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Aquaculture and marine protected areas: Potential opportunities and synergies

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Abstract :

To meet the Convention on Biological Diversity's Aichi Target 11 on marine biodiversity protection and Aichi Target 6 on sustainable fisheries by 2020, as well as the Sustainable Development Goal (SDG) 2 on food security and SDG 14 on oceans by 2030, there is an urgent need to rethink how best to reconcile nature conservation and sustainable development.

This paper argues for effective governance to support processes that apply principles of sustainable development and an ecosystem approach to decide about economic activities at sea such as aquaculture. It describes opportunities, benefits and synergies between aquaculture and MPAs as a basis for wider debate. The scope is not a comprehensive analysis of aquaculture and MPAs, but rather to present examples of positive interactions between aquaculture activities and MPAs. The unintended negative consequences are also discussed to present balanced arguments.

This work draws from four workshops held in 2015 and 2016 and used to collect information from about

100 experts representing various sectors and perspectives.

It is recognized that aquaculture is an important activity in terms of sustainable development. It can play a role in providing food security, poverty alleviation and economic resilience, in particular for MPA local communities, and contribute to wild stock enhancement, as an alternative to overfishing and for providing services to the ecosystem.

This study showed that there is a need from both aquaculture and MPA sides for clarity of objectives and willingness for open and extensive dialogue. The paper concludes by describing a number of tools and methods for supporting greater synergies between aquaculture and MPAs.

The results from this work have already helped to build a common understanding between conservation and aquaculture and initiate a rapprochement for increasing synergies.

Keywords : aquaculture, ecosystem approach, environmental impact assessment, littoral, marine protected area, ocean, sublittoral

1. Introduction

Around 85% of world's fisheries are either being fished at full capacity or already overexploited, and depleted (FAO, 2016a). As the world's population is expected to reach 9.7 billion by 2050 (according to the 2015 United Nations revision of world population prospects (United Nations, Department of Economic and Social Affairs, Population Division, 2015)), global fisheries will continue to be under pressure in order to meet this future demand for food fish. Attention is gradually being drawn to aquaculture as one option to meet this anticipated shortfall. It is projected that aquaculture in 2025 will supply 52% of fish for human food (FAO, 2016a). In the meantime, the need for ocean conservation becomes more acute as the expansion of some human activities directly threatens ocean biodiversity, ecosystem services and aquatic food security (Laffoley & Baxter, 2016). Moreover, global changes, including climate change, have been shown to significantly impact ocean systems. The creation of Marine Protected Areas (MPA) is a key tool that may enable the various Aichi targets to be met (CBD, 2010). However, to be truly successful, they need to be integrated within local contexts; they need to embrace where at all possible and appropriate, sustainable economic activities to be managed in accordance with conservation objectives. Aquaculture might meet these requirements under some conditions and situations, and indeed may be more preferable than other uses, such as fisheries that could and are proposed in multiple-use MPAs. The purpose of this paper is to explore what kind of synergies and opportunities might look like to bring MPAs and aquaculture closer together whilst respecting their individual ideas and ambitions to contribute to ecological and human well-being.

For the nature conservation community (e.g. Non-Profit Organizations, scientists, MPA managers, policy makers, etc.), aquaculture has often been regarded as a source of coastal pollution, habitat degradation or local conflicts with the different local users. However, it may be argued that, if industrial aquaculture is deemed as polluting, unsustainable, and source of social conflicts, on the other hand, traditional aquaculture has very often been addressed as livelihood activity for small and poor communities. The link between shrimp farming and mangrove deforestation is one example where inappropriate farming practices have led to habitat loss and pollution, as have some circumstances associated with intensive net-cage fish farming causing localized inshore eutrophication (Soto et al., 2012). In addition, rearing fish with compound feeds containing high levels of fish meal / fish oil derived from small wild pelagic fish is also considered unsustainable in the long-term (le Gouvello & Simard, 2017). Considerable progress has been made in recent years to reduce the levels of fishery-derived feedstuffs in the feeds used for farming fish and shrimp. There is also the issue of escapees from fish farms, which may affect marine biodiversity. In general, public criticism and negative perceptions of environmental impacts are impediments to the creation of new aquaculture activities (Kaiser & Stead, 2002). This criticism has been reinforced by a number of public campaigns focusing on negative impacts of some aquaculture systems (Alexander, Freeman, & Potts, 2016). However, much progress has been made globally to develop and disseminate good (and "best") aquaculture practices (FAO, 2016c; Fezzardi et al., 2013; IUCN, 2007, 2009a, b; Massa, Rigillo, et al., 2017; Rey-Valette et al., 2008). Moreover, non-finfish aquaculture represents a large proportion of the world's seafood production (FAO, 2016a) and can contribute positively to ecosystem services such as carbon sequestration and nitrogen utilization (Filgueira et al., 2015; Jiang et al., 2015). Additionally, most marine aquaculture operations are located in coastal areas and have a strong overlap with conservation interests as both MPA and aquaculture are highly dependent on good water quality. Therefore, based on the intertwined relationship between aquaculture, the environment and MPAs (Massa, Rigillo, et al., 2017), the potential exists for aquaculture farms to serve as early warning systems for the ecological status of coastal ecosystems. Thus, with appropriate site selection and management, for example through the establishment of allocated zones for aquaculture “AZA” (Sanchez-Jerez et al., 2016), aquaculture interests could be directly aligned with MPA objectives.

Aquaculture is much diversified in terms of the number of aquatic species being farmed, the types of technologies used and the degree of intensification, etc. Between the two extreme situations, on one hand intensive industrial fish farming, and, on the other hand, extensive low density aquaculture driven by communities, there exists a wide range of aquaculture practices, types and scales that could provide opportunities for greater synergies within multiple-use MPAs. Such multiple-use MPAs could also provide alternative livelihoods, moving away from destructive practices and develop sustainable financing opportunities for the MPA management.

If this vision is to become a more plausible reality, the assessment of the sustainability of aquaculture will need to be examined in detail. In particular, comprehensive full cost/benefit and impact assessment analyses of farms should be conducted on a case-by-case basis to provide solid case studies of good practices.

