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Guidance on marine protected area protection level assignments when faced with unknown regulatory information

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ABSTRACT

Strong human use regulations are an important precondition for marine protected area (MPA) effectiveness. Distinguishing MPAs based on their protection levels has shown advantages, but the availability of regulatory information about allowed activities is a major roadblock towards completing assessments at scale. Here, using a California case study, we explore assigning MPA protection levels following the regulation-based classification system (RBCS) under different scenarios of incomplete regulatory information. In the first group of scenarios (A), only readily available information was used, i.e., information contained in direct MPA implementing regulations and management plans. In the second group (B), information was limited to the activities in ProtectedSeas' Navigator that matched those in the RBCS. From group A, 99% and 100% correct classification of fully and highly protected areas, respectively, were obtained when treating unknown aquaculture, bottom exploitation, and bottom extraction as 'prohibited' and boating, anchoring, and fishing activities as 'allowed'. High classification accuracy was also obtained for moderately, poorly, and unprotected areas. From group B, 92% and 94% correct classification of fully and highly protected areas were obtained when using the same assumptions for non-fishing activities but using Navigator's Level of Fishing Protection (LFP) score to guide assumptions about unknown fishing activities. Correct classification rates were poorer with different assumptions. Regulation-based MPA evaluation systems can reliably identify fully and highly protected areas in the face of unknown information, when assumptions about unknown information are guided by contextual indicators such as generally regulated human activities and/or overall level of fishing restriction.

1. Introduction

The effectiveness of fully or highly protected marine protected areas (MPAs) as a tool to restore fish populations and ocean health has been well studied and documented [1–4]. Based on this evidence, numerous international goals have been set to promote the adoption of MPA networks in national waters. Although the CBD Aichi Target to implement 10% of effective MPAs by 2020 was not achieved in many regions, post-2020 targets are anticipated to increase ambition and set a target of 30% of effective protection by 2030 [5]. This new goal was proposed at the 2016 International Union for the Conservation of Nature (IUCN) World Conservation Congress [6] and includes the designation of 30% of global oceans in effective MPAs or Other Effective area-based Conservation Measures (OECMs) by 2030. In January 2021, the Biden administration committed the United States to this goal by executive order. Under the European Biodiversity Strategy and European Green Deal, Europe has already committed to protect 30% of its ocean, with 10% under strict protection [7].

In order for MPAs to realize their potential, MPAs need to implement strong regulatory protections [8–12]. To assess MPA protection levels, the complexity of regulations in each MPA should filter through an evaluation system that uses and verifies the measures in place. One such system is the Regulation-Based Classification System (RBCS) [13], which scores MPAs based on the potential impact of the activities that are allowed within an MPA. The RBCS is part of the Blue Parks awards criteria and is now integrated into the protection levels assessment of the

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recently developed MPA Guide [10]. Recent endeavors used the RBCS to assess the protection levels different countries and regions were using to meet their international coverage commitments [14–17].

Standardized levels of protection, based on regulations, make estimating potential MPA effectiveness possible. Previous studies suggest the extent of human activities allowed within MPAs (i.e., protection levels) matters in achieving conservation benefits [18–21]. Fully, highly, and moderately protected areas (particularly if adjacent to fully protected areas), have been found to provide significant conservation benefits, from which socioeconomic benefits are derived [21,22]. Yet, using protection levels as proxies for potential positive outcomes assumes MPAs are implemented and enforced in the water with enabling conditions being met [10]. Enabling conditions, such as enforcement, monitoring of results, long-term political commitment, sustainable financing, community participation, and benefits sharing, must be in place for a MPA to be effective [10,23–27]. Some of these features are not easily and objectively quantified (e.g., enforcement or compliance) or information is not readily available (e.g., funding), but indicators are needed to ensure MPA enabling conditions and MPA success (e.g., [28]).

In theory, MPA quality related to the level of protection can be obtained by documenting 'allowed' and 'prohibited' marine activities. Globally, this would lead to an overall picture of marine protections worldwide [3,4,13,14–16,21]. In practice, however, detailed regulatory information is not readily available for many MPAs, which can be a major roadblock in reaching that goal; often MPAs are only broadly referenced in bylaws or regional/national legislation [12,29]. Researching all the regulatory information needed for a worldwide assessment of marine protections could be extremely time-consuming. Therefore, easier access to regulatory marine protections, as well as more robust methodologies to assess marine protections despite gaps in regulatory information could be helpful.

