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Improving fisheries co-management through ecosystem-based spatial management: The Galapagos Marine Reserve

Mauricio Castrejón [a,b,*], Anthony Charles [c]

[a] Interdisciplinary PhD program, Dalhousie University, Halifax, NS, Canada B3H 4R2
[b] World Wildlife Fund-Galapagos Program, Calle Piqueros and 18 de Febrero, Santa Cruz, Galapagos, Ecuador
[c] Management Science/Environmental Science, Saint Mary's University, Halifax, NS, Canada B3H 3C3

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ABSTRACT

Ecosystem-based spatial management (EBSM) can provide a mechanism for a strategic and integrated plan-based approach to managing human activities in the marine environment. An EBSM approach was adopted in the Galapagos Marine Reserve (GMR) at the end of the 1990s with the adoption of marine zoning. The latter was created under a co-management regime to reduce conflicts among users arising over incompatible demands for ocean space, to mitigate the impact of human activities on sensitive ecological areas, and to contribute to the sustainability of Galapagos fisheries. Unfortunately, the promise of an EBSM approach in the GMR has not been matched by effectiveness in practice, in achieving the established management objectives. The aim of this paper is to evaluate the shortcomings and lessons learned related to planning, implementation, monitoring, evaluation and adaptation of the GMR's marine zoning scheme, and to provide recommendations to better realize the potential value of the EBSM approach to co-managing the shellfisheries of the GMR.

1. Introduction

A key problem with conventional approaches to fisheries management has been its focus on production from a single target species. That single-species preoccupation has made this management approach inadequate because it did not consider the impact of fishing on non-target species and marine habitats, and neglected the human factors (social, economic, cultural and institutional) that affect fisheries management [1–3]. Recognition of the significant direct and collateral impacts that fishing imposes on marine ecosystems has encouraged adoption of ecosystem-based management (EBM, also referred to as the ecosystem approach to fisheries, EAF). This integrated approach considers the entire ecosystem, including humans, and has as a main goal maintaining an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need [4,5].

Even though EBM has been recognized as a potentially powerful approach for rebuilding depleted marine fish populations and for restoring the ecosystems of which they are part [6], several challenges to its wide implementation must be addressed. One of the most important is a lack of clear, concrete and comprehensive guidelines that outline in a practical manner how EBM can be implemented in marine areas [7].

The EBM approach interacts closely with that of integrated management, which focuses on managing the multiple human uses of spatially-designated areas, and which is typically viewed as incorporating EBM as a fundamental component [8]. The idea is that since marine ecosystems are places, and human activities affecting them (fisheries, tourism, marine transport, oil and gas exploitation, etc.) occur within those places, ecosystem-based management must be inherently place-based [9]. Hence, combining ideas of ecosystem-based management and spatial management, the integrated approach of ecosystem-based spatial management, EBSM, has emerged over the last decade as a way to apply EBM in coastal and marine environments [10].

The main aim of EBSM (which in the marine context of this paper includes marine spatial planning, MSP) is to provide a mechanism for a strategic and integrated plan-based approach to manage current and potentially conflicting uses, to reduce the cumulative effects of human activities, to optimize sustainable socio-economic development and to deliver protection to biologically and ecologically sensitive marine areas [10]. This management approach has been successfully used in several marine areas of the world, with Australia's Great Barrier Reef Marine Park (GBRMP) considered a particularly successful example of its implementation [11,12].

An EBSM approach was adopted in the Galapagos Marine Reserve (GMR, Fig. 1) at the end of the 1990s. This occurred in

* Corresponding author at: Interdisciplinary PhD Program, Dalhousie University, Halifax, NS, Canada B3H 4R2. Tel.: +1 902 441 1611.
E-mail addresses: mauricio.castrejon@dal.ca, maucm@hotmail.com (M. Castrejón).

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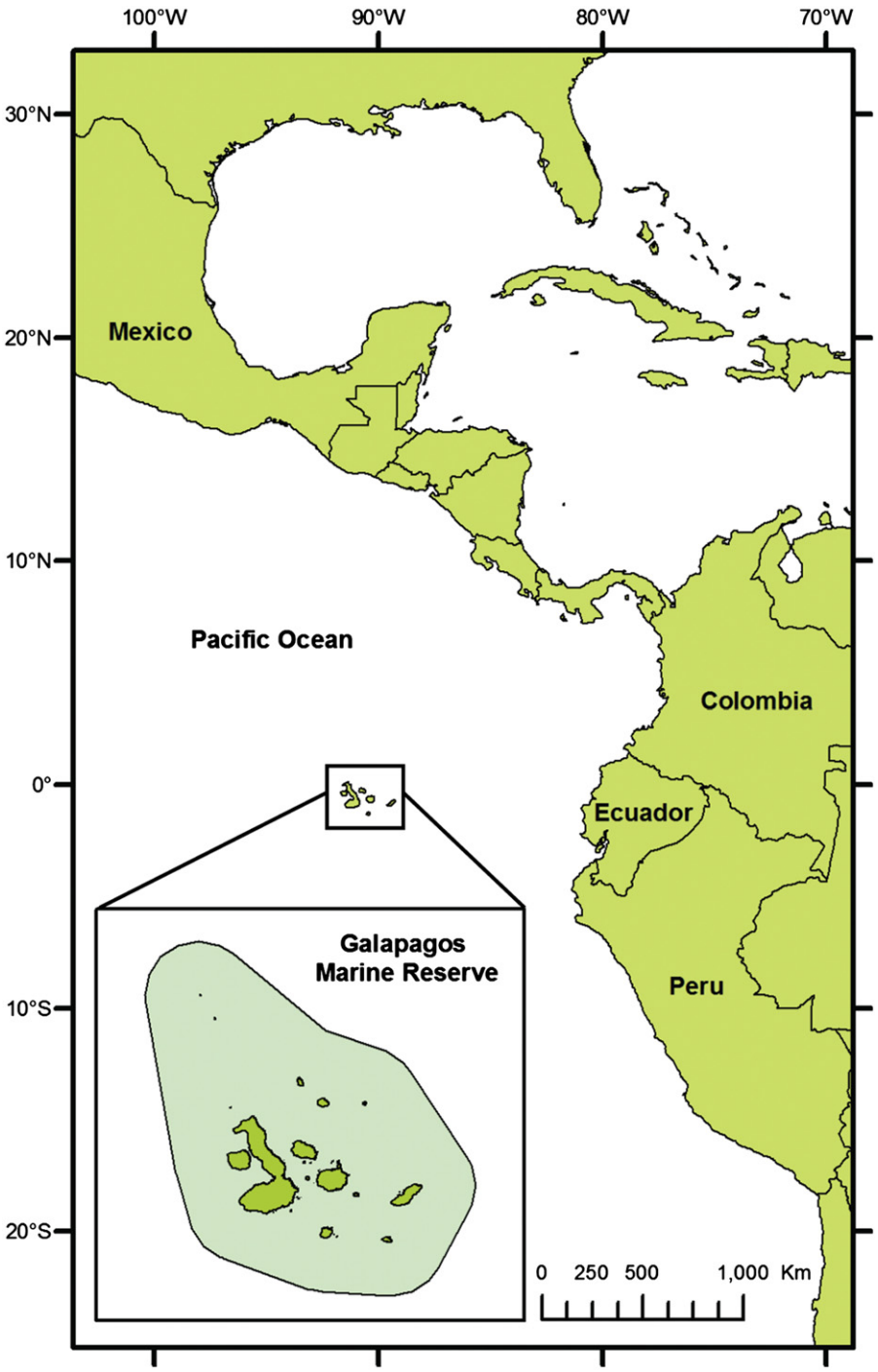