A key aspect though is the need to focus on creating common understanding and dialogue. There is much suspicion about conservation objectives, which some on the aquaculture side consider are contrary to their business interests. For many aquaculture producers, MPAs are viewed as places where no farming is allowed, "*no take/no use*" zones, which is a wrong perception, as a recent IUCN MPA guide pointed out (Day et al., 2012). The reality is that IUCN has defined six categories of MPAs (Tables 1 and 2) whereby the two most commonly applied types (Categories V and VI) allow some aquaculture activities (Day et al., 2012). Category VI reflects multi-purpose MPA aiming to both preserve biodiversity and enhance a sustainable economy by managing related impacts and synergies. However, by looking into details, most MPA categories may allow some type of aquaculture as discussed later in this paper. Quite how appropriate aquaculture should be within a MPA category is, in fact, the essence of this paper.

This is a very timely debate as there is much greater recognition that aquaculture needs good quality water and space (European Commission, 2012; Hofherr, Natale, & Trujillo, 2015; Sanchez-Jerez et al., 2016) and that multiple-use MPAs need environmentally compatible economic activities in order to help provide sustainable financing. This debate is one that is already happening in the context of delivering sustainable development, as Dempster et al. (2006) outlined by saying "*aquaculture and conservation can work together*". The debate does, however, raise significant questions including how can MPAs support aquaculture development, how should aquaculture activities support MPAs and how can negative interactions be minimized and greater common trust be achieved? Beyond the fact of recognizing that aquaculture may be compatible within certain types of MPAs, it also raises the critical issue whether all aquaculture types of production could be adapted to MPAs. Alternatively, would it be possible and indeed practical to define a scope, a specific approach or insist upon a set of principles to accompany the process of making sure that an aquaculture type fits into a MPA type, for reconciling aquaculture and MPAs?

This work aims to explore the relationship between multiple use MPAs and compatible activities. If the Aichi Target 11[2], Aichi Target 6[3], the Sustainable Development Goal 2[4] and SDG 14[5] (CBD, 2010;

[2] Target 11**:** By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas,

United Nations, 2015) are to be met, then the aspirations of nature conservation and development need to be reconciled and in particular, aquaculture and MPAs.

2. Building a picture of MPA and aquaculture interactions

This paper is the result of a project initiated by the IUCN Commission on Ecosystem Management Ecosystem-based Aquaculture Group and supported by Foundation Albert II of Monaco and was developed, from June 2015 to November 2016. Four workshops[6] on the subject were organized and coordinated by the IUCN team. In total, the workshops gathered around 100 people from various nationalities, sectors and perspectives (scientific institutions, consulting offices & private companies, intergovernmental or national organizations). They were organized as open discussions between the organization team and all participants. For this paper, a first preliminary (but not exhaustive) literature review was conducted, to illustrate some of the issues raised by the participants, each of whom was also invited to provide the most relevant articles on this topic to further enrich the paper.

Eight case studies were presented by institutional partners and non-governmental organizations (NGOs). These case studies were not limited to established experience on aquaculture farms within MPAs but offered a broader scope to show diversity of aquaculture systems that have, were or might be settled within MPAs. Mostly from Europe and Africa, these examples offered a variety of approaches and situations that highlighted some potential synergies or critical issues to be further investigated. They followed the same framework, namely presenting the project location, socio-environmental issues and contexts, the MPA and aquaculture respective objectives, the site management and stakeholder's overview. As a conclusion for each case, an analysis of the strengths, weaknesses, opportunities and threats (SWOT) was proposed, as this tool has been widely used in various situations to analyse projects and strategies, to gather opinions of a panel of people from various backgrounds, so that the context can be better captured (Glass, Kruse & Miller, 2015; Helms & Nixon, 2010; IUCN, 2017a; Stead, 2005).

The results of these discussions and exchanges are presented in the following section and highlight the main issues and outcomes. This is supported by three SWOT analysis case studies and many other examples from around the world to illustrate key trends observed. One SWOT analysis case study is from the NGO Blue Ventures and focuses on sea cucumber (*Holothuria scabra*) and carrageenan seaweed (*Kappaphycus alvarezii*) farming in the Velondriake locally managed marine area (LMMA) in Madagascar. The second case study is provided by the Ifremer-Parc Marin de Mayotte team from the island of Mayotte, in the French Indian Ocean Territories and the third summarizes the aquaculture production in Madeira and Canary Islands.

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especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

[3] Target 6: By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

[4] Sustainable Development Goal 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture

[5] Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

[6] As follows: a 2 day workshop conducted in Paris on the 24-25th of June 2015 as part of the Monaco Blue Initiative (MBI), a 1 day workshop on the 23 of october 2015 in Rotterdam as part of the Annual Congress of the European Aquaculture Society (EAS), 1 knowledge coffee on the 4th of September 2016 as part of IUCN World Congress in Honolulu, and a 1 day workshop in Edinburgh, September 2016 (EAS).

3. Identifying synergies between MPAs and aquaculture

The two topics that can frame the exploration of synergies between MPAs and aquaculture are the compatibility of aquaculture and MPA conservation objectives, and the intended purpose of aquaculture projects within the MPA.

3.1 Can aquaculture production be compatible with conservation objectives?

To achieve better opportunities for positive synergies, MPA management should include an evaluation of the potential impacts of aquaculture on the marine environment and socio-economics of those that interact or depend on MPAs for their livelihoods or recreational pursuits. Different aquaculture systems may cause diverse effects on the natural environment, such as habitat deterioration and ecosystem functions disturbance. However, some aquaculture systems may have positive effects for the biodiversity of the site (European Commission, 2012) and their objectives be compatible with MPA targets. Several key questions arise:

- *Can aquaculture play a role for wild stock fauna and flora restoration/conservation?*

Aquaculture is often limited to food production purposes, however some aquaculture can present a positive opportunity for MPAs such as restocking of vulnerable species and enhancement of biodiversity. Aquaculture of the dusky grouper (*Epinephelus marginatus*) for conservation purposes undertaken in Italian MPAs is one example (Donadelli , Longobardi, Finoia, & Marino, 2015). The objective of the programme was to restore the population of groupers after years of overfishing and evaluate the success of restocking related to the survival rate of juveniles in the wild (the original population was reduced by 88% between 1990 and 2000). However, in such cases, caution should also be exercised and levels of genetic differentiation in wild stock be determined beforehand to avoid unwanted genetic impacts (Jørstad & Farestveit, 1999). Farming coral reefs also appears an appealing option in tropical MPAs (Pomeroy, Parks, & Balboa, 2006). A study on community-based coral aquaculture in Madagascar showed that profit can already be made by the second year - marine animal wholesale companies and NGOs being the main clients (Todinanahary et al., 2017). It could be a source of material for reef restoration in MPAs and at the same time reduce the pressure on wild populations. More than 80% of traded corals are still collected from the wild, farming techniques have become inexpensive and adaptable on a small-scale (e.g. village production), for some specific cases, as Todinanahary et al. (2017) recently emphasized. Nevertheless, Edwards & Gomez (2007) pointed out that reef restoration may be costly and less efficient than coral reef preservation which should be considered as the first priority option and, in particular because of coral reef vulnerability to climate change.