Here, the adequacy of estimating RBCS protection levels with incomplete input data was explored, by testing different assumptive methods. Californian MPAs and other Marine Managed Areas (MMAs)[1] in the ProtectedSeas' Navigator database [30] were used as a case study; they are considered to be implemented and meeting the enabling conditions for success [31–35]. It was assessed whether the regulation-based metrics can be robust and reliable using only information readily available from MPA regulations and management plans (referred to in this study as 'direct regulations'). It was also assessed whether Navigator's Level of Fishing Protection (LFP) score [12] can guide assumptions about unknown information to provide a reasonable first estimate of the RBCS protection levels when regulation information is incomplete in the management plans or equivalent legal texts. The use of such guidance in protection level estimations would enable MPA assessments to increase, allowing broad comparisons between MPAs, MPA networks, and other managed areas when the required information in bylaws or regional/national legislation is difficult to obtain or non-existent.

2. Methods

MPA and other MMA management plans rarely address the complete set of fishing and activity restrictions in place, as some activities are often managed through bylaws or regional or national regulations (referred to in this study as 'external regulations'). However, for an accurate assignment of a protection level based on the RBCS, detailed information on allowed activities (e.g., fishing, aquaculture, mining, etc.) is necessary. Therefore, gathering all information to fulfill a complete assessment via the RBCS can be onerous at a large scale or might have to ignore areas where information is not available.

Various world databases document MPAs (e.g., World Database on Protected Areas (WDPA), MPAtlas, MAPAMED, etc.), with regulatory information for some regions (see the MPAtlas with some MPAs classified following the RBCS such as the Blue Parks, and recently The MPA Guide). Further, to facilitate extensive and global assessments in a timely manner, Navigator [30], launched in 2015, contains information on activities 'allowed' and 'prohibited' by regulation, as well as regulatory references for all areas in its database (i.e., MPAs and MMAs). Navigator focuses on activity restrictions on marine life extraction, i.e., mainly fishing [12], but it distinguishes itself from other databases by summarizing direct regulations and documenting a standardized set of uses for every included area. Navigator's Level of Fishing Protection (LFP) score is assigned based on heuristic rules structured in a decision tree that do not require all individual uses to be known. A simplified system capturing regulations, such as LFP, may serve to guide decisions associated with a more complete system (such as the RBCS or The MPA Guide) when detailed information is not easy to obtain.

To explore the adequacy of estimating the RBCS protection levels with incomplete input data, California's network of MPAs and other MMAs (381 areas from Navigator, as of December 2021) was selected as a sample to test potential assumptions that could be made for unknown information globally. For these areas, all the regulations were reviewed through a resource intensive process (whether from direct or external regulations). This allowed gathering the full set of regulations required to follow the RBCS decision tree [13], and assigning those areas with a 'correct' protection level ('real' case or 'Full RBCS'). We worked at the lowest possible resolution, hence MPAs or zones within a MPA in the case of multi-zone MPAs. All of the areas or zones were treated as individual sites (such as in [15,16]) in order to not mask full or high protection in weighted-averaging zone scores. Where no information could be found on fishing gears, anchoring, and/or boating occurring in the assessed region, we considered them not prohibited by regulation (i.e., 'allowed'), as suggested by Horta e Costa et al. [13]. For aquaculture, bottom structures including pipelines and artificial reefs (referred to in this study as 'bottom exploitation'), and mining/oil platforms/sand extraction/detonations (referred to in this study as 'bottom extraction'), data layers were retrieved from the California Department of Fish and Wildlife and the U.S. Bureau of Ocean Energy Management to determine their locations (for pipelines, artificial reefs, and drilling platforms) or active lease locations (for aquaculture[2] and oil/gas). Where an aquaculture, bottom exploitation, or bottom extraction location intersected an area's boundary, that activity was coded as 'allowed', otherwise it was coded as 'prohibited'. These Full RBCS protection levels constituted the baseline for this study.

Comparisons between the protection levels obtained with the full set of regulations (Full RBCS) and those obtained under different scenarios with less information - unknowns - and distinct assumptions allowed validating their performance. Two groups of scenarios were tested (Fig. 1, Appendix Table 1): (A) one using only the direct regulations of MPAs/MMAs (i.e., management plans or equivalent) which often do not provide the full set of regulations required to assign the RBCS; and (B) one using only the information gathered in Navigator with more unknowns due to the reduced number of uses included in Navigator (RBCS input fields with corresponding Navigator fields were used with the remaining considered unknown, detailed in Appendix Table 4). The first group of scenarios (A) reflects what is often available to evaluators, so the aim was to understand if gathering only the information readily available in management plans and equivalents would significantly change the final RBCS protection levels when guided by assumptions. The second group of scenarios (B) is also relevant to test because there

[1] Beyond MPAs, other MMAs in Navigator include areas managed for fisheries purposes, such as permanent gear closure areas, that regulate extraction of marine life; these are rarely addressed by global databases focusing on MPAs, but they can be similarly classified based on existing regulations.

[2] Aquaculture data layers from the California Department of Fish and Wildlife only show relative positions and shapes of lease areas and do not provide definitive legal boundaries.