Fig. 1. Location of the Galapagos Marine Reserve.

order to deal with several ecological, socioeconomic and political challenges strongly related to the rapid growth of fishing and tourism activity in the archipelago [13,14]. The cornerstone for the application of an EBSM approach in the GMR was the adoption of marine zoning, a spatially explicit management tool that was designed, planned and implemented by a consensus-based participatory process between 1997 and 2006 [15,16].

The GMR's marine zoning was brought forward, under a co-management regime, in order to [17]: (1) contribute to the sustainability of Galapagos fisheries by providing potential areas from which fishery stocks can recover and spillover over fishing ground; (2) reduce conflicts among users as a result of incompatible demands for ocean space (e.g., tourism vs. fishing; small-scale vs. large-scale fishing); and (3) mitigate the impact of uses on sensitive ecological areas of the archipelago, which are critical to the functioning of marine ecosystems and the conservation of threatened species [18].

This paper examines the effectiveness of GMR's marine zoning approach, as an illustration of EBSM, based on a set of evaluation criteria widely seen as essential to successful marine management, including EBSM: effective planning, monitoring, implementation, evaluation and adaptation [11,12]. The paper explores the extent to which GMR's marine zoning has achieved these five basic components since its inception, and on the other hand, highlights shortcomings in implementation of EBSM that limit its potential to improve GMR's shellfisheries co-management.

Further, the paper provides a set of insights to improve the GMR's marine zoning. Such an analysis is timely to inform the first comprehensive and integrated management effectiveness evaluation of the GMR's marine zoning, which is being undertaken by the Galapagos National Park (GNP), the institution in charge of the management of the GMR, with the support of several local and international non-governmental organizations (NGOs).

The organization of this article is as follows. Section 2 provides a background on the history of the current marine zoning scheme in the GMR, and its impact on the co-management of shellfisheries. Section 3 examines the shortcomings and lessons learned related to the GMR's marine zoning, while Section 4 provides recommendations to improve its performance. Section 5 presents the main conclusions.

2. History of marine zoning in the Galapagos Marine Reserve

2.1. Creating a legal framework

The Galapagos Archipelago is recognized worldwide by its particular oceanographic and geological features, which influenced the origin of unique terrestrial and marine ecosystems that include a high biological endemism. The unique biodiversity of this place inspired the naturalist Charles Darwin to conceive his famed Theory of Evolution by Natural Selection following his visit to the archipelago in 1835, and was responsible for the designation of the Galapagos Islands as a World Heritage site by UNESCO in 1978.

Management of coastal and marine resources of this unique place faced several socioeconomic and political challenges in the mid1990s [13]. The most significant of these were overcapitalization of the small scale artisanal fishing fleet driven by the rapid development and expansion of the sea cucumber fishery, and exponential growth of tourism activity in the archipelago [14]. Both stimulated new sources of economic development which attracted an increasing number of immigrants from mainland Ecuador. As a result, the total human population of Galapagos increased dramatically, rising from 1346 to 18,640 individuals between 1950 and 2001 [19]. The above factors increased pressure on access and use of the Galapagos marine resources, and on demand for coastal space, as well as increasing the demand for raw material imported from the mainland, thereby increasing the risk of arrival of invasive species to the most pristine areas of Galapagos [20].

Increasing social conflicts and ecological degradation led to adoption of the Galapagos Special Law (GSL) and the Galapagos Marine Reserve Management Plan (GMRMP) in March 1998 and April 1999, respectively [21]. According to the GMRMP, the main management objective is "*protect and conserve the coastal and marine ecosystems of the archipelago and its biological diversity for the benefit of humanity, the local population, science and education*" [17].

The Galapagos archipelago and its surrounding open ocean were designated as a multiple use marine reserve of nearly 138,000 km^2 (Fig. 1) with an extension of its boundaries 40 miles offshore from the "baseline" (i.e., an imaginary line joining the outer islands of the archipelago). However, the most important measure was an institutional shift from a centralized top-down to a co-management approach, coupled with the prohibition of industrial fishing inside the GMR, allocation of exclusive use rights to local fishers, in the form of licenses and fishing permits, and adoption of a spatial EBM-oriented approach [14]. [The term EBSM is not used or explicitly defined in the GSL and GMRMP, but the general and specific management objectives and principles established for management of the GMR [17] are compatible with the definitions provided by McLeod et al. [4] and Douvere and Ehler [10].

In addition, the GSL and the GMRMP provided the legal framework for the institutionalization of two nested decision-making bodies: the Participatory Management Board (PMB) and the Institutional Management Authority (IMA). Both decision-making bodies were used by local stakeholders and GNP's authorities to initiate and institutionalize a consensus-based participatory process to zoning the GMR [21]. This spatially-explicit management tool facilitated the adoption in practice, for the first time, of an EBSM approach.

2.2. Planning phase

The GMR's marine zoning planning phase was undertaken between June 1997 and April 2000. The specific aims were to reduce conflicting uses generated by human activities (e.g., tourism vs. fishing) that coexisted in the same geographical zones; to conserve and protect biodiversity; to ensure the sustainability of economic activities in the RMG; and to enforce the management principles and objectives set up in GSL and GMRMP [17]. The process involved can be subdivided in two main stages, based on the descriptions provided jointly by SPNG [17], Heylings et al. [15], and Edgar et al. [22].

The first stage involved institutionalization of a general zoning provision agreement (June 1997–April 1999). The objectives, zone categories and regulations of the GMR's zoning were generated and agreed upon by a "core group", composed of local stakeholders and GNP representatives, during the planning phase of the GMRMP. As a key element of this, the GMR was divided in three main zones: (1) multiple use zone, (2) limited use zone, and (3) port zone.

