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A regulation-based classification system for Marine Protected Areas (MPAs)

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ABSTRACT

Marine protected areas (MPAs) are a global conservation and management tool to enhance the resilience of linked social-ecological systems with the aim of conserving biodiversity and providing ecosystem services for sustainable use. However, MPAs implemented worldwide include a large variety of zoning and management schemes from single to multiple-zoning and from no-take to multiple-use areas. The current IUCN categorisation of MPAs is based on management objectives which many times have a significant mismatch to regulations causing a strong uncertainty when evaluating global MPAs effectiveness. A novel global classification system for MPAs based on regulations of uses as an alternative or complementing the current IUCN system of categories is presented. Scores for uses weighted by their potential impact on biodiversity were built. Each zone within a MPA was scored and an MPA index integrates the zone scores. This system classifies MPAs as well as each MPA zone individually, is globally applicable and unambiguously discriminates the impacts of uses.

1. Introduction

As anthropogenic activities expand worldwide threatening the maintenance of ecosystem services [20,31], marine protected areas (MPAs) have been increasingly seen as one of the most important tools for managing and conserving marine ecosystems [15]. The exclusion or reduction of extractive and destructive activities within MPAs has been adopted as a way to halt or reverse biodiversity loss and ecosystem degradation, maintain or enhance ecosystem services, and recover and manage exploited resources. After more than thirty years of systematic planning, implementing and monitoring MPAs, they have become part of any conservation and management strategy [15,21].

The current Aichi Biodiversity Targets of the Convention on Biological Diversity call for ten per cent of coastal and marine areas being conserved through MPAs and integrated into the wider seascapes by 2020 [4]. Despite this and other commitments, Spalding et al. [27] reviewed 10.280 MPAs showing that they represent only 5.51% of the areas under national jurisdictions and 0.17% of the high seas. Moreover, 94% of existing MPAs allow fishing activities therefore not providing protection to all components of biodiversity [8].

The recent designation of large scale MPAs account for more than 80% of the area under protection, with the ten largest MPAs containing 50% of that area [10,17,28]. This seems to be driven by international commitments leading to a 'race' towards MPA designation, although many are placed in remote areas, lack management plans, allow many types of extractive activities, are not enforced nor monitored, potentially leading to a false sense of protection by society at large [17,22,23]. This fact challenges the assessment of progress towards conservation targets centred on area coverage alone.

Additionally, the majority of MPAs include a large variety of zoning and management schemes, ranging from single to multiple-zoning and from no-take to multiple-use areas [26,30]. An effective classification system for MPAs that encompasses this variability is essential since mislabelling may prevent a correct evaluation of the existing types of MPAs and their usefulness to accomplish stated objectives and goals [29].

The International Union for Conservation of Nature (IUCN) global categorisation of protected areas distinguishes six categories based on their management objectives [3,12]. Day et al. [9]

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produced guidelines to apply this categorisation system to MPAs, but this remains problematic [1,13,24] since: i) the main objectives of MPAs are many times vaguely mentioned in management plans; ii) regulations may be inconsistent with the stated objectives, with misinterpretations likely to occur; and iii) many MPAs are multi-purpose and comprise different zones which, although having different rules, are not being effectively differentiated by the current IUCN system.

The assessment of progress towards ocean conservation targets needs better reporting of existing MPAs but also to be based on a deep understanding of what is effectively being protected, and if IUCN categories are not consistent, the usefulness of this system when applied to MPAs is in danger of becoming meaningless [13]. A consistent and adequate classification system is required to allow a future understanding of expected outcomes of different protection types (besides the well-studied no-take areas), which is necessary to inform management decisions. Since IUCN categories were not designed to capture the variety of regulations within MPAs and are therefore precluding the use of a representative classification of MPAs worldwide, a categorisation system that reduces uncertainty is urgently needed.

Here, a new regulation-based classification system for MPAs and zones within MPAs focusing on the potential impacts of allowed uses is presented and supported by an easy-to-follow decision tree. This is a robust, simple and globally applicable classification, providing an alternative to or complementing the current IUCN system of categories for MPAs.