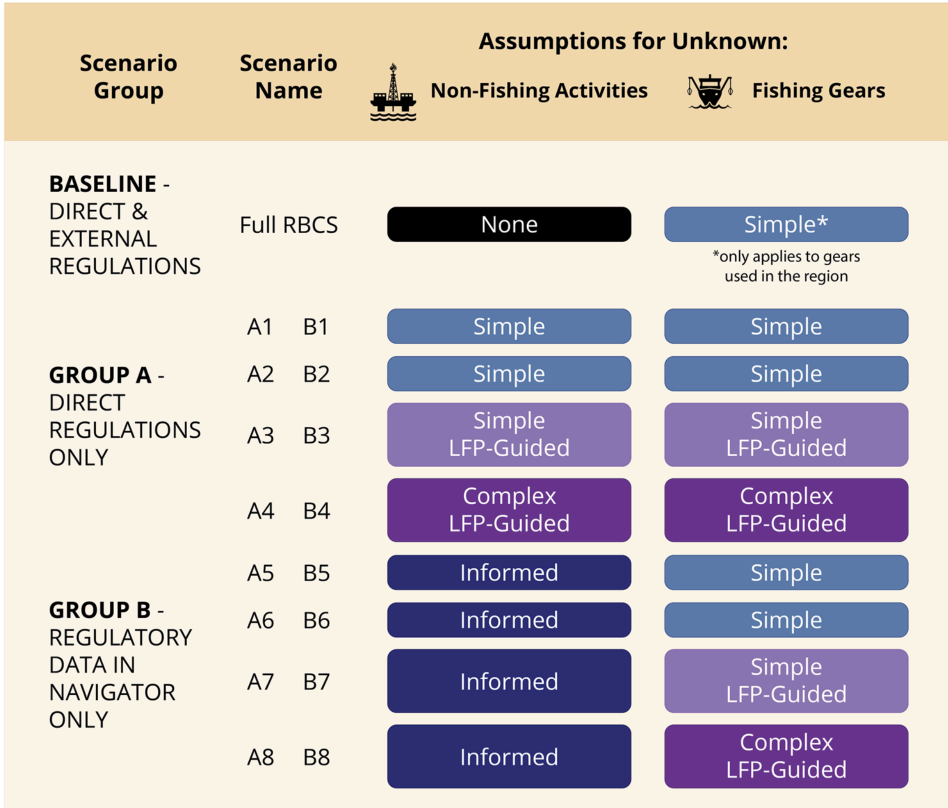

Fig. 1. Assumptive methods used in each scenario. See Appendix Table 1 for a full description of input information and assumptive methods for unknown fishing gears and non-fishing activities used in each scenario.

are already more than 20,000 areas in over 120 countries assessed in Navigator, including all American and European MPAs [36]. These areas could be classified following the RBCS or The MPA Guide if guidance on what to do with the unknowns is clarified scientifically and the performance is satisfactory. The type and number of unknowns were evaluated for both groups of scenarios, comparing the number of unknowns between each scenario and the Full RBCS, to understand common unknowns and their impact in final classifications.

Within each group of scenarios (A and B), eight scenarios, named A1-A8 and B1-B8, with increasing complexity in assumptions pertaining to unknown fishing gears and non-fishing activities were tested. Simplest assumptive methods included assuming all unknown fishing gears and non-fishing activities 'allowed' or all 'prohibited', and more complex methods were tested to understand if the classification results could be improved. These included applying different assumptions to unknown non-fishing activities (*informed assumptions*), unknowns for different types of areas (*LFP-guided assumptions*), or a mix of approaches, with some assumptions being applied to unknown fishing gears and others to unknown non-fishing activities.

Informed assumptions, used in scenarios A5-A8 and B5-B8, were applied to unknown non-fishing activities. For aquaculture, bottom exploitation, and bottom extraction, given their environmental impact and weight in the RBCS and because they are commonly absent or incomplete in management plans and regulated by external regulations (e.g., specific bylaws with leases), assumptions related to these activities are important. In addition, because such activities in the United States are generally subject to extensive regulatory requirements such as environmental assessments, public comment periods, and permitting, unknowns in these fields were coded as 'prohibited'. Non-fishing activities that are ordinarily unrestricted unless explicitly stated otherwise, such as boating and anchoring, were coded 'allowed' if unknown.