There is, however, a lack of guidelines for a responsible approach to stock enhancement through aquaculture which will hamper future progress. Such guidelines would need to cover the need for appropriate management tools such as risk assessment and benefits analysis, pathogen free specimens and genetic monitoring, relevant to each local context.

- *Can aquaculture be designed for fisheries enhancement and/or as an alternative to excessive overfishing of vulnerable fisheries?*

Even though restocking for fisheries based on aquaculture has been well developed in many countries for decades such as Japan (all fisheries) and in the USA (salmon fisheries), these kinds of aquaculture depend on specific national and local traditions, formal governance mechanisms, markets, and rely on appropriate monitoring tools, in order to avoid impacts on wild stocks.

Some MPAs are established in order to alleviate the pressure on wild fish stocks and restore population health. Aquaculture cages or farming infrastructures may serve as potential nurseries/feeding grounds and shelters for wild populations under controlled conditions (Dempster et al., 2006; Yang et al., 2015). Tropical seaweed production trials undertaken in Costa Rica showed that cultivated seaweed plots rapidly and significantly enhanced local biodiversity compared to control areas, notably for a large number of fish species (Radulovich, Umanzor, Cabrera, & Mata, 2015). In Kenya's coastal areas, small scale aquaculture of extractive species is being developed to provide alternative livelihoods and diminish fishery pressure in coral reefs (FAO, 2016b). Traditional coastal lagoon management in some particular areas of the Mediterranean (e.g. the *vallicoltura* in North Italy) is also a good example where traditional extensive aquaculture (mainly based on restocking and hydraulic management) and artisanal fisheries are implemented in sensitive ecosystems, and these have remained unchanged for centuries and contribute to the livelihood of coastal communities (Cataudella, Crosetti, & Massa, 2015).

Aquaculture activities can also be an alternative for fishing especially in regions of great poverty. Sea cucumber (*Holothuria scabra)* and red "cottonii" seaweed (*Kappaphycus alvarezii*) farming in the Locally Managed Marine Area of Velondriake in Madagascar helps reduce the pressure on natural marine resources (Table 3) (IUCN, 2017a). In this area, the small-scale fisheries employ 87% of the adult population and generate an average of 82% of all household income. Aquaculture diversifies livelihoods among farming communities, reducing local dependence on over-exploited capture fisheries. However, a quantification of these impacts should be further investigated as increased incomes from aquaculture activities may also lead to higher investments in fishing gear and consequently to a greater exploitation of fisheries.

A socio-economic marine livelihoods study conducted in Rodrigues in 2015 showed that most fishers were willing to do other work than fishing per se, but 56% stated that they did not have other alternatives to fishing to secure food or income (Hamilton, Stubber, & Stead, unpublished data). Access to appropriate aquaculture training might be the key factor for future transition in fishing communities interested in considering aquaculture. However, as outlined in the SWOT analysis for the Blue Ventures case in Madagascar (Table 3) (IUCN, 2017a), the usual animosity between fishermen and aquaculturists may constitute a serious threat to the project's success. On the other hand, where an MPA has led to the displacement of fishers and created tensions between MPA rangers and fishers with the latter arguing there are few alternative sites or it is more expensive to find new fishing areas, then considering particular types of aquaculture in MPAs might offer an alternative source of food and income to fishers among other benefits.

Additionally, aquaculture may become an increasingly important provider of work for women (Monfort, 2015; Slater, Mgaya, Mill, Rushton, & Stead, 2013). Thus, to counter any reduced access to marine resources through creation of MPAs, the inclusion of aquaculture in these areas especially when managed effectively could offer women a chance to generate income and food under the protection of rangers. For example, in Madagascar, more than 50% of Velondriake LMMA aquaculture farmers are women (Table 3) (IUCN, 2017a).

- *Can aquaculture play a major role for food security, poverty alleviation and economic resilience of MPA local communities?*

Even a limited access to seafood products (algae, finfish, crustaceans and shellfish from fisheries or aquaculture) for local consumption was demonstrated to increase resilience in vulnerable populations. In particular, it helped people face food and nutrient shortages by providing a source of unsaturated omega-3 fatty acids, high-value and easily digestible proteins, carbohydrates, fiber and a wide range of micronutrients (Msangi et al., 2013). In a social study conducted in five countries, over 50% of 2,520 respondents were considering aquaculture as a way to improve health and nutrition and for being part of a reliable and affordable food source (Alexander et al., 2016). The impressive increase in aquaculture production has contributed to maintaining the overall low price of fish and increase the average availability of seafood per capita to consumers around the world (FAO, 2016a).

Aquaculture helps in several ways, directly and indirectly, by reducing poverty and food insecurity (Toufique & Belton, 2014). Some aquaculture farms (seaweed, sea cucumber, corals, etc.) operate with low running costs and no feed inputs (Table 3) (IUCN, 2017a; Todinanahary et al., 2017). Production methods may be simple, easily transferred to artisanal fishers (Radulovich et al., 2015) and require minimal technical support after initial training.

Direct collaboration with fish farms may lower costs and improve logistics of MPAs. In a pilot project fish farm in Madeira from 1990s (IUCN, 2017a), located nearby a remote terrestrial protected area (TPA), there was a close collaboration between the farm management and the conservation authority. Park rangers would often come on board the fish farm boat during routine work and take the ride to survey the protected coast. Besides, TPA rangers on duty, once on land would “keep an eye” on any unwanted boat approaching the cages. MPA management authorities may also receive fees from aquaculture since it benefits from a specific location and clean environment. This opportunity is, however, dependent on Small and Medium Enterprises (SMEs) and industrial production rather than on community-based small scale aquaculture.

