; Stein et al., 2008; Warren et al., 2007). However, this well-developed approach of warfare ecology (see Machlis and Hanson, 2008) has rarely been demonstrated in the marine environment.

Artificial infrastructures which support human activity are common in marine (and nearshore) enclosures. The placement of artificial structures may have severe negative effects on the marine environment. Indirect effects which include habitat loss, hydrodynamic changes, organic enrichment, and toxic contamination, may influence habitats and the ecosystem over the long or short term (Heery et al., 2017). In addition, direct effects include alteration of species communities and dynamics, through biotic pressures and colonization by invasive species (Airoldi et al., 2015; Ferrario et al., 2016). The growing attention in the past decades to these effects brought scientists, engineers and decision makers to suggest ways to mitigate these negative effects by ecological engineering and policies and the implementation of certain regulations (Bergen et al., 2001; Chapman and Underwood, 2011; Dafforn et al., 2015a,b; Dyson and Yocom, 2015; Techera and Chandler, 2015). Yet, further research is required in order to determine which structures can support which marine communities, in what way and under which conditions (Perkins et al., 2015).

By contrast, few studies present interesting environmental benefits that can be achieved from the presence of marine infrastructures, especially those within enclosed areas. Guerra-García et al. (2004) and García-Gómez et al. (2011) found larger individuals and higher recruitment of *Patella ferruginea*, in enclosed sites which were either military or private properties and therefore less accessible to the public than other sites. They suggested that these areas be recognized as valuable and that they be protected and serve as small ($< 0.2\ km^2$) marine reserves called artificial marine micro reserve (AMMR). Bouchoucha et al. (2016) found that marinas provide a refuge for native juvenile *Diplodus* fish species and may provide artificial nursery for rocky species. Burt et al. (2013) highlight the importance of breakwaters for supporting coral reef fish communities in the rapidly developed marine environment of the Persian Gulf. In addition, studies have revealed the benefits of habitats created by the introduction of marine infrastructures such as oil rigs and offshore wind farms (Kaiser and Pulsipher, 2005; Smyth et al., 2015; Wilson and Elliott, 2009). The efforts to mitigate the negative effect of infrastructures along with further research on the effect of infrastructure on the composition and function of marine ecosystem can further conservation opportunities such as these.

From a reconciliation ecology point of view, enclosed areas, either with or without infrastructure within them, have the potential to contribute to the conservation of marine environments. We will now ask how can this be effectively integrated into an MSP process.

4. Modeling for identification of reconciliation opportunities

Reconciling ecosystem needs with human activity in marine infrastructure enclosures can be more effectively achieved if the potential synergies, opportunities and impacts are identified early on, i.e., prior to infrastructure construction rather than afterwards. For infrastructure planning and design, conservation will always be a secondary objective. However, integration of reconciliation ecology into the planning process can be achieved if planners consider issues such as preferred ecological assemblages (e.g., García-Gómez et al., 2015), critical elements of habitat design (e.g., Dafforn et al., 2015a; Sella and Perkol-Finkel, 2015), ecology (e.g., Ferrario et al., 2016), impacts of long term human activity on the marine ecosystem (Willsteed et al., 2017), impacts of construction processes on the ecosystem (e.g., Korbee et al., 2015; Korbee et al., 2014), and management schemes which align with conservation targets (e.g., Airoldi et al., 2015; Dafforn et al., 2015b).

Careful examination of conservation opportunities within existing or planned infrastructure enclosures which were not constructed yet, and the subsequent determination of whether the benefits of the enclosures outweigh the anticipated losses they cause, is a complex analytical process. It is especially difficult to assess whether planned enclosures would supply conservation opportunities as it is difficult to foresee the ecosystem structure that will develop in the area over time. Therefore, modeling can be used to predict the effect on the ecosystem after construction based on data collected from similar enclosures in the same region. To execute such modelling, planners should incorporate the use of best available biological and ecological data (see Browne and Chapman, 2017) which is based on long term monitoring of species abundance and distribution. They should also make use of information on the management of existing or proposed infrastructure enclosures such as the type and intensity of different activities taking place at the site, and then use the modeling tools for testing the suggested integration. The plan and management activities can be later evaluated and adjusted accordingly based on the performance of the integration over time.