For the LFP-guided assumptions, Navigator's LFP score was used as a basic/heuristic and first step assessment of an area's protection level based on general information of one of the RBCS dimensions (i.e., fishing). Two versions of the LFP-guided assumptions were tested. In the simple version, unknown fishing gears and non-fishing activities were considered 'prohibited' for those areas consistent with fully and highly protected areas and 'allowed' for the areas consistent with moderately, poorly, and unprotected areas. Simple LFP-guided assumptions for unknown non-fishing activities were used in scenarios A3 and B3 and for unknown fishing gears in scenarios A3, B3, A7, and B7. In the complex version, for unknown non-fishing activities: i) unknown bottom extraction was considered 'prohibited' for the areas consistent with fully, highly, and moderately protected areas and 'allowed' for the areas consistent with poorly and unprotected areas; ii) unknown bottom exploitation and aquaculture were considered 'prohibited' for the areas consistent with fully and highly protected areas and 'allowed' for the areas consistent with moderately, poorly, and unprotected areas, and iii) unknown boating and anchoring were considered 'allowed' for all areas. Unknown fishing gears were considered 'prohibited' for those areas consistent with fully and highly protected areas and 'allowed' for the areas consistent with moderately, poorly, and unprotected areas, except for fishing gears with an impact score of 9 (highest impact) (i.e., bottom towed fishing gears; see the table in [13] for RBCS fishing gear impact scores) in the moderately protected areas, in which case they were considered 'prohibited'. Complex LFP-guided assumptions for unknown non-fishing activities were used in scenarios A4 and B4 and for unknown fishing gears in scenarios A4, B4, A8, and B8.

To support using the LFP scores to guide decisions in the RBCS, a chi-square test of independence was performed between the LFP scores and RBCS protection levels, under the Full RBCS, for the 381 study areas. Results showed a significant and relatively strong association between the Full RBCS protection levels and LFP scores (χ^2 (16, n = 381) = 657.3, $p < 0.001$; Cramer's V = 0.66), suggesting LFP scores can help guide assumptions about unknown information. The distribution of the RBCS protection levels and LFP scores are plotted in Appendix Fig. 1.

RBCS protection level estimates from each scenario were evaluated by computing the percentage of correctly classified areas with respect to the Full RBCS as well as false positive and negative rates. A false positive indicates an area where the RBCS protection level assigned by a scenario did not match that area's 'correct' RBCS protection level calculated by the Full RBCS. A false negative occurs when an area that scored a given RBCS protection level in the Full RBCS was assigned a different RBCS protection level in a scenario. In basic terms, the false positive rate indicates what percentage of areas assigned a given RBCS protection level are incorrect for that level, while the false negative rate indicates how many areas that should be a given RBCS protection level are 'missed' (i.e., assigned an incorrect protection level). The calculation of RBCS protection levels in each scenario was conducted in Python.

3. Results

The Full RBCS protection levels for California MPAs and other MMAs, calculated using all available information including activity restrictions from sources other than MPA management documentation, are reported in Fig. 2 and Appendix Table 2, constituting the baseline for this study.

The analysis of the unknowns (Appendix Table 3) revealed that some fishing gears were only known after searching external regulations (in the Full RBCS scenario). Most often these were drift nets, fish traps, fixed fish traps madragues, lines, longlines (bottom), longlines (pelagic), purse seining (bottom), purse seining (pelagic), spearfishing/diving, traps, and trawl pelagic. These gears were not regulated by direct regulations in 25–42% of the California areas. All fishing gears had unknowns in some MPAs when only searching for direct regulations - even those that are more destructive such as bottom trawls. Some gears such as trammel nets, gillnets, or dredges also display some unknowns even