The multiple use zone includes deep waters (>300 m) located inside and outside the GMR's boundaries; all human activities permitted by the GNP can be undertaken (fishing, tourism, scientific research, navigation and surveillance manoeuvres).

The limited use zone embraces the coastal waters (<300 m) that surround each island, islet or protruding rock. This zone was divided in four subzones:

- Comparison and protection (conservation subzone).
- Conservation and non-extractive use (tourism subzone).
- Conservation, extractive and non-extractive (fishing subzone).
- Areas of special temporary management (ASTM).

The first three of these, the conservation, tourism and fishing subzones, have regulations associated with them as follows:

- Scientific research is permitted in all subzones (tourism, fishing, and conservation).
- Diving, cruise ships, sailing, kayaking, snorkelling, surfing, and swimming are only permitted in the tourism subzone.
- The various fishing activities – handline, pole and line, mesh netting, hooka diving, and trolling – are only permitted in the fishing subzone.

The fourth subzone, the ASTM, can be implemented within any of the other subzones and includes special areas conceived to implement experimental management schemes in the future (e.g., seasonal closures), or to allow the recovering of species and marine habitats that have been severely affected by human activities (overexploitation, oil spill, etc.) or by extreme environmental conditions (e.g., El Niño).

However, the "core group" did not reach a consensus about the boundaries and distribution of the limited use subzones (i.e.,

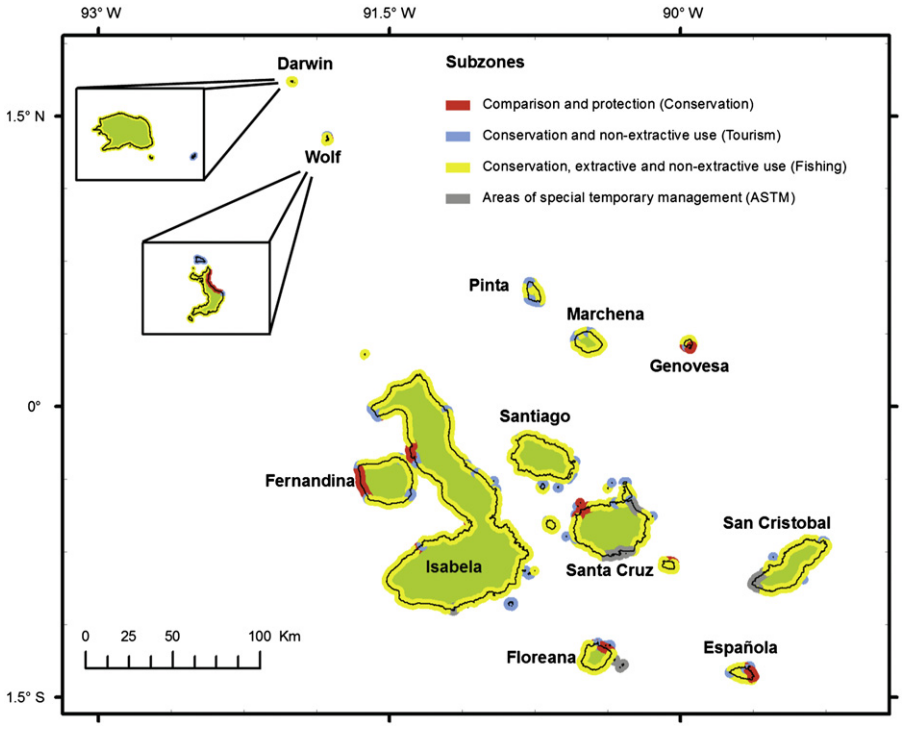

Fig. 2. Marine zoning of the Galapagos Marine Reserve (limited use zone).

conservation, tourism and fishing subzones). The resolution of the no-consensus points was postponed and, instead, a process to create a "provisional coastal zoning (PCZ)" was agreed upon [15]. As a result, the GMRMP was approved in April 1999 without including a complete and integrated zoning scheme.

The second stage of the process involved development and consensus on the above "provisional coastal zoning" (April 1999–April 2000). A "zoning group" was formed of representatives of the national park, local small-scale fishers, tourism operators and NGOs, and developed a proposal, which was reviewed and approved by PMB in April 2000.

Each stakeholder group negotiated based on their particular interest, with the goal being to minimize the short term impact of zoning over their own economic activities. Specifically, with regard to the key issue of establishing no-take zones, each resource harvesting group sought to avoid placing these in areas with high densities of the most valuable species for their corresponding sector. According to Edgar et al. [22], sea cucumber fishers argued for having no-take zones only in those areas with low densities of sea cucumbers. On the other hand, tourism operators promoted no-take areas specifically for those areas with high concentrations of large pelagic species, such as hammer-head and white-tip sharks, which are valuable species for scuba diving tourism. Finally, NGOs did not line up with any of these human use sectors, instead arguing for the protection of a range of sites of different sizes and at various distances apart, representative of different habitats in each of the five bioregions recognized by Harris [23]. Overall, this mix of objectives led to a negotiated geographic distribution of no-take zones within the GMR [22].

The final stages in reaching consensus on the zoning utilized "*an innovative method for conflict management, which was strongly based on incentive and pressure strategies*" ([15], p. 16), which were aiming to link directly the final PCZ proposal to the management of the GMR's fisheries [15]. In other words, decisions on all measures to regulate the area's fisheries in 2000 were conditioned on the achievement of a zoning agreement. Even more important as an incentive for adoption of the zoning was the agreement to develop an "action plan" to provide alternative livelihoods to the fishing sector in order to "compensate" them for the short-term impacts of the zoning [15]. These included the promise to allocate commercial diving and sport fishing licenses to those fishers that wanted to leave commercial fishing and become tourist operators.

The zoning arrangement was finally approved by "consensus" in 2000. It includes 130 management zones, comprising 14 separate conservation zones, 62 tourism zones, 45 fishing zones and 9 mixed management zones ([22]; see Fig. 2). Conservation and tourism zones (i.e., no-take zones) encompass 18% of the Galapagos coastline [15]. Each individual zone ranges in size from small offshore islets to a 70 km span of coast [22]. However, no offshore boundaries were established. As a result, the total marine area per zone was not legally agreed on.

2.3. Implementation phase

The co-management system faced several conflicts after the zoning was approved, most related to management of the sea cucumber fishery and to development of the legal framework necessary to implement the principles and rules established in the GSL and GMRMP [14]. As a consequence, the physical demarcation of the zoning was delayed by six years. During that period, enforcement was weak as the GNP lacked adequate control and surveillance infrastructures, and some fishers were unaware of the zoning boundaries [24]. As a result, the GNP decided to focus on preventing illegal harvesting of tuna and sharks by large-scale fleets from mainland Ecuador, and to combat local illegal fishing during sea cucumber and spiny lobster fishing seasons [25]. Despite those efforts, several infractions occurred, most related to illegal fishing of sea cucumber in no-take zones [24].