2. Materials and methods

A total of 100 MPAs worldwide were sampled with available detailed regulations for both MPAs and each zone inside those MPAs to capture the global heterogeneity of MPA and zone types. This was based on information from peer-reviewed papers listed in Sciberras et al. [25] and from global databases of MPAs such as MPAGlobal [30], the World Database on Protected Areas (WDPA, UNEP-WCMC; http://www.protectplanetocean.org/) and MPA atlas (http://www.mpatlas.org/).

As several MPAs have multiple zones, a total of 194 zones, of which 126 were partially protected areas (areas where some type of extractive uses are allowed), and 68 no-take areas were represented. For each MPA and for each zone information on size, regulations (allowed and restricted uses, and mitigation measures of uses, if any), and assigned IUCN category when available in the global MPA databases was gathered. When zones of a given MPA or MPAs within a network shared the same regulations under the same management plan, they were combined into a single zone or MPA (summing their respective sizes), to avoid over representation of specific zone or MPA types. This aggregation resulted in 54 MPAs with a total of 115 zones (84 partially protected areas and 31 no-take areas) (Appendix A, Table A.1).

Since many MPAs and zones did not had an assigned IUCN category and some were found to be misclassified in the global MPA databases, IUCN categories were independently assigned to all MPAs and to all zones within each MPA (Appendix A, Text A.1), strictly following the guidelines in Day et al. [9]. Since in a few cases it was impossible to distinguish between category V or VI, the intermediate category "V/VI" was created.

2.1. Zones and MPA scores

Uses allowed inside each zone within a MPA were grouped in five categories: commercial fisheries, recreational fisheries, aquaculture, bottom exploitation and non-extractive uses (Appendix A, Text A.2; Tables A.2, A.3). A score was assigned to each use based on its potential impact on biodiversity and habitats as described in published literature (see Appendix A for specific references) and/or perceived through expert knowledge. Fishing gear scores were weighted by mitigation measures whenever applicable (i.e. specific regulations at each zone) (Appendix A, Table A.4). For any given zone, a zone score based on the types of uses allowed inside that zone was calculated by computing a weighted average of the scores of the five categories of uses. In multiple-zoning MPAs, the zone scores were then averaged weighting them by the area occupied by each zone in the MPA, creating a MPA score (Appendix A, Text A.2–A.5).

Each of these scores were compared to both the originally assigned and newly assigned IUCN categorisation using linear models to assess whether they explain the impacts of uses in each zone and MPA or, on the contrary, if there were significant mismatches between the IUCN categories and the measures of impact captured by the scores.

2.2. Zones and MPA classification

A classification system of zones was built based on four steps. First, the different zones were grouped in six classes using the allowed number of fishing gears: 0 (no fishing gears);]0–5],]5–10],]10–15],]15–20], > 20. A significant linear response was found between these zone classes and the zone scores described above (ANOVA with Fisher distribution on the linear model; $p < 0.001$), with all classes being significantly different from each other ($p < 0.001$). However, since zones allowing few but highly destructive uses were found to occur, a second step used the gear with the highest score in each zone as an additional condition to account for large impacts (Table 1; see also Appendix A, Text A.2 for details). A score of 0 means that no fishing gears are allowed; ≤ 5 corresponds to highly selective and low impact gears (e.g. lines, octopus traps); 6–8 to more impacting gears (e.g. fish traps, bottom longlines, pelagic towed gears); and 9 to the most destructive gears affecting biodiversity and ecosystems (e.g. bottom trawling, bottom purse seining). So, if a zone has just a few gears but those

Table 1
Gear scores for commercial and recreational fisheries. See Table A.2 and Appendix A (Text A.2) for details.