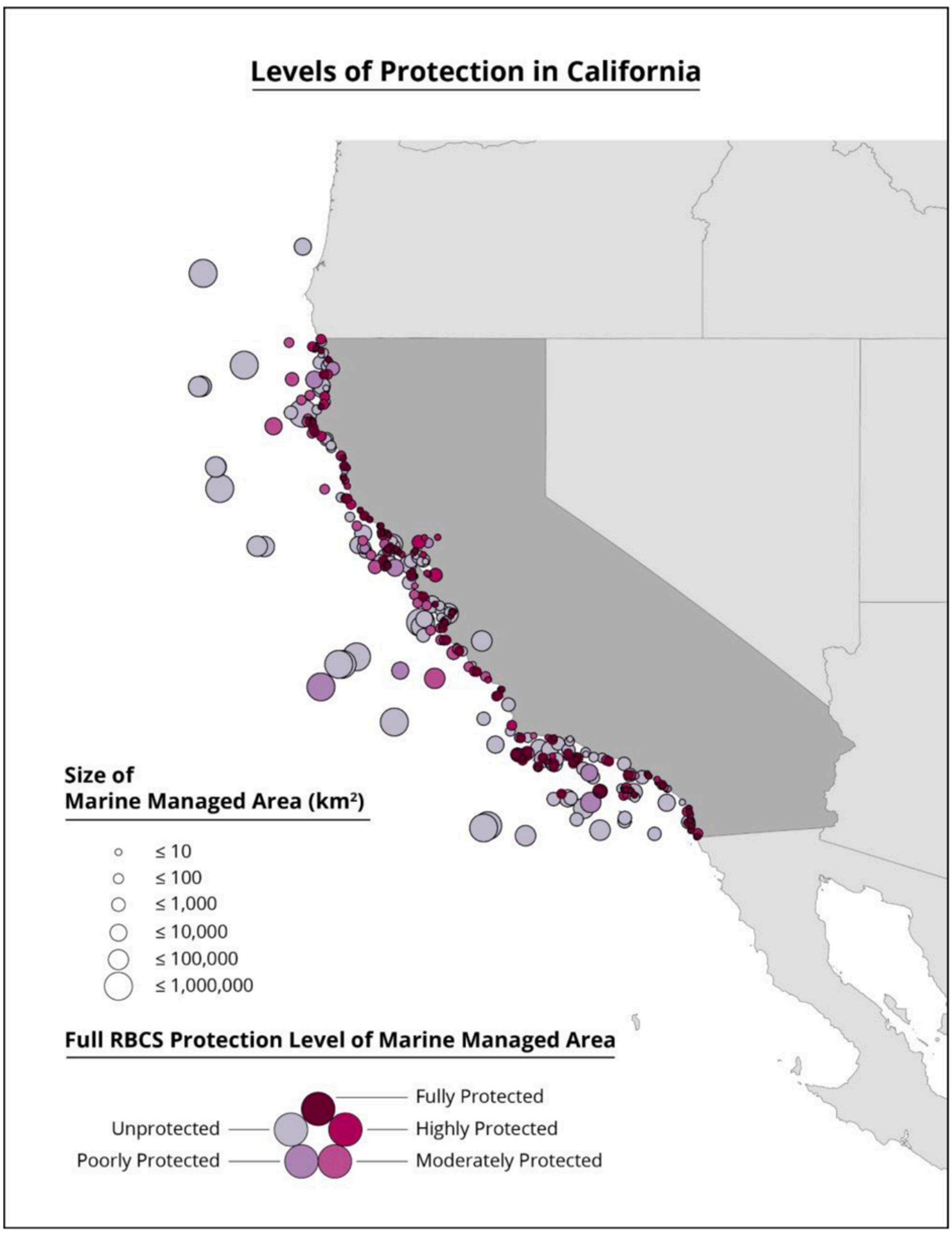

Fig. 2. Map of California MPAs and other MMAs, illustrating their size and Full RBCS protection level. Included are all areas that at least partially overlap California marine waters; each dot represents the centroid of the MPA/MMA boundary.

after researching the entire set of existing regulations (both direct and external) for an area or region. References to non-fishing activities were even less available in direct regulations with 45%, 60%, 97%, and 98% of areas having no information about anchoring, aquaculture, bottom exploitation, and bottom extraction, respectively. When evaluating average unknowns across fishing gear and non-fishing activity fields by RBCS protection level, the percentage of unknowns increased as protection level decreased, except for unprotected areas which had somewhat less unknowns than poorly protected areas (Table 1).

The scenarios within group A included all fields in the RBCS but only used information readily available in direct regulations. Both simple assumptive methods returned poor classification results (Table 2). When all unknowns were assumed ‘allowed’ (A1), fully to moderately protected areas from the Full RBCS shifted towards being classified as less protected, (Table 2, Appendix Table 5). When all unknowns were assumed ‘prohibited’ (A2), moderately to unprotected areas from the Full RBCS shifted to being classified as more protected (Table 2, Appendix Table 6). Both simple assumptions were not representative of ‘reality’. Table 2 summarizes the assumptions and results for all scenarios in group A.

To test the reasonableness of the informed non-fishing activity assumptions in scenarios A5-A8 and B5-B8, which treat unknown aquaculture/bottom exploitation/bottom extraction as ‘prohibited’ and boat/anchoring as ‘allowed’, the codings (‘allowed’ or ‘prohibited’) of each non-fishing activity for each individual area were compared to their respective codings in the Full RBCS. Over 90% of the informed non-fishing activity assumption codings for each activity matched their respective Full RBCS codings (Table 3), proving the assumptions appropriate for use.

In the scenarios of group A that used the informed non-fishing assumptions (A5-A8), the first two options tested for the unknown fishing gears were all ‘allowed’ (A5) or all ‘prohibited’ (A6). Strong matches were obtained for all categories in A5, with each protection level having 90% or higher correct classification compared to the Full RBCS - 99% and 100% of correct classifications were obtained for fully and highly protected areas, respectively, with very low percentages of false negatives (Table 2, Appendix Table 9). This means that, in California, commercial non-fishing activities (e.g., aquaculture/bottom exploitation/bottom extraction) which are mostly regulated by external regulations, are not commonly allowed within MPAs/MMAs, and this is adequate to assume them as ‘prohibited’, while recreational non-fishing activities (e.g., boating/anchoring) are generally allowed so it is adequate to assume that as well. Regarding fishing gears, this indicated that when not stated in direct regulations, fishing gears are typically allowed. Indeed, poor results were obtained when unknown fishing gears were considered ‘prohibited’ (A6), with moderately to unprotected areas from the Full RBCS being classified as more protected with high error rates (Table 2, Appendix Table 10).