The modeling approach proposed here (Fig. 1) for examining conservation opportunities is based on using existing data and examining different planning or management scenarios. First, the ecosystem is modelled together with human activities, where human activity type and frequency and its effect on each component of the ecosystem are defined. This enables examination of ecosystem response to human activity type and frequency and therefore provides information on how the ecosystem will respond in the long term to different configurations of activities (i.e., management scenarios). The result provides guidance regarding the possibility of integrating and reconciling marine conservation in areas designated for construction. These steps could be

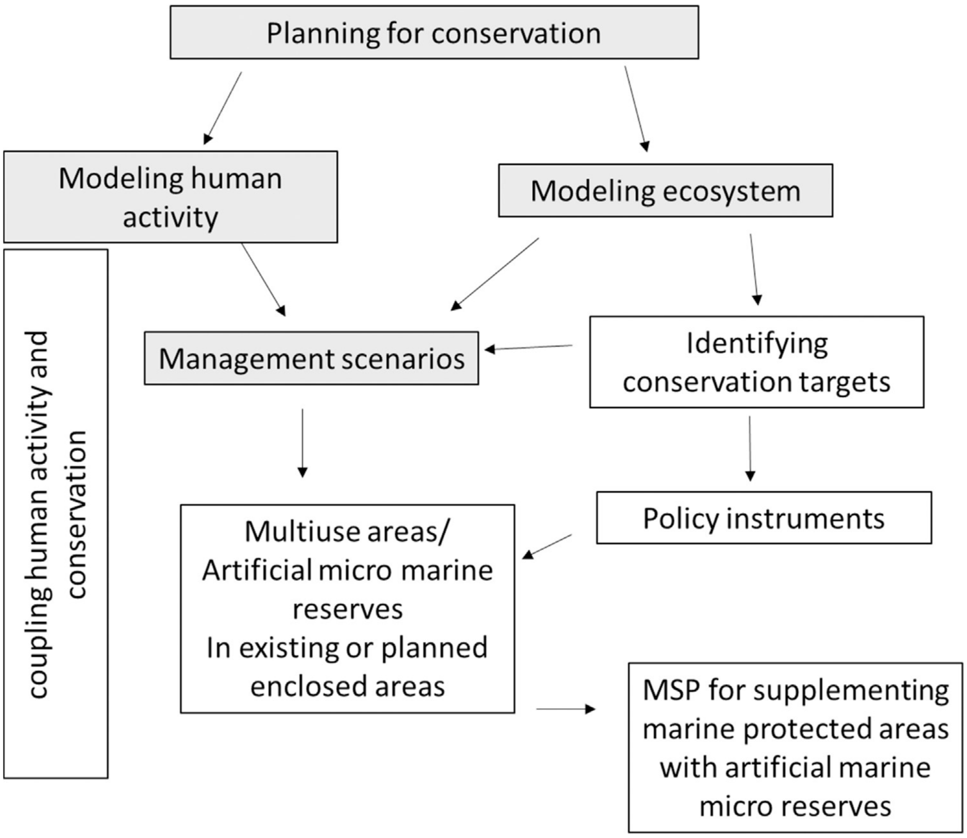

Fig. 1. The process of planning using reconciliation ecology approach to infuse marine conservation goals. Gray- highlighted stages indicate those dedicated to examining integration possibilities. All others are for ecosystem-based planning process.

applied to examine the conservation potential of existing infrastructure enclosures.

In order to achieve broad-scale conservation through MSP in ways that reconcile human uses and marine conservation, examination of the management scenarios should be only the first part of planning for the marine environment (Fig. 1). Following this part, firstly, management scenarios should be examined for specific infrastructure enclosures within the larger planning framework: The modeling of the ecosystem is thus used to *identify conservation targets* that were not identified prior to modeling of the ecosystem. For example, the modelling may reveal expected decline of a certain populations in response to direct or indirect effect of interspecific competition for resources. These conservation targets could be included in planning of an area that seek to implement EBM (see Arkema et al., 2006) for planning of an area. Secondly, the result of the scenario-examination is used to design *policy instruments* such as environmental legislation, regulations for marine infrastructure and fishery management that promote marine conservation in enclosed areas. Thirdly, these results are used to identify all areas in the region which are compatible with marine conservation goals, thus “reconciling” their use with this purpose. This may result in the *designation of these areas as artificial marine micro reserves* (García-Gómez et al., 2015) *or multiple-use areas* (Michler-Cieluch et al., 2009) which may supplement marine protected areas to enhance connectivity and conservation in the region. We will base the planning and management of marine enclosures to function as *artificial marine micro reserves* according to the modelling of interactions and conditions we see in similar existing enclosures in the region with, as required, a high degree of uncertainty being taken into account.