Fishing gear (commercial or recreational)	Gear score
Beach seines	8
Cast nets	3
Dredges (bivalves)	7
Drift nets	5
Fish traps	6
Fixed fish traps "madrague"	6
Gillnets	6
Hand dredges (bivalves)	5
Hand harvesting	4
Intertidal hand captures	3
Lines (jigs, hook and line, rod, troll)	5
Longlines (bottom)	5
Longlines (pelagic)	4
Purse seining (bottom)	9
Purse seining (pelagic)	5
Spearfishing/diving	3
Surrounding nets near shore	8
Trammel nets	8
Traps (lobster/octopus/crab)	4
Trawl (bottom)	9
Trawl (pelagic)	5

≤ 5 corresponds to highly selective and low impacting gears (e.g. lines, octopus traps)
6-8 medium impacting gears (e.g. fish traps, bottom longlines, pelagic towed gears)
9 to the most destructive gears affecting biodiversity and ecosystems (e.g. bottom trawling, bottom purse seining)

Table 2
Aquaculture and/or bottom exploitation scores. These scores are as follows: 0= not allowed, 1= aquaculture or bottom exploitation are allowed (but mining/oil platforms/sand extraction/detonations are not), 2= both aquaculture and bottom exploitation are allowed with no restrictions (or if aquaculture is not allowed but mining/oil platforms/sand extraction/detonations are).

Activities allowed	Score
Aquaculture and bottom exploitation not allowed	0
Aquaculture OR bottom exploitation allowed, but not mining/oil platforms/sand extraction/detonations	1
Both aquaculture AND bottom exploitation allowed with no restrictions (or if aquaculture is not allowed but mining/oil platforms/sand extraction/detonations are)	2

are very destructive (e.g. bottom trawling), this will influence the zone classification (see results).

In a third step, a simplification of the aquaculture and/or bottom exploitation score was used as follows: 0= not allowed, 1= aquaculture or bottom exploitation are allowed (but mining/oil platforms/sand extraction/detonations are not), 2= both aquaculture and bottom exploitation are allowed with no restrictions (or if aquaculture is not allowed but mining/oil platforms/sand extraction/detonations are) (Table 2). This step aimed at accounting for a few cases where highly impacted activities occurred inside MPAs.

Finally, a fourth step aimed at differentiating impacts within no-take zones (i.e. zones without fishing gears). Here, boating /anchoring were considered as indicators of impacts of non-extractive recreational uses since most of these uses are regulated through these two activities, as follows: 0 (anchoring not allowed); 1 (boating /anchoring allowed but anchoring is fully regulated: restricted to particular areas or mooring buoys); 2 (boating /anchoring allowed but anchoring is only partially regulated or unregulated) (Table 3).

These four steps allowed building our regulation-based classification system for all zones within MPAs at a global scale. Accounting for the potential impacts of uses, and particularly of fishing gears, is supported by the assumption that regulations of allowed uses are related to their potential impacts, so areas with stricter conservation measures usually allow fewer uses, with lower impacts.

Further, an MPA index was calculated as a weighted average of each zone class inside a MPA by the proportion of its area in the whole MPA, as follows:

$$\boldsymbol{I_{MPA}} = \sum_{z=1}^{n_z} \boldsymbol{w_{z_i} C_{z_i}} \quad (1)$$

where $\boldsymbol{I_{MPA}}$ is the MPA index, $\boldsymbol{C_{z_i}}$ is the class of the zone i, and $\boldsymbol{w_{z_i}}$ is the proportion of the area occupied by the zone i in the MPA, as:

$$\boldsymbol{w_{z_i}} = \frac{\boldsymbol{A_{z_i}}}{\boldsymbol{A_{MPA}}} \quad (2)$$

Table 3
Boating and/or anchoring scores as indicators of impacts of non-extractive recreational uses. These scores are as follows: 0= anchoring not allowed; 1= boating /anchoring allowed but anchoring is fully regulated: restricted to particular areas or mooring buoys; 2= boating /anchoring allowed but anchoring is only partially regulated or unregulated.

Activities allowed	Score
No anchoring	0
Boating and/or anchoring allowed but anchoring is fully regulated: restricted to particular areas or mooring buoys	1
Boating and/or anchoring allowed but anchoring is only partially regulated or unregulated	2

where $\boldsymbol{A_{z_i}}$ is the area of the zone i and $\boldsymbol{A_{MPA}}$ is the total area of the respective MPA.

MPA scores calculated above were then related to the MPA index, to check the efficiency of the latter in explaining those scores. The MPA index aimed at both accounting for all uses within each zone and to weight the different zones within each MPA. Since the MPA index and scores were highly correlated, the MPA index was used to classify MPAs in five classes (see results). These MPA classes were finally tested against the MPA scores to assess the consistency of this approach and validate the MPA index.