For scenarios where assumptions were differentiated according to a previously calculated protection level (using LFP scores) (A3 and A4), good results were obtained when unknown activities were assumed ‘prohibited’ in areas consistent with fully and highly protected areas and ‘allowed’ in the others (A3; Table 2, Appendix Table 7). However, a slight increase in performance was obtained when considering unknown bottom extraction as ‘prohibited’ in areas consistent with moderately protected areas, boating/anchoring as ‘allowed’ in all areas, and unknown fishing gears as ‘allowed’ in areas consistent with moderately protected areas except for large-impacting fishing gears (i.e., bottom towed fishing gears) (A4; Table 2, Appendix Table 8). These two scenarios showed a high rate of correct classification for almost all protection levels, except for poorly protected areas, with fully, highly, and moderately protected areas showing 99%, 96% or 97%, and 100% correct classification, respectively. However, the overall performance was lower than scenario A5, with these scenarios (A3 and A4) showing a substantially larger percentage of false negatives for moderately and highly protected areas (in A3 only). Most false negatives corresponded to downgrades (i.e., assumed less protected) compared to the Full RBCS classification.

When mixing the informed non-fishing activity assumptions and the simple LFP-guided assumptions for fishing gears (A7) or the more complex LFP-guided assumptions for fishing gears (A8), the overall performance was better than in previous scenarios, particularly for moderately and poorly protected areas (Table 2, Appendix Tables 11 and 12). This improvement seems related to the impacting non-fishing activities which, in the California region, are typically not allowed (according to these results). Hence, better performances are reached when

Table 1
Average percentage of unknown information, by RBCS protection level (n = 381).

	Fishing Gears		Non-fishing Activities	
Protection level (according to Full RBCS)	Full RBCS (avg. % unknown)	All other scenarios (avg. % unknown)	Full RBCS (avg. % unknown)	All other scenarios (avg. % unknown)
Fully Protected	0	0	1.10	11.60
Highly Protected	0.09	0.21	0.58	9.13
Moderately Protected	1.67	4.74	0.79	10.87
Poorly Protected	4.84	16.09	6.72	22.05
Unprotected	3.39	11.71	2.10	8.66

Table 2
RBCS classification results summary for all scenarios in group A.

Scenario Name & Description	Classification Shift	Match with Full RBCS	Correctly Classified (%)
A1: using direct regulations w/ simple assumptions	Shift to less protected	Weak	45
A2: using direct regulations w/ simple assumptions	Shift to more protected	Weak	53
A3: using direct regulations w/ simple LFP-guided assumptions	Minor shift to less protected	Strong	84
A4: using direct regulations w/ complex LFP-guided assumptions	Minor shift to less protected	Strong	91
A5: using direct regulations w/ informed non-fishing assumptions, simple fishing assumptions	Minor shift to more protected	Strong	95
A6: using direct regulations w/ informed non-fishing assumptions, simple fishing assumptions	Shift to more protected	Weak	53
A7: using direct regulations w/ informed non-fishing assumptions, simple LFP-guided fishing assumptions	Minor shift to less protected	Strong	95
A8: using direct regulations w/ informed non-fishing assumptions, complex LFP-guided fishing assumptions	Minor shift to less protected	Strong	95

Table 3
Informed non-fishing activity assumption coding match with Full RBCS coding.

Activity	Match with Full RBCS (%)
Aquaculture	92
Bottom exploitation	93
Bottom extraction	92
Boating / anchoring	100

these are considered 'prohibited' in all area types. However, mixed scenarios A7 and A8 resulted in very similar results, suggesting that the better performance in A4 compared to in A3 was likely related to fishing assumptions (prohibiting highly impacting fishing gears in the areas consistent with moderately protected areas in A4 but allowing them in those areas in A3).

When applying the same tests and scenarios of group A to group B, which have more unknowns due to fewer individual activity and gear categories in Navigator, similar poor (though poorer) results were obtained for the simple assumptions (B1 and B2; Table 4, Appendix Tables 12 and 13). Table 4 summarizes the assumptions and results for all scenarios in group B.

When LFP scores were used to guide assumptions for both the unknown fishing gears and non-fishing activities (B3), a good classification was found for fully and highly protected areas with 92% and 94% of correct classification, respectively, and low percentages of false negatives, compared to the Full RBCS (Table 4, Appendix Table 15). Considering fully and highly protected areas together as a group, correct classification rose to 97%. The percentage of false negatives was high in moderately and poorly protected areas though. The slight improvement in the performance of the less protected levels with the complex LFP-guided assumptions (B4) was due to the fact that if an area is consistent with a moderately protected area and bottom extraction is considered 'allowed' (like in B3), that area would be classified as poorly protected; whereas in B4, since bottom extraction is considered 'prohibited' in areas consistent with moderately protected areas, that area might keep the same class. This means that bottom extraction is likely not allowed in areas consistent with moderately protected areas.