- *Can aquaculture provide services to ecosystems such as enhanced carbon sequestration, nutrients or phytoplankton consumption and is this beneficial?*

Certain types of aquaculture have the potential to support local ecosystem services through their interactions with such services, though this issue sometimes leads to conflicting results and has yet to be demonstrated at scale. A potential carbon sequestration function was demonstrated for seaweed fields and shellfish farming in several studies (Filgueira et al., 2015; Jiang et al., 2015; Massa, Onofri, & Fezzardi, 2017). A nutrient-related bio-mitigation function is also proposed for non-finfish aquaculture. Cultivated seaweeds can use nitrogen to grow and therefore can mitigate eutrophication episodes (Wu et al., 2015). According to Filgueira et al. (2015), farmed bivalves contribute to nutrient regulation in coastal areas. Other authors suggested that cultured shellfish could mitigate coastal eutrophication (Cranford et al., 2007; Lindahl, 2011; Petersen et al., 2014; Rice, 2001) and also play a role in benthic restoration (Dumbauld, Ruesink, & Rumrill, 2009).

This nutrient-related bio-mitigation function provides the basis for the recent development of Integrated Multi-Trophic Aquaculture (IMTA) (Chopin, et al., 2012; Martinez-Espiñeira et al., 2016; Soto, 2009). For instance, within the same coastal area, cultivated shellfish and seaweeds could benefit from the organic and inorganic effluents generated by finfish farms and thus, reduce the impacts of the latter on the surrounding environment. The overall gross nutrient balance of this diversified aquaculture production system is almost neutralized. However, on the downside, attention should also focus on the potential interference with the hydraulic patterns of the area, exposure to pathogens and impacts on benthic communities through increased bio-deposition loadings (Jiang et al., 2015; Lamprianidou, Telfer, & Ross, 2015).

Some forms of aqua-silviculture are also possible by combining aquaculture with mangrove replanting and landscaping (Soto, 2009). In this direction, new perspectives are also in development concerning integrating artificial reef and multi-trophic aquaculture to improve local biodiversity and environmental integration, mixing environmental green engineering and aquaculture performance (Medioni, et al., 2013). MPAs may offer field opportunities under the right circumstances to investigate and test such innovative aquaculture systems and approaches on a pilot scale.

To conclude, whatever the objective of aquaculture production is, compatibility with MPA objectives and conservation targets relies on an integrated and ecosystemic approach. Joined-up thinking on producing species adapted to local conditions, on carrying capacity concept, and on different rules related to best practices for site selection (IUCN, 2009a; Sanchez-Jerez et al., 2016) need to be considered alongside one another, as discussed in the following sections. Efforts are hampered by lack of mutual knowledge, lack of good documented examples and associated guidelines for the industry to follow.

3.2 Defining a frame for enhancing synergies between MPAs and aquaculture

3.2.1 Providing clarity on purposes and management objectives?

What is evident is that clarity of purpose and intent both for MPA managers and aquaculture operations will be critical in creating greater opportunities and synergies in the future. For aquaculture, this means being clear from the outset and having discussions as early as possible on the type and location and intensity of the proposed operation. Undertaking this in the knowledge of the MPA objectives should mean a better basis for informed discussion and debate. For MPAs clear management objectives should be defined, discussed, debated and agreed among the stakeholders of the MPA, as a prerequisite for each project of aquaculture within an MPA. If the Aichi targets are to be met, the majority of MPAs designated are likely to be, on current performance, multiple-use MPAs in the IUCN categories V and VI. Only a small minority are currently IUCN category IA or IB, i.e. no-take zones. Once designated, governance and management systems should be set up for each MPA. More than a debate on MPA category ("*No take*" zone or multiple-use zone), the crucial challenge is to make sure that the right management tools are in place in order to satisfactorily meet the MPA objectives. This reflects the perennial challenges authorities face with delivering effective management and why IUCN has created the Green List process of well-managed protected areas – to invoke clear standards for management (https://www.iucn.org/theme/protected-areas/our-work/iucn-green-list).

3.2.2 Understanding the practical relationship between aquaculture and MPAs. Which comes first, the aquaculture production or the MPA?

Within the broad topic of defining a framework for enhancing synergies it is evident that, in practice, three different broad contextual situations occur concerning the MPA and aquaculture relationship:

- Development of a multiple-use MPA in an existing aquaculture area.
- Development of aquaculture farms in multiple-use MPAs.
- Joint Creation of multiple-se MPAs with associated aquaculture operations.

The distinction between the situation where one comes before the other is already in place in some national legislative frameworks, for example in Scotland. Here, there is a coherent and pragmatic framework for managing aquaculture activities within MPAs which is based on raising the basic simple question, which existed first, the aquaculture activity or the MPA.

a. Development of a multiple-use MPA in an existing aquaculture area.

The first situation is where aquaculture farms exist before the MPA is actually declared and set up by the authorities. This situation is well illustrated by Scottish cases, where many salmon or shellfish farms existed before MPA declarations. A similar situation takes place in The Estero Real Nicaragua where the shrimp farms, both intensive and extensive existed before the area was declared RAMSAR (FAO, 2014). Those situations appeared to be very widespread on all continents leading to various options. For instance, in Scotland, when planning a new MPA, the Scottish Government must undertake a Partial Business Regulatory Impact Assessment (PBRIA). This must outline the case for the MPA and identify sectors which will be impacted with the designation of the MPA. The PBRIA must identify specific costs to any industry within a proposed MPA and balance this against the conservation objectives of the proposed MPA to assess the likely impact of designation.

In these cases, the general presumption has been that the aquaculture farm should not be displaced but an impact assessment of the farm should be conducted against the objectives of the MPA. According to the results, trade-offs should be set up in order that both the farm operation and the MPA management can each meet their objectives. Where this proves not possible and in extreme cases this could lead either to displacement of the farm or to re-definition of the MPA limits. There is nevertheless a clear opportunity for MPA managers and the nature conservation sector to try and achieve the MPA objectives by including a broad surface of interesting habitats within the new MPA boundaries, and around the aquaculture concessions. During the planning of MPA creation, issues for the aquaculture farms such as extension capacity, use of best practices, new species/new aquaculture production technologies such as Integrated Multi Trophic Aquaculture (IMTA) should be discussed clearly.

b. Development of aquaculture farms in multiple-use MPAs.