3. Results

The zone score was compared to the originally assigned IUCN categories at the zone level (Fig. 1A). Categories Ia and II were not significantly different and both were marginally non-significantly different from category IV ($p=0.07$ and 0.06, respectively) and from category VI ($p=0.06$ and 0.05, respectively), and were not different from category V. When using the reassigned categories (Fig. 1B), categories Ia and II were also not significantly different from each other but were significantly lower ($p<0.001$) than those of all other categories, segregating the no-take zones from the partially protected areas, although significant differences were only found between category IV and V/VI ($p<0.001$) with marginally non-significant differences occurring between category IV and V ($p=0.07$).

The MPA score was also compared to the originally assigned categories (Fig. 1C). The MPAs for which no category was reported showed a large variability in the associated score, the same applying to category II ($N=3$), with no significant differences between any of the categories. When using the reassigned categories (Fig. 1D), a large variability was present in category V/VI which was significantly different from all other categories ($p<0.05$) except from category VI. Category II and categories VI and V/VI were also differentiated ($p<0.05$).

Both the total number of uses (explained at 99% by the number of fishing gears, both commercial and recreational) and number of fishing gears were highly correlated with the zone score (Spearman $\rho=0.98$, $p<0.001$ and $\rho=0.97$, $p<0.001$, respectively) (Appendix A, Figure A.1). From the 84 partially protected zones, all allowed some form of fishing. Therefore, the number of fishing gears allowed inside each zone within a MPA was chosen as the main indicator of our classification system. However, non-fishing recreational uses such as boating and diving commonly occur in most MPAs, whereas non-fishing commercial activities such as bottom exploitation or aquaculture occurred only in 21 (18%) out of the 115 zones analysed but can have a disproportionate high impact on marine ecosystems.

Therefore, a classification system for MPA zones was built based on three criteria for partially protected areas (where fishing occurs), as follows: i) number of fishing gears; ii) highest fishing gear score; iii) aquaculture / bottom exploitation scores. For no-take zones, a fourth criteria was added, the boating / anchoring score (Fig. 2A, Tables 1–3).

The classes for these MPA zones were tested with a linear model against the zone score to assess whether the proposed classification system captures the gradients of impacts on marine biodiversity and ecosystems (Fig. 3). All classes were significantly different from one another ($p<0.001$; except between classes 1 and 3 where $p<0.05$). The exceptions were between class 3 ($N=4$) and the two nearest classes (2 and 4), where no significant differences were found, and a marginally non-significant difference was obtained between classes 1 and 2 ($p=0.06$).