Table 4
RBCS classification results summary for all scenarios in group B.

Scenario Name & Description	Classification Shift	Match with Full RBCS	Correctly Classified (%)
B1: using Navigator data w/ simple assumptions	Shift to less protected	Weak	26
B2: using Navigator data w/ simple assumptions	Shift to more protected	Weak	44
B3: using Navigator data w/ simple LFP-guided assumptions	General shift to less protected	Strong for Fully and Highly Protected, Weak for Moderately, Poorly and Unprotected	62
B4: using Navigator data w/ complex LFP-guided assumptions	General shift to less protected	Strong for Fully and Highly Protected, Weak for Moderately, Poorly and Unprotected	65
B5: using Navigator data w/ informed non-fishing assumptions, simple fishing assumptions	Shift to less protected	Weak	26
B6: using Navigator data w/ informed non-fishing assumptions, simple fishing assumptions	Shift to more protected	Weak	44
B7: using Navigator data w/ informed non-fishing assumptions, simple LFP-guided fishing assumptions	General shift to less protected	Strong for Fully and Highly Protected, Weak for Moderately, Poorly and Unprotected	62
B8: using Navigator data w/ informed non-fishing assumptions, complex LFP-guided fishing assumptions	General shift to less protected	Strong for Fully and Highly Protected, Weak for Moderately, Poorly and Unprotected	65

The scenario mixing the informed assumptions for the non-fishing activities and the simple LFP-guided assumptions for fishing gears (B7) performed the same as B3, indicating that LFP-guided assumptions for non-fishing activities ('allowed' in areas consistent with moderately, poorly, and unprotected areas) or considering all these activities as 'prohibited' (informed), resulted in the same performance and classification (Table 4, Appendix Table 19). The same occurred in scenario B8 (Table 4, Appendix Table 20). This suggests that the non-fishing activities do not significantly impact final protection levels when fishing is weakly regulated (i.e., less fishing gear information is available). However, the large number of unknowns, particularly in the less protected areas, preclude a correct classification. Fully and highly protected areas more often explicitly prohibit the most damaging activities in their direct regulations, and thus are much less subject to assumptions.

4. Discussion

While it is known that protection levels, together with enforcement and other enabling conditions, matter for MPA effectiveness [10,18–21,23,24–28], this study shows the impact that the general lack of key regulatory information available in direct regulations can have on protection level assessments. In many of the California MPAs/MMAs, direct regulations did not specify whether the complete set of fishing gears required by the RBCS were 'allowed' or 'prohibited', sometimes not even addressing the more destructive gears such as bottom trawling. Non-fishing activities, such as aquaculture, bottom exploitation, and bottom extraction were rarely addressed in direct regulations. Such results suggest that these areas were not planned to manage non-fishing commercial activities or to work as a tool for wider marine spatial planning [37,38]. Further, besides the reduced quality of direct regulations, these results also expose the lack of external regulations, whether regional or state, about fishing gears with substantial impact in the seabed or in marine resources, such as trammel nets, gillnets, or dredges. According to these results, managers and users do not know if they can use these gears inside or in the region of particular MPAs/MMAs. This is occurring in a particularly well-regulated and managed region of the world that is committed to strong conservation efforts, including good examples of MPA implementation and management [31–35]. These findings highlight that direct regulations should be given further attention and importance while being planned and revised, to ensure that they mention all regulations that apply within the area, as good management plans are key for the success of MPAs [27].

By comparing scenario outcomes, guidance can be provided on how to classify MPAs according to their protection levels when complete information is not available in direct regulations. Since these are the mechanisms that should regulate MPAs and should contain the information about what can be done inside them [27], they represent the main and central resource evaluators have while assessing protection levels. Before this study, in the absence of sufficient direct regulations, each evaluator would either search for additional information, use local knowledge, use their expertise, or a combination of these when assessing whether fishing gears and non-fishing activities are 'prohibited' or 'allowed' in particular MPAs. However, at a global scale, such individual decisions could compromise comparisons between areas or countries. By testing assumptions and displaying their performance, guidance is offered for coherent and comparable assessments when direct information is incomplete and precludes correct classifications. According to the results of this study, simple and homogeneous assumptions were not representative of reality.