To achieve what we propose, planners can make use of existing modeling tools that have already formulated established connections between ecosystem components and human activities. For example, Ecopath with Ecosim (EwE) is a modeling tool that is directly relevant to ecosystem-based management as it allows exploration of management policy options (e.g., Heymans et al., 2016). For the use of this tool, the ecosystem consists of resources and biomass transfer between resources (Polovina, 1984). Ecosystem resources are trophically linked biomass pools, where each single species represents a functional group. Human activity and its effects on the various functional groups can be incorporated in the Ecopath model (Fig. 2). The Ecosim module, which is based on the Ecopath model, enables simulation of different management scenarios, modelling the change biomass over time for each functional group. In order to accurately model the ecosystem and to validate the model, basic inputs should be based on high quality data regarding species distribution, biological traits such as reproduction

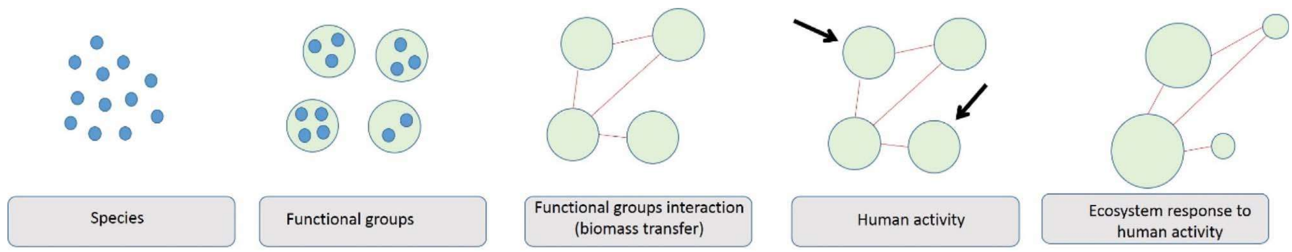

Fig. 2. Basic ecosystem modelling process. Species form functional groups which interact in the form of biomass transfer. Time dynamic modelling enables examination of how human activity (even if directed to a certain group) may affect the ecosystem.

and food consumption, and species interaction within the ecosystem. This type of data should be collected by well-designed survey, experiments and extensive literature reviews (Browne and Chapman, 2017; Chapman and Underwood, 2011).

Another similar, useful tool is the Atlantis ecosystem model which considers the biophysical system (nutrients, flora and fauna), industry, socioeconomic drivers and management. Although both Atlantis and EwE applications were initially-fishery management-oriented modelling tools, both are used today for other purposes such as examining management of multiple use areas, examining the effects of climate change on ecosystem, and biophysical effect assessment (see Port Metro Vancouver, 2014; Weijerman et al., 2015).

Both Atlantis and EwE modeling tools have been previously used to address various management issues. For example, an Ecopath model of Lake Kinneret was used by scientists to overturn a management decision to cull native cormorants assumed to cause a significant decline in commercial fishing catch. The model proved that cormorant removal would not result in increased catches and the management decision was cancelled (Ofir et al., 2014). In Guam, an Atlantis model was built using input from local resource managers, and was used to prioritize fishing management scenarios in a coral reef area. Researchers were able to determine not only which management scenario would most benefit the environment, but also to draw conclusions regarding the anticipated cost of each management scheme and the effect that climate change will have on the ecosystem depending on the different management scenarios (Weijerman et al., 2016). These examples show that modelling results can be the basis for management decisions that can then be incorporated into MSP, and furthermore for aspects of MSP related to construction (and engineering) of marine infrastructure.

The use of such modelling tools enables managers to forecast the effect of different management options on the ecosystem on a decadal timescale. To date, the coupling of ecosystem-modeling with human activity has been used mainly for designing management schemes (that include stipulations such as restrictions on fishing) and was not used for planning (i.e., the allocation of sea uses). Yet such modelling has the potential to be used as part of an MSP process that incorporates the EBM approach in order to predict the impact of both physical infrastructure, their management options, and general management options for the benefit of the marine environment. This approach also requires constant monitoring and review in order to validate the model and the success of the integration of human activity and marine conservation.

5. Conclusions

Marine conservation can benefit from MSP that goes beyond allocating areas for marine protected areas. Reconciliation ecology offers an opportunity to enhance EBM through conservation-oriented MSP by identifying conservation potential in almost any area of human use. However, more research is needed on how modelling approaches that incorporate the ecosystem and human activity, such as EwE and Atlantis, can then be used for MSP. Moreover, high quality data on marine ecosystem based on long term monitoring,performed by well-designed surveys and experiments is crucial for planners to use for these models (Browne and Chapman, 2017; Chapman and Underwood, 2011).

Despite multiple uses of the marine environment (such as fisheries, military, industry, and recreation), many countries, for example United-States, Russia, Israel, Egypt, and Denmark do not yet have a general marine plan that is aimed at balancing conservation with development (e.g., IOC-UNESCO, 2017; Portman, 2015). The future development of such plans will be an opportunity to make use of what is purposed here There is already a need to meet the requirements of the EU's 2014 Marine Planning Directive (European Parliament, 2014), emphasizing the timeliness of what we propose. As pointed out by this legislation and others, there is no questions that the growing concern for the state of the marine ecosystem coupled with increased human activity in the marine environment highlights the need for integration of marine conservation science and practice within planning processes.

Marine enclosures may supplement marine protected areas by adding more areas which are inaccessible for fishing and harvesting, enhancing connectivity between marine populations and encouraging cooperation of industry, maritime and military sectors to achieve conservation goals.

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