After classifying the zones, the ultimate goal of this system is to

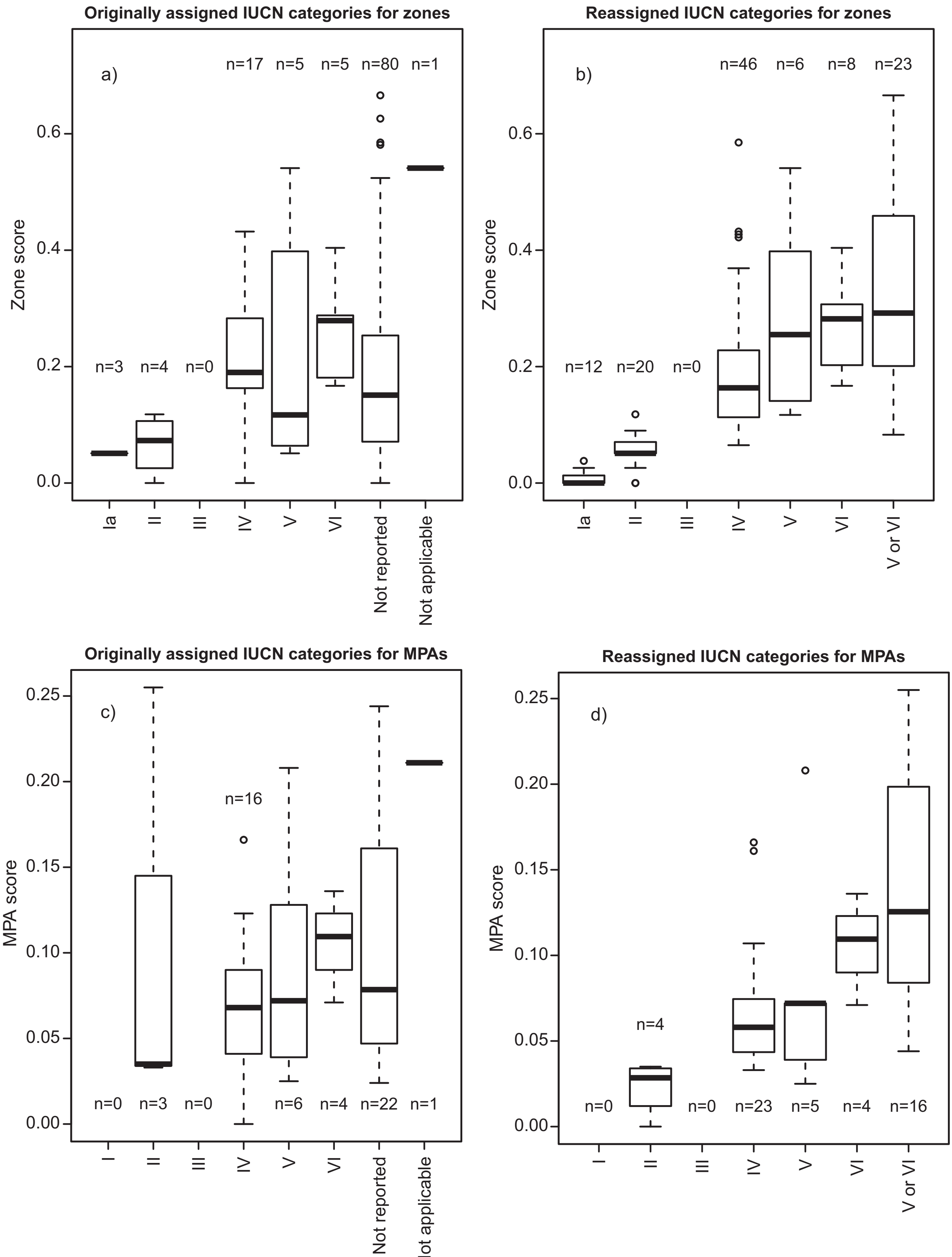

Fig. 1. Relationship between zone and MPA scores and IUCN categories. Box plots of zone scores (a-b) and MPA scores (c-d) across originally assigned (a-c) and reassigned (b-d) IUCN categories: I-Ia (strict nature reserve); II (wilderness area); III (natural monument or feature); IV (habitat/species management area); V (protected landscape/ seascape); VI (protected area with sustainable use of natural resources). The category V or VI was assigned when it was not possible to differentiate categories V and VI based on the available information. Category III was not represented in the sampled zones. Categories I and III were not represented in the sampled MPAs.