The zoning system was physically demarcated in September 2006, but despite this, illegal fishing in no-take zones continues to occur [26]. Nevertheless, the adoption of a vehicle monitoring system (VMS), jointly with the improvement of surveillance and

sanction capacity, has contributed successfully to reduce illegal harvesting by large-scale fleets, which frequently attempt to harvest tuna and shark species inside the boundaries of the GMR (M. Villalta, Galapagos National Park, Ecuador; personal communication).

2.4. Monitoring phase

Before the physical demarcation of the GMR's marine zoning, the Charles Darwin Foundation (CDF), a locally-based international NGO that provides scientific advice to the GNP and PMB, conducted a broad-scale subtidal independent survey in 2000–2001 [22]. Its main aims were to define the ecological baseline of each management zone before the physical demarcation of the GMR's zoning, and to clarify broad-scale marine biogeographical patterns across Galapagos [27].

Three main results were obtained by Edgar et al. [22]: (1) the mean sea cucumber density in the western sector of Galapagos, the most productive sector of this species, was three times higher in zones open to fishing (14 ± 4.2 ind $100\,m^{-2}$) in comparison with conservation zones (42.2 ± 10.9 ind $100\,m^{-2}$); (2) the mean density of spiny lobster and Galapagos grouper was not different between management zones; (3) the mean shark density was five times higher in tourism zones in comparison with conservation and fishing zones. These results reflected the bias associated with the selection and distribution of no-take zones within GMR [22]; i.e., that the compromises inherent in their selection led to their having low intrinsic densities of sea cucumbers and high densities of large pelagics.

These human dimensions were dominant in the actual selection of no-take zones, rather than more ecologically-oriented aspects. For example, Edgar et al. [27] showed that Galapagos coastal waters were best divided into five marine bioregions referred to as far-northern, northern, south-eastern, western and Elizabeth—the latter being a bioregion located in the western part of Isabela Island, whose proportion of endemic species is anomalously high. As a result, these authors argue for a higher level of protection of the far-northern and Elizabeth bioregions, which are not properly represented and conserved by the current GMR's zoning design.

While such aspects were not built into the current marine zoning design (and would need to be better incorporated in any future adaptation of the design), the results obtained by Edgar et al. [27] were used by the zoning commission, jointly with the GMR's approved zoning design and the advice of external consultants, to develop a long term ecological subtidal monitoring program (ESMP). This program was designed to evaluate spatial and temporal patterns of change in coastal marine ecosystems across the different bio-geographic regions in the GMR, before and after zoning implementation, and in relation to oceanographic, climate and human impacts [28].

In October 2004, the PMB reviewed and approved the ESMP proposal. The responsibility to manage the ESMP was given to the CDF. Since then, CDF scientists have compiled a unique 12-year bio-physical dataset to support an assessment of the management effectiveness of the zoning. The ESMP is mostly funded by international aid agencies and NGOs.

In addition to the ESMP, the CDF and the GNP have managed the Participatory Program of Fisheries Monitoring and Research (PIMPP) since 1997. The latter marked the beginning of the systematic collection of fishery-related data in Galapagos [14]. The PIMPP was the most important monitoring program between 1997 and 2006, particularly during the expansive phase of the sea cucumber fishery (1999–2002). However, over the past 50 years, the CDF has also compiled large amounts of other oceanographic, ecological and biological data about Galapagos marine habitats and native and endemic species. In recent years, most monitoring efforts have focused on the project-basis collection of socio-economic and governance data, in particular to evaluate performance of the co-management system [21], the socioeconomic impact of tourism [29], and the potential impact of climate change on Galapagos [30].

2.5. Evaluation and adaptation phase

According to the GMRMP, the zoning system was to be adapted and made "permanent" two years after its declaration, based on the results of an assessment of management effectiveness [17]. The latter had to include an evaluation of the initial ecological and socio-economic effects of the zoning. However, there is not yet a comprehensive, integrated, peer-reviewed quantitative analysis of marine zoning effectiveness nor of application of the EBSM principles in the GMR. As a consequence, the marine zoning scheme has not been formally adapted. Furthermore, decision-makers have not received regular and conclusive feedback about the ecological and socioeconomic impacts of the EBSM over Galapagos marine ecosystems and over the range of activities affecting it.

Despite this lack of comprehensive assessment, there is some evidence, both positive and negative, concerning the performance of marine zoning in the Galapagos. First, for the particular case of shellfish fisheries, recent studies suggest that marine zoning, in conjunction with the establishment of a co-management system, have not been effective in preventing overexploitation of the sea cucumber and the spiny lobster fisheries [31,14]. Both management measures have not been enough to eliminate the fishers' incentive to compete with each other for a bigger proportion of the total allowable catch (TAC) each fishing season. Such behavior, known worldwide as a "race for the fish", has encouraged over-capitalization as fisherman seek to increase their competitiveness through investment in more substantial and faster vessels, and high technology fishing equipment. The resulting intense search for short-term profit, combined with a lack of social and institutional mechanisms for resource stewardship, has compromised the long-term recovery of fishery stocks. This is indeed a situation in which the "tragedy of the commons" [32] seems to apply.

As sea cucumber and spiny lobster stocks have declined over the last decade, the race for fish has intensified resulting in more illegal fishing and more restrictive management measures, such as the reduction of TAC and fishing season length. This has led fishers to work within an increasingly competitive environment, encouraging risk seeking behaviors, and creating dangerous work conditions. For example, the decline in spiny lobster abundance in the shallow waters around Galapagos has encouraged fishers to dive at night, deeper and for longer periods in order to sustain or increase their catch rates. As a result, the number of fishers with decompression sickness has increased during the last decade [14].

In contrast to the above negative outcomes, a preliminary study suggests partial benefits associated with marine zoning in the Galapagos. According to [33], the proportion of larger individuals of groupers (*Mycteroperca olfax*), endemic sea basses (*Paralabrax albomaculatus*) and Galapagos grunts (*Orthoprostis forbesi*) is significantly higher in no-take zones in comparison with fishing zones. This trend has been observed in particular areas where the level of protection from fishing is higher, whether due to high levels of tourism and/or such areas being near to the enforcement authority's outposts [33].