The second situation illustrates the case where there is an existing multiple-use MPA and there is a call to develop aquaculture within the area in order to meet some of the local community's objectives. In this situation, the type of aquaculture systems would need careful selection to meet the needs of the community and be compatible with the management objectives for the MPA.

In Scotland, planning permission is required for all new shellfish and finfish aquaculture developments, change of use, and alterations to existing approved sites (Nimmo, MacLaren, Miller, & Cappell, 2016). As part of this process Scottish Natural Heritage, Scottish Environment Protection Agency and Marine Scotland Science are statutory consultees. This process involves the production of an Environmental Statement which will determine if an Environmental Impact Assessment (EIA) is required. An EIA is required if the development is to take place in a sensitive area (such as an MPA), or if a finfish production site exceeds a certain size. In the case where the aquaculture development is within an MPA of a Natura 2000 type, the EIA will trigger a Habitats Regulation Appraisal (HRA). This is undertaken under the Conservation Regulation of 1994 which requires all Competent Authorities to carry out an Appropriate Assessment where activity within a protected area is likely to have a significant impact on a protected area. It has been deemed that the HRA is the Appropriate Assessment for aquaculture development in MPAs in Scotland. The HRA must 'provide, and analyse sufficient information to allow a competent authority to ascertain whether the plan or project *will not* adversely affect the site's integrity'. There is no presumption against aquaculture use within MPAs as long as the conservation objectives of the MPA are not compromised.

The question of site selection is well documented in the literature and should take into account environmental as well as aquaculture technical and socio-economic issues (IUCN, 2007, 2009a). If socio-economical sustainability of local fisheries accepts levels of sustainable capture on wild stocks within MPAs, these levels of compliance depending on the sensitiveness of coastal habitats should similarly allow aquaculture co-development in some MPAs. Clearly the species being considered for cultivation will be a major issue if it is non-native or could disrupt native populations. Some guidance on aquaculture and MPAs for the Natura 2000 sites has been developed within the European community and can be an example of interest for other countries as it explains in details a step-by-step procedure for a full impact assessment (European Commission, 2012).

<u>c. Joint Creation of multiple-use MPAs with associated aquaculture operations.</u>

In the third situation, the MPA is established and the associated aquaculture production(s) are set up almost at the same time, as simultaneous and/or supporting developments. Such a situation requires:

- A proper management system in place for the MPA.
- Clarity on the aquaculture objectives.
- Methods and tools in place to evaluate and monitor the aquaculture production impacts.
- A good governance system in place for both the MPA and the aquaculture operations, including involvement of all local stakeholders to ensure effective and meaningful on-going discussions and agreed decisions.

This situation is illustrated by the French Mayotte case (Table 3; IUCN, 2017a) although the fact may be argued that some aquaculture productions of a non-native carnivorous fish (at a very small scale) existed in this area, prior to the Mayotte marine park being founded. The pre-existing situation of the farm is in fact the main reason why such an aquaculture production system was authorized within the multiple-use MPA. The key critical issues are related to how the decisions are made to allow such aquaculture production, how it will be monitored, and implemented, what is the development plan of such aquaculture production on a short, mid and long term.

These two last contexts (*b* and *c*) are very similar in the sense that the establishment of an aquaculture farm in the MPA requires a clear rationale and objectives. The selection and advantages of a specific aquaculture project against other economic activities (e.g. tourism, fisheries, etc.) should be underpinned and acknowledged by the MPA managers and their stakeholders. Comparison between aquaculture and other activities in terms of impacts or risks is necessary to address information on the best choice of economic development within an MPA. Various options of aquaculture types, systems, purposes and scales should be studied to optimally adapt the specificity and needs of each potential site and minimize adverse effects and the overall environmental footprint. The way an aquaculture project interacts with a MPA is related to the characteristics of the project, its design and its management as well as the scale of the operation. Thus, a small scale aquaculture facility poorly sited in a multiple use MPA (category IV through to VI, though most likely the latter category) may be more damaging to nature conservation than a well thought-through larger scale operation. For the Scottish and French authorities, for instance, carnivorous fish productions are acceptable, provided that “good practices” are applied within the farms and a good monitoring of the aquaculture impacts is on place (e.g. Mayotte and Scotland).

Similarly, the location and level of coverage, the location of the sites should be discussed with local stakeholders and aquaculture professionals in a concerted approach binding sustainable development, social integration and environmental considerations. MPA managers should be trained by visiting diverse type of aquaculture farms to reach a better understanding on aquaculture concerns and limiting factors.

3.2.3 Can the development of a matrix on MPA types and aquaculture help to improve synergies?

It is evident that at the strategic level there is a relationship between the different types of aquaculture and their general compatibility with the different types of MPAs as defined by IUCN. The question arises as to whether it is therefore possible to further develop this idea beyond the general advice already provided by IUCN.

If there is a need for a matrix of risk to assess MPAs types and aquaculture types, then a simple matrix may prove most effective, similar to those used by IUCN in its marine guidelines illustrated in Table 2 (Day et al, 2012). Such a relational table could match different types of aquaculture with the different categories of MPAs. This should, however, be done with considerable caution. Table 4 is provided as an example of such potential approach that could be undertaken and has not been ratified through consultation by IUCN. Such a matrix could only ever be general guidance, as so many of the specific issues are related to local conditions and discussed earlier. It could however provide a flexible frame to further explore potential synergies between aquaculture and MPAs, and help all concerned identify specific issues that should be monitored. Eventual decisions to proceed or not or to modify ideas will depend on the overall case assessment. In addition, even where the illustrative example of Table 4 shows compatibility (i.e. green) this does not prevent the need for comprehensive discussions and evaluation of siting and impacts.

3.2.4 Could integrated multi-trophic aquaculture (IMTA) provide opportunities for synergies with MPA management objectives?