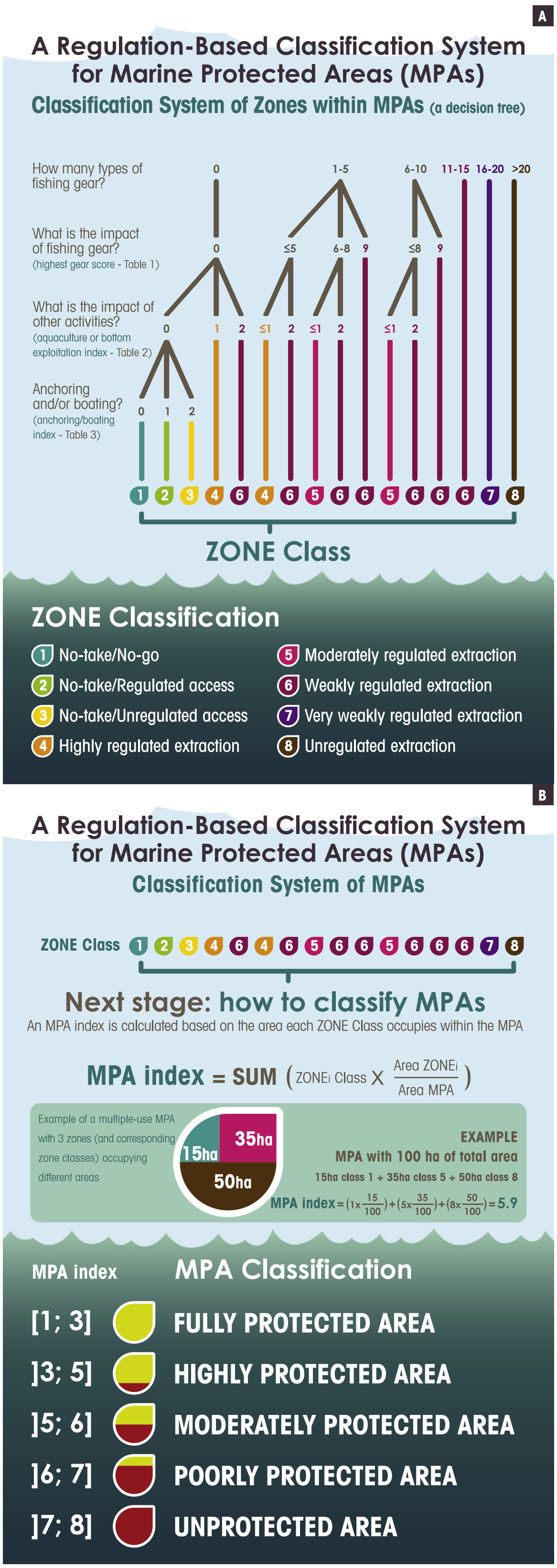

Fig. 2. Decision tree of the regulation-based classification system. Step-by-step sequence of decision tree for classifying zones (Fig. 2A) and MPAs (Fig. 2B).

classify each MPA. The MPA index (see methods) was highly correlated with the MPA score (Spearman ρ=0.88; $p<0.001$) (Appendix A, Figure A.2). The MPA index classes (fully protected;

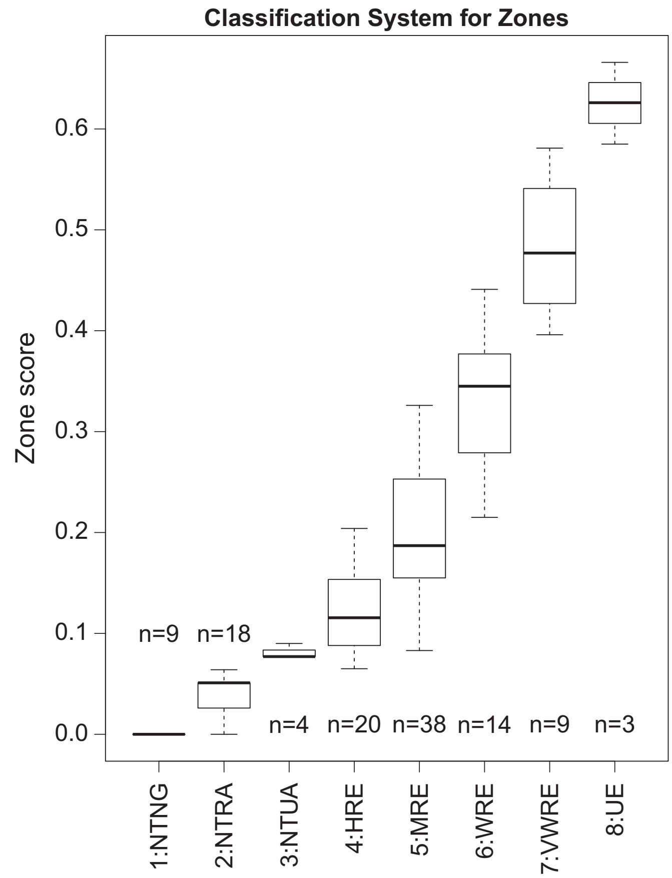

Fig. 3. Relationship between the zone score and the zone classes. 1: NTNG = No-take/no-go; 2: NTRA = No-take/regulated access; 3: NTUA = No-take/unregulated access; 4: HRE = Highly regulated extraction; 5: MRE = Moderately regulated extraction; 6: WRE = Weakly regulated extraction; 7: VWRE = Very weakly regulated extraction; 8: UE = Unregulated extraction.