3. Concerns arising with marine zoning in the Galapagos

The marine zoning scheme represents undoubtedly the best effort undertaken to date to manage the GMR through an EBSM

approach. However, application of EBSM in the GMR, through marine zoning, has been severely limited by lack of effective enforcement and a high rate of non-compliance by fishers, who consider fisheries management measures, including no-take zones, as illegitimate [34]. As noted above, the most important shellfisheries of the GMR, the sea cucumber fishery (*Isostichopus fuscus*) and the spiny lobster fisheries (*Panulirus penicillatus* and *P. gracilis*), show signs of overexploitation [31]. The steady expansion of tourism activity in the archipelago, jointly with the carrying out of illegal sport-fishing operations, are generating new conflicts between local tourism and fishing sectors (E. Naula and M. Casafont, Galapagos National Park, Galapagos, Ecuador; personal communication). Furthermore, a recent study shows that the current GMR's marine zoning design is not providing enough protection to several threatened species and key biodiversity areas [18].

These problems with EBSM have contributed to a lack of credibility and legitimacy concerning what could be potentially a valuable tool to co-manage the GMR's fisheries. In this section, such problems are examined from the perspective of the five basic components essential to successful marine management, including EBSM, as outlined earlier in the paper: effective planning, monitoring, implementation, evaluation and adaptation.

3.1. Planning issues

3.1.1. Short-term approach

The GMR's marine zoning system was created without a strategic and integrated long-term plan-based approach. It is clear that the consensus-based approach used during the planning phase focused mainly on determining no-take zones without considering the "bigger picture" needed to adopt an EBSM in a marine protected area (MPA: [35]). As a consequence, the zoning only impacted the places where fishing (and tourism) can take place, not the inappropriate incentives and the institutional failures that lead to fisheries overexploitation. The latter problem areas include reactive governance with a short term vision, inappropriate allocation of use rights (licenses and fishing permits), excessive fishing capacity, limitations in monitoring, control and surveillance, and weaknesses in the organization and social cohesion of the local fishers' organizations [31,14].

3.1.2. Excessive focus on no-take zones

The zoning system has been considered in Galapagos as synonymous with no-take zones. This represents a serious misconception about EBSM, also present in other parts of the world [36]. It is necessary to highlight that no-take zones represent only one type of MPA, and only one of many management tools available for the successful implementation of EBSM in the marine environment, such as territorial user rights for fisheries (TURFs), seasonal closures, spatial gear restrictions, etc. [6]. Thus no-take zones need to be evaluated and compared to viable alternative management tools, and used, where appropriate, as one element in a broader package of measures [37].

3.1.3. Unexpected incentives

The "innovative" incentive-pressure strategy described and used by Heylings et al. [15] to encourage consensus on zoning, contributed in reality to the generation of perverse incentives and to the loss of credibility and legitimacy for zoning, especially among grassroots fishers. As described in Section 2.2, this strategy produced a final zoning consensus when the PMB declared that all management measures required to regulate the GMR's fisheries during 2000 would be implemented only if there was a zoning consensus (the 'pressure' component of the strategy). Furthermore, the PMB agreed to develop an "action plan" to provide alternative livelihoods to the fishing sector in order to "compensate" them for the short-term impacts of the zoning (the 'incentive' component).

The fishing sector's representatives signed the agreement for implementation of zoning expecting that the Ecuadorian Government (represented by the GNP) and NGOs would produce alternative livelihoods for the entire fishing sector, which in 2000 included a total of 1229 fishers as registered by GNP [14]. The zoning agreement could be considered a win–win situation for fishers for two reasons: (1) most no-take zones were declared outside the main sea cucumber fishing grounds [22], the most valuable and abundant fishery resource of the GMR at that time, so it is quite probable that the short-term economic impact of the zoning on the fishing sector was low, particularly given that enforcement was weak [24]; and (2) the GNP and NGOs agreed to make a "compensation payment" to fishers, in the form of new "alternatives", for 18% of "their" fishing grounds becoming no-take zones. However, an unexpected result happened, in that the incentive-pressure strategy encouraged non-fishery individuals, mainly from mainland Ecuador, to obtain fishing licenses, in order to get access to the sea cucumber fishery (legally opened in 1999), as well as the alternative livelihoods that were promised. This contributed to the exponential growth of the fishing sector, which increased between 1999 and 2000 from 795 to a historic maximum of 1229 fishers [14]. This trend intensified the 'race for the fish', which eliminated any incentive to conserve sea cucumber and spiny lobster fisheries. In other words, fishers were not encouraged to conserve fishery resources in the long term because, in the end, all fishing license holders, including those not dependent on fishing for their livelihoods, were to be compensated with "alternatives".

A few years after approval of the zoning system, conflicts abounded in the management of sea cucumber, as most fishers felt "cheated" in that expected "alternatives" were not implemented as quickly as they expected. As a result, the credibility and legitimacy of the zoning (and the GNP and NGOs themselves) declined severely between 1999 and 2001 [38]. Currently, such lack of legitimacy has a strong impact on fishers' decision to comply with the regulations, particularly with no-take zones [34].

3.1.4. Lack of attention to threatened species

The design of the zoning system is not offering enough protection to all threatened species of Galapagos. Edgar et al. [18] point out that of the 38 inshore key biodiversity areas (KBA) recently identified in Galapagos, 27 currently possess protection from fishing. Such areas occupy 8.5% of the coastline (142 km). The remaining 11 KBAs are located inside fishing zones (7) and multi-use zones (4). These authors argue for the implementation of no-take zones in certain zones, located in Isabela and San Cristobal Islands, which possess threatened species of macroalgaes and gastropods not found in any other site of the archipelago. According to Edgar et al. [18], all KBA's could be protected by converting only 1.9% of the current total fishing area in no-take zones.

3.1.5. Lack of attention to spatial structure

The spatial structure of sea cucumber and spiny lobster stocks in the archipelago was not considered in GMR's zoning design. Several studies have shown, in a descriptive manner, that the distribution of sea cucumber and spiny lobster in the GMR is spatially heterogeneous, as is the allocation of fishing effort [39,40]. Nevertheless, no study has attempted to measure and model the spatial dynamics of shellfish stocks and of the fishing fleet. As a consequence, such spatial patterns have been ignored during the design of management strategies. Such information is

fundamental to understanding the population dynamics and distribution patterns of these species (which do not fit the classic models developed for conventional stock assessments) and to evaluating the applicability of spatially explicit management measures (TURFs, seasonal closures, spatial gear restrictions, etc.) in order to reduce overexploitation risks.

3.2. Implementation issues

In addition to previously-noted issues over enforcement of regulations, there are also very specific operational concerns. For example, physical boundaries in the zoning scheme are inadequate to demarcate the offshore boundaries of each subzone—especially at night when most fishing activity takes place. There is a need for a new system of boundary demarcation based on coordinates of latitude and longitude, to simplify boundary description, as has been implemented in the Great Barrier Reef Marine Park (GBRMP) of Australia [11]. The latter interfaces zoning boundaries with modern navigating devices, such as Global Positioning Systems (GPS), and contributes to improve public understanding, enforcement and compliance in the GBRMP.