By definition, integrated multi-trophic aquaculture (IMTA) provides an interesting perspective on achieving the implementation of an ecosystem approach and the integration of aquaculture within its environment, while reducing negative externalities and maximizing its capacity to develop biodiversity and resilient ecosystems. In this context some applications of IMTA could be of interest within MPAs providing enhanced opportunities to secure management synergies.

IMTA could certainly be deployed in various cases as in Table 4 (e.g. high density fish cage cultures, shellfish culture, sea cucumber culture...), although a specific assessment of the proposed local IMTA system must be conducted to define the level of compatibility according to the MPA category. For instance, there are interesting cases in Europe and Canada where IMTA is implemented on a pilot scale, but this type of aquaculture has not been able yet to expand for broader application for a number of reasons, including blocking regulations or public perception (Alexander et al., 2015, 2016; Martínez-Espiñeira et al., 2015, 2016). Sufficient attention should be drawn toward biosecurity issues and a full risk analysis should be undertaken (Neori et al., 2004; Troell et al., 2003). Innovative designs should be validated outside MPA boundaries before applying into MPAs. Fisheries and Oceans Canada (DFO) is examining the development potential for IMTA operations and how this type of aquaculture could help fish farmers improve fish health and the environmental performance of their operations while maintaining economic viability (DFO, 2016). Various IMTA researches are underway regarding optimization of combined species, species interactions and environmental management.

3.2.5 Do non-native species aquaculture operations pose difficulties in achieving greater synergies with MPAs?

The acceptance or non-acceptance of the aquaculture production of a non-native species within an

MPA is also a critical point. For the nature conservation community, it seems unacceptable that within an MPA, an aquaculture production of non-native species could be allowed. From a pragmatic point of view, however, this strong positioning is difficult to maintain in all circumstances. Non-native species are widespread, even in MPA marine ecosystems. In world aquaculture, it has been a major trend for decades (Gollasch, Cowx & Nunn, 2008; Gollasch, Nunn & Cowx, 2009). Global oyster production has been based on the introduction of new species of oysters in order to overcome epidemic outbreaks of the local oyster species. Even in the situation where the aquaculture production is based on a local species like Atlantic salmon in Scotland and Norway, it may also be argued that the domesticated farmed fish are genetically distinct the local wild species. Consequently, each case of aquaculture should be contextually analysed with regard to this particular issue of non-native species, and whether in particular the species concerned is already farmed in the local or national context. Clearly new introductions into an entire ecoregion of the world would need far greater scrutiny. This is not just from the conservation standpoint but also link with aquaculture and fisheries issues because of unfortunate episodes in the past, where one introduction has inadvertently led to other pests gaining a foothold in new regions of the world to the disadvantage of all concerned. The frame provided by the European Union with a risk analysis, and using the precautionary principle, may provide a very valid approach, as it has been approved and validated by the scientific expert community (European Union, 2008, 2011). But this issue is obviously a very critical point that needs to be further investigated.

4. Discussion

Many potential synergies exist between MPAs and aquaculture and vice versa. Indeed, if these were explored more fully greater options for sustaining multiple-use MPAs in cooperation with aquaculture may be found providing more environmentally friendly alternatives to other types of developments now being proposed in MPAs.

In the coming years MPA managers and their stakeholders should come together more to better understand the aquaculture sector, its constraints for production, and its needs for water quality. At the same time, MPA managers should always work to reduce conflicts, and should also explore optimizing advantages, especially in the area of supporting conservation efforts, restocking, and lowering environmental footprint and intensity of production systems.

In this context, the concept of an ecosystem approach to aquaculture provides a set of very valid tools, as it aims at integrating human activities within the wider ecosystem so that it promotes sustainable development, equity and resilience of interlinked socio-ecological systems (IUCN, 2007, 2009a; Ross, Telfer, Falconer, Soto, & Aguilar-Majarrez, 2013; Soto et al., 2012). It includes the carrying capacity concept defined as the maximum biomass of a farmed species that can be supported without violating the maximum acceptable impacts to the farmed stocks and its environment (Stigebrandt, 2011). Both ecosystem approach and carrying capacity concepts supported by model tools such as FARM or MERAMOD, can help investigate the various impacts of a potential project of aquaculture and determine its most relevant scale (Ferreira et al., 2009). The development and application of marine spatial planning together with integrated coastal zone management (ICZM) are also dynamic processes facilitating site selection - with the correct water quality and siting measures - for aquaculture applications (European Commission, 2012).

From those approaches, whatever the situation is, the aquaculture producers and MPA management bodies should develop dialogue with other stakeholders. SWOT analysis as illustrated by Table 3 may provide a valid tool, shared with stakeholders, to analyse on-going projects of aquaculture within an MPA and identify the actions to correct weaknesses and prevent failures.

Alongside the traditional view of MPAs, more options for cooperation may open in the future through new guidance IUCN will develop for the Convention on Biological Diversity to further elaborate achieving Target 11. This will focus on 'Other Effective Area-based Conservation Measures' or OECMs as they are becoming known (IUCN, 2017b). Whilst the guidance on what may be an OECM is still under development, the underlying principles are clear. The origin and governance may be very different but the ultimate outcome of an OECM should result in the same nature conservation protection and the security achieved by MPAs. This elaboration of guidance, available from 2018, will expand opportunities to embrace a wider range of partners in the delivery of effective marine nature conservation and this may indeed represent further opportunities for synergies and cooperation with the aquaculture industry.

In fact, an analysis for identifying opportunities can be developed based on socio-economical and environmental criteria related to the existing MPAs or the local habitats and species. The local situations are very dependent on the culture, the countries, the local political will and the local environments. Further discussions should be developed to clarify common visions and global criteria that would not hamper initiatives and integrated approaches developed locally. An analysis should be undertaken of the benefits of the aquaculture production within a multiple-use MPA, or/and around the MPA versus other activities. Tourism may not be a solution in many areas as it causes adverse effects to the coastal social and ecological systems if not properly handled (Davenport & Davenport, 2006).