highly protected; moderately protected; poorly protected; unprotected) were then tested against the MPA score with linear models showing highly significant differences between all MPA classes ($p<0.001$) (Fig. 4). This MPA index is therefore a straightforward way to compare the overall protection levels among MPAs (Fig. 2B).

4. Discussion

A classification system that is simple and globally applicable to MPAs and to each individual zone within multiple-zoning MPAs was developed, by scoring each allowed use based on its potential respective impact on biodiversity. The scores are obtained at the zone level and then integrated at the MPA level, taking into account the relative size of each zone within each MPA. This approach thus allows classifying MPAs as well as each MPA zone individually knowing which types of uses are allowed inside the MPAs and MPA zones.

When assessing protection measures in MPAs, it is essential to have a classification system that allows both to incorporate cumulative levels of disturbance on marine ecosystems and to include the myriad of combinations of regulations and uses occurring many times in multiple zones inside those MPAs. In fact, despite the amount of studies and reviews evidencing the overall ecological benefits of no-take areas over open or partial protected areas [6,7,18,19], few studies have evaluated different levels of partial protection [2,11,16,25], and none followed the same

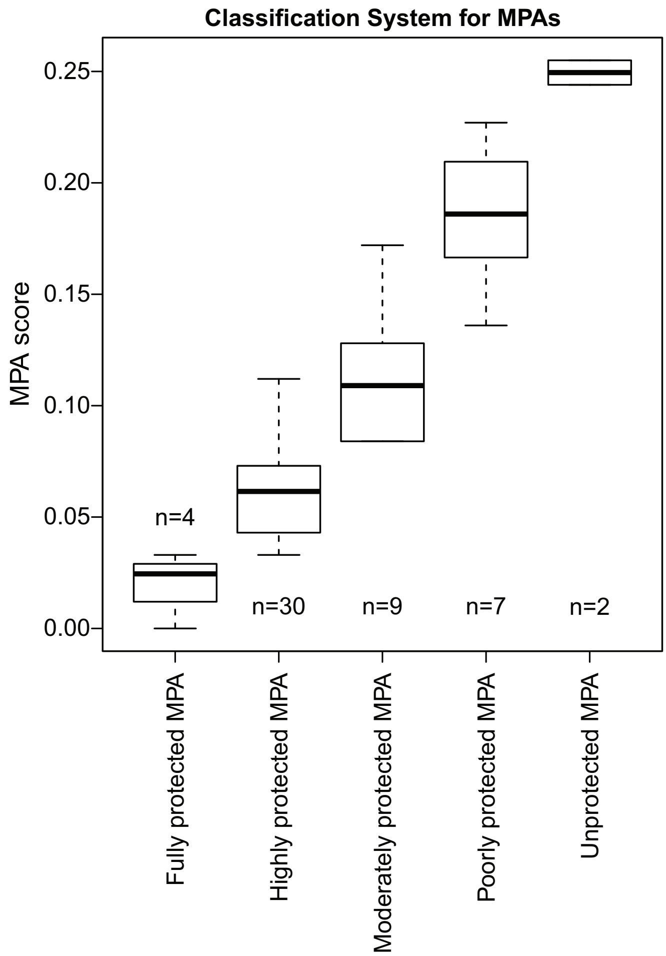

Fig. 4. Relationship between the MPA score and the MPA classes.

classification for zones, highlighting the lack of a proper classification system.