Concerns have also arisen with the original names assigned to each subzone, which proved complicated, confusing and difficult to remember. In fact, the names have been already changed by stakeholders. For example, fishers refer to the conservation, extractive and non-extractive use subzone as the "Fishing zone", while tourism operators refer to the conservation and non-extractive use subzone as the "Tourism zone".

3.3. Monitoring and evaluation issues

A large amount of spatially-explicit ecological and fishery related-data has been collected over the last 13 years, but such information has never been integrated and analyzed in a comprehensive way. Indeed, integrated and interdisciplinary studies have been relatively rare in Galapagos, representing only 8% of scientific references published between 1535 and 2007 [41]. Accordingly, there is a need for comprehensive evaluation, integration and coordination to produce suitable spatial planning information.

Furthermore, most research has focused on the baseline assessment and ongoing monitoring of biological and oceanographic aspects of the zoning with little attention to the "people side". For example, in contrast to the large amounts of temporal and spatial information on the abundance and distribution of target and non-target species that has been collected on a regular basis during the last decade, little information has been collected on such topics as local fishery knowledge, perceptions about management regulations, market and non-market values of ecosystem services, and historical and current resource use patterns. It is important to recognize that not only fishery management but also the planning, implementing and managing of MPAs require taking into consideration the human dimensions (social, economic and institutional) that affect the outcomes of implementation [35].

3.4. Adaptation issues

Adaptive management has been institutionalized as a management principle in the Galapagos legal framework (i.e., GSL and GMRMP), but it has not been properly implemented. For example, the GMRMP indicates that the zoning system would be adapted and made "permanent" after a two-year period time after declaration, based on the results of an assessment of management effectiveness [17]. However, it did not provide clear guidelines about how to take into account new information or shifting conditions, so adaptation (amendment) of the system (and indeed the GMRMP) has never occurred since inception.

Indeed, the terms "provisional" and "permanent" used in the GMRMP are in opposition to the adaptive management concept. In particular, use of the term "permanent" has created a serious misinterpretation about the foundations of adaptive management, which could result in future resistance by stakeholders (or decision-makers) to adaptation of the zoning design.

4. Toward effective zoning in the Galapagos Marine Reserve

The lessons learned through the identification and analyses of issues in the previous section are fundamental to adapt and improve the zoning system in the GMR. This section provides some paths to the future, drawing on lessons learned from the GBRMP [42,11], as well as from the recommendations and guidelines provided by Hilborn et al. [37]; Wilen [43]; Gilliland and Laffoley [44]; Charles and Wilson [35]; and Douvere and Ehler [10].

4.1. Effective planning

The most important step to improve the GMR's zoning is adopting a strategic and integrated long-term plan-based approach, which considers the "bigger picture" needed to adopt an EBSM for GMR's fisheries management. The process followed in Australia's GBRMP to establish a large, comprehensive, and representative network of no-take areas within a broader spatial management framework, represents a successful example of the practical adoption of an EBSM to manage a multiple-use marine reserve. According to Fernandes et al. [42], the key success factors that were central to review and adapt the GBRMP zoning were: focusing initial communication on the problems to be addressed; applying the precautionary principle; using independent experts; facilitating input to decision making; conducting extensive and participatory consultation; having an existing marine park that encompassed much of the ecosystem; having legislative power under federal law; developing high-level support; ensuring agency priority and ownership; and being able to address the issue of displaced fishers. These factors of success should be carefully evaluated in the context of Galapagos and used, if appropriate, to evaluate and to adapt the GMR's zoning.

4.2. Appropriate no-take zones

The reality that no-take zones represent only one of multiple management tools available for the successful implementation of EBSM must be emphasized. A portfolio approach, based on a judicious combination of management tools, provides a more robust approach to resource governance [45]. Indeed, a recent integrated assessment of the status, trends, and solutions in marine fisheries worldwide found that a combination of traditional approaches (catch quotas, community-based management) coupled with strategically placed fishing closures, more selective fishing gear, ocean zoning, and economic incentives is the best potential solution to restore marine fisheries and ecosystems [6].

Furthermore, having seen in Galapagos that zoning is a useless management tool if it is not appropriately enforced, it is worthwhile to adopt the insight of Hilborn et al. [37] that no-take zones (or marine reserves) must be evaluated previous to their implementation in the context of: (1) clear management objectives, (2) the social and institutional ability to maintain and enforce the closures, (3) existing management actions that no-take areas could complement under certain conditions; and (4) the capacity to monitor and evaluate success.

4.3. Suitable incentives

The incentive-pressure strategy (*sensu* Heylings et al., [15]) to encourage consensus on zoning should not be used again during the adaptation phase of the GMR's zoning. It is clear that such a strategy generated perverse incentives that led to the loss of credibility and legitimacy in the zoning. Instead, it is necessary to establish new mechanisms to realign economic incentives with resource conservation. This critical component of successful rebuilding efforts for fisheries [6] focuses on what is referred to variously as fishing rights, tenure, or dedicated access privileges [45–47]. Which form of fishing rights fits which type of fishery is a complex matter [45], depending on the frequent pre-existence of fishing rights, on the species involved, on the history of the fishery, and many other factors. However, when chosen well, these have effectively eliminated the race for the fish in many fisheries around the world—whether through TURFs, individual quotas (catch shares), rotation of fishing grounds or other means [31,48,49].

For example, the exclusive allocation of TURFs to small-scale fisher communities in Chile has generated a sense of exclusive use and ownership among fishers. This has resulted in [31,50]: (1) a co-management success with long-term effects in the economic welfare of fishers; (2) the strengthening of fishers' organizations, which led to the implementation, by fishers themselves, of effective monitoring, control and surveillance procedures, and (3) the accomplishment of objectives for management and conservation. In addition, TURFs have proved to be useful as experimentation tools to refine stock assessment and management procedures. Furthermore, recent studies have shown that, under certain conditions, strategically sited MPAs can be an effective complement to TURFs, increasing abundance and fishery profits [51].

4.4. The "people" side of EBM and MPAs

Attention must be paid in equal terms to the biological, oceanographic and human dimensions related to the planning, monitoring, implementing and managing of the GMR's zoning. The importance of people-oriented aspects has been highlighted with regard to ecosystem-based management, notably in regard to fisheries [5] and to MPA creation and implementation (or adaptation), to improve acceptance and ultimate performance of MPAs [35]. The latter authors suggest ten key "human dimensions" considerations for MPAs: objectives and attitudes, "entry points" for introducing MPAs, attachment to place, meaningful participation, effective governance, the "people side" of knowledge, the role of rights, concerns about displacement, MPA costs and benefits, and the bigger picture around MPAs. Such people-oriented factors should be evaluated in the Galapagos context and taken into account during the evaluation and adaptation phase of the GMR's zoning.