An aquaculture production may represent a more sustainable activity for the local community, but the entire value chain (aquaculture farmers, processors, traders, retailers, consumers and other intermediaries of aquaculture sea products) has to be addressed with regard to local players and stakes (Jespersen, Kelling, Ponte & Kruijssen, 2014; Tran, Bailey, Wilson & Phillips, 2013). What are the farm capital investors, and whether the MPA's aquaculture product is intended to supply a local market, or intended for export are crucial questions to be answered as well as the whole value chain structure and governance. For instance, in the Madagascar and Mayotte cases, the productions are destined exclusively for export (IUCN, 2017a). However, they serve the local community interests by providing them with an income. Obviously, it is essential to monitor and control potential impacts of aquaculture activities, but it is also important to show how aquaculture can provide services to other activities. Aquaculture within an MPA should work as a win-win relationship and build greater potential benefits with stakeholders such as fisheries and tourism. This will be essential to support the choice of aquaculture activities within an MPA.

Environment Impact Assessment (EIA) can be required by national authorities. The European Commission is proposing a flow chart step-by-step procedure to conduct an Appropriate Assessment (AA) to assess the implication of the aquaculture project in respect of the Natura 2000 site's conservation objectives (European Commission, 2012). Depending on each MPA case and specific related issues, special requirements for targeted impacts may be needed. Once in place, continuous monitoring of practices and maintenance of the validated production objectives are essential to avoid deviation. The difficulty in assessing good practice leads to questioning the potential requirement of existing aquaculture standards (Fezzardi et al., 2013; IUCN, 2009b). In MPAs, aquaculture should be developed on the basis of best practices. Those good practices may be recognized and controlled through a certification process. However, existing standards such as organic or ASC (Aquaculture Stewardship Council), may not address the objectives of an MPA, though they may address some nature conservation issues (Pelletier & Tyedmers, 2007). New certification standards could be created ("certified MPA-friendly") but this may lead to an uncertain and time-consuming process. The relevance and validity of such a certification standard for all cases would be questionable considering the diversities of MPAs and aquaculture. Moreover, the use of certification standards may even actually create a gap between emerging and wealthy industrial country situations. Indeed, most of the current western created standards (e.g. ASC) are impossible to apply for local small incomes communities (Jonell, Phillips, Rönnbäck, & Troell, 2013). In this sense, clarifying the potential added market value for aquaculture products coming out of an MPA and the benefits from developing specific certification should be investigated further.

Impact assessment tools such as Life Cycle Analysis (LCA) or Ecological Footprint (EF) are being adapted for aquaculture activities (Hall, Delaporte, Phillips, Beveridge, & O'Keefe, 2011; Pelletier et al., 2007; Pelletier et al., 2009). However, due to the diverse and multidisciplinary nature of the environment issues and highly variable production processes, the implementations so far do not reflect the full diversity of aquaculture activities and often neglect social aspects of sustainability (Samuel-Fitwi, Wuertz, Schroeder, & Schulz, 2012). The costs and difficulty of finding the required scientific data are also limiting. This monitoring activity should be developed with aquaculture professionals to keep it operational and adapted to the realities of fish farm operations.

Key in future processes will be the quantification of either benefits or impacts on MPAs and the discussions have already raised many interesting scientific questions which offer outstanding opportunities to deepen understanding. There is a need for research concerning ecosystem services, dynamics and functions but also considering the economic impacts. The contextual approach to analysing the social impacts of aquaculture is also lacking and should be strengthened (Krause et al., 2015). Where systems are in place, such as at the Veta la Palma extensive and semi-extensive aquaculture farm, located in the Donana Natural Park, they have provided data which already resulted in more than 30 peer reviewed studies being published (Walton et al., 2015).

5. Conclusions

Undeniably, to meet Aichi's Targets of 10%, countries will need to dramatically expand the designation of MPAs, the bulk of which, on current experience, will fall into the categories of multiple-use MPAs. However, more than just a percentage, it is conservation objectives that should be reached and to do so, it will be essential that the right types of governance and management systems are in place. This is a critical issue as MPAs expand to cover greater areas of the ocean. Similarly, the aim of the aquaculture projects should also be clearly set out alongside adequate governance and management of the operations.

Understanding the relationship and options for the relationship between aquaculture and multiple-use MPAs is critical in developing opportunities for greater synergies. This in turn has the potential to develop a simple matrix of aquaculture systems vs MPAs categories to support broader discussions in both communities. However, there is a great challenge around setting rigid assumptions and rules around the MPA and aquaculture relationship. The diversity of farming methods using a wide range of technologies and species predicates against this. In most cases, approaches will anyway need to be adapted or applied according to the objectives of specific MPAs. A matrix may be useful for broader discussions but a case-by-case and stepwise approach will always need to be taken through a participatory approach, using tools appropriate to the circumstances, available data and the specific requirement of the specific MPA - with an equal consideration of ecological, social and economic issues.

Examples do exist though. They include providing alternative livelihoods for small-scale fisheries to encourage them to shift to low impact aquaculture, such as sea cucumber ranching and rope-based seaweed aquaculture. More broadly, where economic income is needed within a multiple use MPA and choices can be made, options for properly selected aquaculture site may be far more preferential and sustainable than other economic options which would involve destruction and/or permanent loss of habitats and species. However, there is a lack of tools to conduct comparative studies at the social and economical levels.

Thus, there is no simple answer to this issue of how to deliver enhanced synergies between MPAs and aquaculture. This is not a case of ‘banning’ aquaculture in multiple-use MPAs - except “badly practised aquaculture” - but what does go forward should be compatible to the conditions and local setting. Benefits and limits of the combination between MPA and aquaculture have to be further explored and investigated. Closing these gaps would have measurable benefits – creating a better understanding all around, a better vision of real impacts of aquaculture, a better understanding on the role and importance of MPAs, and above all the opportunity to develop new innovative projects and perspectives for the common good.

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List of tables

Table 1. The main types of management categories (Day et al., 2012) (noting that whilst 1A and 1B encompass what is frequently referred to as 'no take' or 'marine reserves' the other categories reflect a wider range of uses alongside conservation of nature)

IUCN CATEGORY		MAIN OBJECTIVE OR PURPOSE
IA	Strict Nature Reserve	Managed mainly for science
IB	Wilderness Area	Managed mainly to protect wilderness qualities
II	National Park	Managed mainly for ecosystem protection and recreation
III	Natural Monument	Managed mainly for conservation of specific natural/cultural features
IV	Habitat/Species Management Area	Managed mainly for conservation through management intervention
V	Protected Landscape/ Seascape	Managed mainly for landscape/seascape conservation and recreation
VI	Managed Resource Protected Area	Managed mainly for the sustainable use of natural ecosystems

Table 2. Matrix of activities that may be appropriate for each IUCN management category (Day et al., 2012).