The IUCN categorisation showed a poor match to the regulations applied to the protected areas considered in this study. Not only there was a large variability within the same category but also there is no clear trend from more restricted (category Ia) to less restricted categories (V or VI). Moreover, there was also a significant proportion of areas misclassified, indicating that misinterpretations of IUCN guidelines when applied to the marine environment are still common [9,12]. This creates confusion since the current IUCN system, although being based on objectives and not on allowed uses, follows nevertheless a list of compatible uses. Misapplication of guidelines in the assignment of IUCN categories to MPAs has evolved as a topic of concern [13,24]. For instance, in Canada, MPAs included in categories Ia, Ib and II are open to some form of commercial harvesting [24]. In Australia, recreational fishing is allowed in numerous category II MPAs (which are supposed to be no-take) and fishing gears used in New South Wales MPAs are not in accordance with category IV requirements [13]. These facts raise concerns about possible misrepresentations of what is really being protected, how it is being protected, and how international conservation targets are being met.

The difficulty in ascribing IUCN categories to zones within MPAs is further illustrated when applying the 75% rule in the IUCN system to multiple-zoning protected areas, which is particularly critical for numerous MPAs [3]. This is many times a very difficult criterion to comply with which is probably one of the causes of the lack of categorisation for many MPAs in the global databases since a large proportion of those are multiple-zoning MPAs. Therefore, the current IUCN categorisation does not capture the potential impacts of activities on marine ecosystems and biodiversity and has several implementation difficulties.

A previous attempt to develop a classification system for MPAs [1] did not make progress on the systematisation of uses within classes, concentrating commercial extractive activities (of any kind) in only one level. This would include almost all MPAs analysed in the present study or in Robb et al. [24], and therefore does not distinguish between the current uses occurring inside MPAs at a global level. Sciberras et al. [25] also attempted to distinguish different MPAs based on allowed fishing gears and their relative impacts, grouping areas in three regimes. However, their aim was to evaluate the ecological responses of different levels of protection (no-take and partial protection) and the authors did not include in their analyses all regulated uses nor accounted for multiple-zoning MPAs.

In an ideal world, a global classification system for MPAs should differentiate all actual uses and their real impacts. However, this is not achievable due to a lack of a robust set of scientific studies and long-term and globally applicable monitoring procedures providing reliable and comparable data to support such a system. The consequence of not accounting for the intensity of users' pressures inside, outside and among MPAs is a reduced robustness and accuracy of MPA assessments, which is highlighted in most reviews evaluating responses of no-take areas over open areas [6,7,19] and the benefits of partial protection [18,25].

Despite potential challenges of reporting MPAs to global databases, which should be addressed as part of the compliance with binding international agreements, information reported is central to assess area coverage and protection types. By updating common MPA information (e.g. year of establishment, area, objectives, regulations, levels of protection), countries should be able to correctly classify MPAs according to a simple and straightforward classification system such as the one proposed here.

Management effectiveness, i.e. governance, implementation, surveillance and compliance of regulations, has been also reported as decisive for MPAs success ([5,14,23], IUCN Green List of Protected and Conserved Areas), and its relation to the different MPA classes should be tested. The regulation-based classification system for MPAs here proposed could be a useful tool for the current IUCN Green List process which "aims at recognising success in achieving conservation outcomes, as well as measure progress in, and impact of, equitable governance and effective management of protected areas". Future studies evaluating ecological effectiveness of different MPA regulations and designs should also include management effectiveness as a relevant explanatory variable, among others. Indeed, governance types suggested by IUCN are apparently suitable, include a variety of scenarios globally and can be combined with any classification system when evaluating the effectiveness of MPAs or zone classes [9].

5. Conclusion

The best next thing to having a robust dataset on MPA effectiveness at the biological and socio-economic dimensions (which is currently lacking and challenging to obtain), is to assess managers' and policy-makers' goals when designing, classifying and implementing MPAs. This can be achieved through a system that integrates different levels of potential impact of uses allowed inside these areas, based on the regulations of those uses. This system can be used as an alternative or in combination with the current IUCN categories.

The classification system proposed here is based on classes that represent an increasing gradient of impacts of uses resulting in a simple and realistic classification, less prone to errors in the assignment of those classes. This is supported by an easy-to-follow decision tree, which allows unambiguous classification of zones and MPAs. This is a robust, simple and globally applicable system to be applied by scientists, managers, spatial planners and policy-makers when designing new MPAs, assessing existing ones and comparing outcomes at a global scale.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2016.06.021.

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