4.5. Spatial dynamics

The spatial dynamics of fishery resources (notably the key sea cucumber and spiny lobster stocks) and of the fishing fleet must be measured and modeled to assess the applicability of spatially-explicit management measures (TURFs, seasonal closures, spatial gear restrictions, etc.) in order to reduce overexploitation risks. Consider, for example, the case of broadcast spawners, such as sea cucumbers, which – as for many sedentary species – require high density concentrations in order to reproduce successfully. Such high-density patches are the first to be targeted by fishers in a fishery regulated by catch or effort limits [37], making management measures such as total allowable catch (TAC) inappropriate in the fisheries for these species. In this case, a spatially explicit management tool, such as seasonal closures, could be more effective than a TAC (e.g., to protect sea cucumber juveniles). On the other hand, caution is needed with spatial measures such as no-take zones since changes in the distribution of fishing effort could lead to overfishing of the stocks located outside the zone [37,52]—it is thus necessary to evaluate the impact of zoning on fleet distribution.

4.6. Better monitoring

Current monitoring programs must be evaluated, adapted, and coordinated with the goal of producing needed spatial planning information, integrating the collection of socioeconomic data on a regular and strategic basis. According to Day [11], the establishment of a robust monitoring system to evaluate the effectiveness of marine spatial management plans requires a major institutional reorientation at the policy level. In the case of Galapagos, it will require a major adaptation of the GMRMP, including as a priority the allocation of suitably long-term governmental funding to ensure the continuity and efficiency of the monitoring programs.

Also important are efforts to better utilize existing data (biophysical, socioeconomic and fishery data) in order to extract the maximum value from them [44]. Furthermore, the above-noted monitoring capability of VMS together with the recent implementation of an Automatic Identification System (AIS) for the entire local fishing fleet, provides an unique opportunity to better understand the spatial behaviour of fishers, and thereby to predict how this behaviour interacts with spatial population processes to determine the character of exploited meta-populations; and to understand the implications of policy options ranging from no-take zones to TURFs [43].

4.7. Evaluation of management effectiveness

Such an evaluation of the GMR will facilitate adaptation of the marine zoning scheme, taking into consideration the scientific information available, the local fishery knowledge and the lessons learned as outlined above. Recent guidelines have been published in relation to evaluation of management effectiveness of MPAs [11,44], to the practical adoption and application of the ecosystem approach to fisheries (EAF) taking into account its human dimensions [3], and to undertaking marine spatial planning (MSP) on a step-by-step basis [53]. The latter guidelines, which are largely based on analysis of MSP initiatives around the world, including the GBRMP, lead to a comprehensive spatial management plan for a marine area or ecosystem. This plan is implemented through a zoning map and/or a permit system, the latter based on the zoning maps and the comprehensive spatial plan [53]. One important aspect of this guideline is an explicit recognition that other management measures besides zoning (e.g., seasonal closures, TURFs, limitation of fishing effort, etc.) are needed to manage the diversity of human activities that take place on MPAs.

5. Discussion

Implementation of marine zoning in the GMR represents an important step forward, but to date it has not adequately provided the mechanisms to address the roots of fisheries management failures that led to the overexploitation of the main shellfisheries of the GMR. Several institutional and socioeconomic challenges must be overcome in order to successfully adopt the recommendations described in the previous section.

5.1. Credibility and legitimacy

One of the most important challenges to meet is to re-establish the credibility and legitimacy of the GMR's marine zoning. To accomplish this objective it will be fundamental to engage stakeholders in the re-zoning process, through extensive and participatory consultation. The latter was identified by Fernandes et al. [42] as a key factor for the successful review of Australia's GBRMP zoning.

As a first step, participants in the decision-making bodies formed earlier – PMB and IMA – need to agree upon and support the process that is being implemented by GNP's authorities to evaluate for the first time the management effectiveness of the GMR, as well as the adaptation process that will be followed to fine-tune the GMR's zoning design. This will contribute to a more efficient use of the economic and human resources locally available.

However, an even more important step will be to engage GMR's grassroots fishers, a difficult task due to a lack of social cohesion, leadership and representativeness of fishers' organizations (i.e., co-ops). This problems are illustrated by Avendaño's [54] results showing that 51.4% of the 262 members of COPROPAG (one of the major co-ops of the GMR) believes the main problem facing their cooperative is a lack of unity, followed by bad leadership (14.6%), lack of economic capital (12.9%), and lack of organization (5.8%). Consequently, most grassroots fishers do not trust their leaders, most not being considered legitimate representatives of fishers' interests [21]. For this reason, many decisions taken by the PMB and IMA are not considered legitimate by grassroots fishers. To overcome this problem, extensive and participatory consultation is needed beyond the boundaries of the PMB. Such a process could be adapted from that described by Fernandes et al. [42], and include not only those in the small-scale fisheries sector but also tour operators, naturalist guides, conservationist, researchers, representatives of local governments and the general public. This will contribute credibility and legitimacy to the evaluation and adaptation processes of the GMR's zoning and, at the same time, will provide voice to several members of local communities whose interests are not currently represented in the PMB, but who have influence or are influenced by the decisions taken concerning management of the GMR.

5.2. The co-management system

Another institutional challenge to face is the uncertainty about the future role of the Galapagos' co-management system, caused by recent changes in Ecuador's legal framework, which could discourage and delegitimize the participation of stakeholders in the re-zoning process. Ecuador approved a new constitution by referendum in September 2008, which resulted in fundamental changes to the Galapagos' government structure.

According to article 258 of the new constitution, the province of Galapagos will be managed by a Government Council, to replace IMA as the main manager of the Galapagos province. However, the functions and the relationship of the Government Council to the GNP (the main manager of the GMR) and the PMB have not been approved and specified yet in the corresponding legal framework (i.e., Galapagos Special Law). Thus, the future role of the Galapagos co-management system is uncertain, and will be known only at the end of the reform process of the Galapagos Special Law, which began in 2009 and is expected to conclude at the end of 2012.

Unfortunately, the failure of the GMR's marine zoning and its co-management system has disappointed many fishers and decision-makers, as well as those scientists and conservationists who strongly promoted co-management in Galapagos to this point. As a result, the Ecuadorian government is proposing changing the GMR's co-management system from an advisory type to a consultative type (*sensu* Sen and Nielsen, [55]). Considering this scenario, members of the PMB and the IMA should seek agreement on the consultation and decision-making process to adopt for evaluating and adapting the GMR's marine zoning. This should be done before the end of the reform process for the Galapagos Special Law, making clear how stakeholder inputs will be used to develop the new zoning plan, as well as the procedure that will be implemented to take the final decision on how to re-zone the GMR. This will be fundamental to legitimize the decision-making process, thereby contributing to encouragement of stakeholder participation and avoidance of potential conflicts between the Ecuadorian government (i.e., Government Council) and GMR stakeholders.