The best assumptions to follow when using direct regulations (group A scenarios) are those using informed assumptions for non-fishing activities (A5) or those with LFP-guided assumptions for both non-fishing activities and fishing gears (A4) or a mix of both informed (for non-fishing activities) and LPF guided assumptions (for fishing gears) (A7 and A8). All these assumptive methods returned high percentages of correct classification and low percentages of false positives and false negatives. The fact that the informed assumptions for non-fishing activities (i.e., assuming impactful activities as ‘prohibited’) resulted in a good performance compared to the Full RBCS protection levels (in scenarios A5, A7 and A8), is likely due to these activities being mostly forbidden in the California MPAs/MMAs by external regulations. Since this might not be the case in numerous MPAs [17], the evaluator should select this option with caution and based on knowledge about the region being assessed. Even though these non-fishing activities are mostly prohibited, some cases existed where they were allowed in California MPAs/MMAs. Hence, the overall good performance following these informed assumptions also highlights the stronger role of fishing gears in the RBCS, compared with non-fishing activities. This suggests that fishing gears are very important to know for an accurate assessment and that is why the best assumptions have considered fishing gears carefully.

The best LFP-guided assumptions for fishing would be to assume that all the unknown fishing gears that are typically used in the assessed region are ‘allowed’ in areas consistent with poorly and unprotected protected areas, whereas unknown fishing gears that are low or medium impact (i.e., excluding bottom towed fishing gears) can also occur in areas consistent with moderately protected areas (such as in scenarios A4 and A8). Although this is not what is assumed when all unknown fishing gears are ‘allowed’, as in scenario A5 where the performance of assumptions was very good, it results in similar protection levels in the California MPAs/MMAs where areas consistent with fully and highly protected areas had clear direct fisheries regulations without unknowns and fishing gears were not considered ‘allowed’. In conclusion, as general guidance, scenario A4 would be best suited for areas where no previous knowledge exists or where MPAs are known to have impacting activities occurring inside them. Scenario A8 would be best for areas where such activities are not typically occurring within MPAs. Both options have very good performance for fully and highly protected areas (both with 99% and 97% of correct assignment and 0% and 2% false negatives for fully and highly protected areas, respectively). Further, both options require a quick, previous assessment of general fishing restrictions to assess their levels of fishing protection (LFP) [12], to proceed with the respective guidance.

The best assumptions to follow when using the data already gathered by Navigator (group B scenarios) are also those from scenarios B4 and B8, performing the same. The main difference between these two options is in considering the unknown non-fishing activities as all ‘prohibited’ (as in B8) or only ‘allowed’ in areas consistent with less protected areas (as in B4). The fact that they performed the same suggests that when there are several unknown fishing gears, the impact of this on the final classification outweighs the impact of using informed assumptions for non-fishing activities. To demonstrate, areas that had differing Aquaculture or Bottom Exploitation Index scores (step 3 of the RBCS, detailed in [13]) between scenarios B4 and B8 were all consistent with moderately, poorly, and unprotected areas. As such, fishing gear counts (step 1 of the RBCS, detailed in [13]) in these areas ended up being high since all unknown fishing gears were assumed ‘allowed’, and areas with a fishing gear count of > 10 are automatically classified by the RBCS as poorly protected or unprotected without considering the impact of non-fishing activities. Both scenarios B4 and B8 offer good classification performance for fully protected areas (92% of correct assignment and 0% of false negatives) and relatively good performance for highly protected areas (94% of correct assignment but 29% of false negatives), suggesting this approach works, at least, to distinguish these two protection levels from the others. While this result is weaker than the scenarios using full direct regulations (group A), it shows that fully and highly protected areas could still be classified with a reasonably high level of accuracy using the existing data in Navigator.

Assessing existing ocean protection using standardized measures is critical given global goals to protect increasing percentages of ocean and increasing attention on the quality of operational implementations [39–43]. Studies show that fully and highly protected areas are more effective overall than moderately protected areas [4,18,19,44], so being able to accurately classify fully and highly protected areas is of greatest importance, which scenarios A4, A8, B4, and B8 were found to accomplish. The ability to assign protection levels (following the RBCS or The MPA Guide in the near future) via existing MPA databases, allows for faster global assessments of protection. Using the Navigator database to assign RBCS protection levels is supported by this study if it can be done in tandem with data improvements by gathering further direct regulations.

This study provides validated guidance for decisions to make in the face of incomplete regulations. Due to the common lack of information on impacting activities, getting the best possible information for a given region and MPA is an important effort, but missing information should not preclude assigning protection levels to understand the potential quality of protection in place.

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CRediT authorship contribution statement

Alex Driedger: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Jennifer Sletten:** Investigation, Data curation, Writing – original draft, Writing - review & editing. **Claire Colegrove:** Investigation, Data curation. **Timothé Vincent:** Data curation. **Virgil Zetterlind:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Joachim Claudet:** Methodology, Writing – review & editing. **Barbara Horta e Costa:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision.

Data Availability

Data will be made available on request.

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Declaration of Competing Interest

ProtectedSeas is a part of the Anthropocene Institute. The Navigator database used for analyses in this article is the work product of the five authors affiliated with the Anthropocene Institute.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2022.105441.

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