Activities	**Ia**	**Ib**	**II**	**III**	**IV**	**V**	**VI**
Research: non-extractive	Y*	Y	Y	Y	Y	Y	Y
Non-extractive traditional use	Y*	Y	Y	Y	Y	Y	Y
Restoration/enhancement for conservation (e.g. invasive species control, coral reintroduction)	Y*	*	Y	Y	Y	Y	Y
Traditional fishing/collection in accordance with cultural tradition and use	N	Y*	Y	Y	Y	Y	Y
Non-extractive recreation (e.g. diving)	N	*	Y	Y	Y	Y	Y
Large scale high intensity tourism	N	N	Y	Y	Y	Y	Y
Shipping (except as may be unavoidable under international maritime law)	N	N	Y*	Y*	Y	Y	Y
Problem wildlife management (e.g. shark control programmes)	N	N	Y*	Y*	Y*	Y	Y
Research: extractive	N*	N*	N*	N*	Y	Y	Y
Renewable energy generation	N	N	N	N	Y	Y	Y
Restoration/enhancement for other reasons (e.g. beach replenishment, fish aggregation, artificial reefs)	N	N	N*	N*	Y	Y	Y
Fishing/collection: recreational	N	N	N	N	*	Y	Y
Fishing/collection: long term and sustainable local fishing practices	N	N	N	N	*	Y	Y
Aquaculture	**N**	**N**	**N**	**N**	*****	**Y**	**Y**
Works (e.g. harbours, ports, dredging)	N	N	N	N	*	Y	Y
Untreated waste discharge	N	N	N	N	N	Y	Y
Mining (seafloor as well as sub-seafloor)	N	N	N	N	N	Y*	Y*
Habitation	N	N*	N*	N*	N*	Y	N*

Key: N = No
N* = Generally no, unless special circumstances apply
Y = Yes
Y* = Yes because no alternative exists, but special approval is essential
* = Variable**;** depends on whether this activity can be managed in such a way that it is compatible with the MPA's objectives

Table 3. SWOT analysis of three cases of aquaculture activities within MPAs (noting that background information of these cases is presented in the brochure “Aquaculture and Marine Protected Areas: Exploring Potential Opportunities and Synergies” (IUCN, 2017a) (https://portals.iucn.org/library/sites/library/files/documents/Rep-2017-003.pdf))

Community based Aquaculture of carrageenan seaweed and sea cucumber in the Velondriake Locally Managed Marine Area, Madagascar (Blue Ventures - A. Harris)	
Strength ● Increasing market price for sea cucumbers and steady price for seaweed, ● Strong, local commercial partners and experienced NGO, ● Low running costs, low technical expertise and no feed inputs, ● Little environmental impact of farming activities ● Hatchery production: No overfishing for larvae from the wild, ● Diversification reducing local dependence on over-exploited capture fisheries, ● Greater connectedness of previously isolated villages/ financially marginalized community members,	**Weakness** ● Accessible to impoverished communities only if capital costs covered by donor funding, or through a contract farming agreement with a private partner, ● Few best practice guidelines to inform the development of the model, ● Single provider of sea-cucumber juveniles limits the bargaining power of farmers, ● Profitability not yet high enough to encourage professionalization to full-time farming,
Opportunities ● High level of interest and desire to participate in farming initiatives from other communities allows for rapid expansion in suitable habitats, ● Profitability of both models increasing yearly, ● Developing community farming associations to increase the bargaining power of farmer,	**Threat** ● Storms and cyclonic activity damaging pens and animals, ● Epidemics of a disease with little understood aetiology / epiphytic algal infestations, ● Theft and fishermen animosity, ● Negligible policy framework to guide the development of aquaculture activities and contract farming initiatives in Madagascar,

Finfish cages in Mayotte marine park (IFREMER -M. Callier)	
Strength ● MPA framework for the development of sustainable aquaculture/Marine Spatial Planning, ● Current production compatible with the specifications of organic farming (low density/no antibiotic), ● Good expertise in aquaculture, ● Sheltered lagoon cyclonic storms,	**Weakness** ● Lack of general infrastructure (roads) and specific (processing plant, cold chains), ● Low local investment capacity, ● Low number of species produced, non native selected species, ● Insecurity (installations), ● Lack of marketing strate,
Opportunities ● Stable political system, ● Growing demand for protein, ● Biodiversity: possibilities of diversification and IMTA,	**Threat** ● Urbanization and demographic change, ● Climate change, ● Cost of labor, ● Availability of shore land and competition with other coastal uses,

Aquaculture production in the archipelagos of Madeira and Canary Islands (C.Andrade - R.Haroun)	
Strength ● Studies show no significant impact of fish farms, ● Aquaculture industry reaching maturation stage with economic, social and environmental issues integrated into the business, ● Marine Reserves zonation provide an example integration of MPAs and economical activities,	**Weakness** ● Lack of public awareness of aquaculture as "clean" industry, ● Lack of knowledge and cartography of marine biocenosis in MPAs may introduce a principle of precaution excluding fish farms from MPAs,
Opportunities ● Marine Spatial Planning as a tool to integrate aquaculture activities in MPAs, ● The establishment of MSP may launch pilot projects of fish farms in marine reserves – testing farms interaction with conservation purposes, local communities, tourism attractions etc.	**Threat** ● Implementation of single purpose MPAs (conservation) or other limiting regulations during the MPS process, ● Competition of aquaculture with tourism in MPAs, ● Absence of political will to implement MSP principles,

Table 4. Possible example of a risk matrix Aquaculture systems and MPAs categories.

Categories	I	II	III	IV	V	VI
Restoration purpose aquaculture						
Medium density invertebrate (e.g. sea cucumber) culture						
Low density shellfish culture						
High density seaweed culture						
Low density pond /lagoon fish culture						
High density shellfish culture (table, long-lines						
Medium density on-land circulating system fish pond culture						
High density on-land close system fish culture						
High density fish cage culture						

Key: = No Y = Yes

= Variable**;** depends on whether this activity can be managed in such a way that it is compatible with the MPA's objectives