5.3. Right-based management

However, the most important institutional and socioeconomic challenge facing Galapagos fisheries relates to a lack of clearly defined and limited fishing rights. This problem, which lies at the roots of fisheries management failures, is reflected in the misalignment of economic incentives with respect to resource conservation. To address this, and thereby improve the GMR's zoning, it will be necessary to implement a new rights-based management system, through amendments to the Galapagos' legal framework as well as a practical mechanism approved by the PMB and IMA (or Government Council).

This task will require selecting, in a participatory way, a new portfolio of use rights [45,46] taking five key factors into consideration:

(1) There is likely a need to re-allocate fishing licenses, in a manner that privileges the historical activity in the fishery and the performance of active fishers, as well as the distribution of the fishing effort according to the productive capacity of fishery resources, and the particular labour needs of each fishery. To do so, there will need to be changes to the legal framework to provide mechanisms to re-allocate fishing licences, based on the number of active (full time and part time) fishers, and to make it legally possible to exclude those inactive license holders listed in the GNP's fishing registry. For example, in 2008, only 33% and 37% of the total 1101 license holders registered by the GNP participated actively in the sea cucumber and spiny lobster fisheries, respectively [14]. The remainder are "inactive fishers", and these license holders are typically recognized, by fishers themselves, as opportunistic individuals that only keep their fishing license to gain access to economic "alternatives" created by NGOs and the GNP.
(2) The institutionalization of co-management in the Galapagos Special Law has not been sufficient to ensure its success [31], but strong support to the PMB from the Ecuadorian government can assist this local decision making-body in facilitating participation, capacity building and secure access and management rights for fishers. Otherwise, the outcomes expected will continue to be similar to those obtained commonly by a top-down management approach.
(3) There is no "magical recipe" or one-size-fits-all solution to eliminate the race for fish [1,31,45]. Consequently, each use rights option (e.g., TURFs, individual quotas, no-take zones, seasonal closures, etc.) must be evaluated and adapted, considering the particular socio-ecological conditions of Galapagos, so that together they provide the necessary incentives, and increase the probabilities of success in management. This implies conducting interdisciplinary and integrated (systems-oriented) research to understand and describe the dynamics of the main interacting subsystems in the fishery system: resource (e.g., sea cucumber), resource users and resource management [56,1].

(4) The new rights-based management system must guarantee the fundamental rights of fishers, such as food, livelihood, and participation in decision-making. Following the recommendation of Kearney [57], fishery managers should ensure their focus goes beyond narrow economic efficiency measures to include economic and social objectives relating to local communities (such as employment, feasible access of community members to the fishery, and avoidance of excessive concentration of ownership).
(5) To increase the chances of success for the new rights-based co-management system needed in the GMR, the Ecuadorian government needs to adopt a strategic and integrated long-term plan-based approach that contributes to improving the leadership, social cohesion and organization of fishers. The latter factors have been identified as fundamental to the successful implementation of co-management regimes [31,49].

5.4. Lessons for beyond the Galapagos

Drawing on the specific lessons learned in this case study of the shortcomings of the Galapagos fisheries management system, there emerges five more general insights potentially relevant as well within other contexts of ecosystem-based spatial management (EBSM), marine zoning and related management approaches worldwide:

(1) The probability of success of EBSM is strongly reduced if it is adopted without a strategic and long term plan-based approach and adequate funding.
(2) The institutionalization of marine zoning under a co-management regime is not enough to ensure its success if major shortcomings exist within its five basic components (planning, monitoring, implementation, evaluation and adaptation).
(3) Lack of enforcement, inappropriate allocation of fishing rights and the presence of perverse incentives all contribute to a loss of credibility and legitimacy, as well as disincentives to conserve fishery resources.
(4) No-take zones are not useful, and may be counter-productive, if inadequately enforced, and if designed without taking into consideration the spatial dynamics of the resources and fleet, as well as the spatial distribution of key biodiversity areas.
(5) Adaptive management requires that clear and straightforward guidelines be specified in the corresponding legal framework to be applied in practice.

A serious and collaborative analysis, by Galapagos' management authorities and local stakeholders, of shortcomings experienced in GMR's marine zoning and lessons learned as a result (as described throughout this paper) will contribute to improving the effectiveness of what could be one of the most important fisheries management measures of the GMR. The resulting insights, such as those described in this section, may well be useful further afield, as aspects of ecosystem-based spatial management are explored and implemented in fisheries around the world.

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Glossary

Automatic Identification System (AIS): A very high frequency (VHF) radio broadcasting system that transfers packets of data over the VHF data link (VDL). The latter enables AIS equipped vessels and shore-based stations to send and receive identification information that can be displayed on an electronic chart, computer display or compatible radar using global positioning systems (GPS). AIS is used by vessel traffic services (VTS) stations to monitor vessel location and movement primarily for traffic management, collision avoidance, and other safety and fisheries management applications (e.g., enforcement of no-take zones). Available from: http://www.amsa.gov.au/publications/ais_brochure.pdf, [accessed May 2012];

Co-management: "*A partnership arrangement in which the community of local resource users (fishers), government, other stakeholders (boat owners, fish traders, boat builders, business people, etc.) and external agents (non-governmental organizations [NGOs], academic and research institutions) share the responsibility and authority for the management of the fishery*" [Pomeroy RS, Riviera-Guieb R. Fishery co-management: a practical handbook. Oxford: Oxford University Press; 2006];

No-take zone: A type of MPA where all extractive activities are prohibited permanently or temporally. Available from 〈http://www.mpa.gov/glossary.html〉, [accessed May 2012]. Also referred to as "marine reserve" or "no-take reserve" [Al-Abdulrazzak D, Trombulak SC. Classifying levels of protection in marine protected areas. Mar Policy 2012;36(3):576–82];

Marine protected area (MPA): *"Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment"* (Resolution 17.38 of the 17th General Assembly of the IUCN, 1988);

Marine zoning: A spatially explicit tool that consists of regulatory measures to implement marine spatial plans. It specifies allowable uses in all areas of the target ecosystem(s). Different zones accommodate different uses, or different levels of use [Agardy T. Ocean zoning: making marine management more effective.UK: Earthscan/James & James; 2010];

Rights-based management: A fisheries management regime in which access to the fishery is controlled by fishing rights which may include not only the right to fish, but also specify any or all of: how the fishing may be conducted (e.g., the vessel and gear); where they may fish; when they may fish; and how much fish they may catch [46].