Research & Reviews: Journal of Ecology and Environmental Sciences
e-ISSN:2347-7830
p-ISSN:2347-7822

What are the Main Drivers of MPA Failings?

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Research Article

Received: 02/08/2016
Accepted: 20/11/2016
Published: 28/11/2016

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Keywords: Marine protected areas, Systematic review, Protection failings, Non-compliance, Management

ABSTRACT

Non-compliance and its drivers are some of the most critical reasons as to why marine protected areas (MPAs) fail to have peak effectiveness but are not comprehensively studied. A systematic review (SR) protocol was used to determine the main drivers of non-compliance in MPAs that could compromise protective efficacy and lead to failings. Fourteen of the most commonly mentioned drivers were identified, and the weight of evidence behind each of these drivers was analysed through the SR. Instances of non-compliance in temperate MPAs were found to be underreported in comparison to their tropical counterparts, which may be attributed to there being fewer temperate MPAs, a bias towards tropical MPA studies, or that temperate MPAs have fewer instances of non-compliance. Four drivers were reported in tropical MPAs and for all drivers, frequency of citations was higher for tropical than temperate MPAs. Drivers were not equally represented in frequency across MPAs and lack of an adaptive management plan was observed at a greater frequency than expected, suggesting it may be fundamental in leading to MPA failings and non-compliance. No significant association was found between the frequency of the driver mentioned and either MPA age, size or climate. A checklist of ten questions was created from the 14 drivers identified to identify if an MPA is at risk of failing. This checklist of indicators combined with the results of this SR will aid MPA managers in quickly evaluating if their MPA is at risk of failing in its protective objectives. The results of this SR are fundamental in bridging the gap between researchers and practitioners using an evidenced-based approach to MPA planning and management.

INTRODUCTION

Marine protected areas (MPAs) have numerous definitions depending upon location, objectives and management regime. However, they can be broadly defined as a distinct geographical area that is recognised, managed and dedicated through legal or other effective means, aiming to achieve the long term conservation of nature and its associated cultural values and ecosystem services [1]. MPAs are commonly, and in most instances wrongly, perceived as a cure-all for restoring damaged, degraded or at-risk ecosystems to pre-human impact levels, which are often impossible to determine. The implementation of large MPAs does not guarantee success in meeting conservation aims, and many MPAs are "paper parks" which lack appropriate governance [2]. The Convention on Biological Diversity (CBD) acknowledged that rapid MPA creation without proper management is often ineffective at restoring biodiversity. This statement combined with the statistic that only 1.17% of marine areas had protected status by 2010 resulted in the CBDs target to have 10% of global oceans in protected areas by 2012 delayed until 2020 [3].

There is an urgent need for an analysis of what drives MPA failures, following the introduction of the 23 new Marine Conservation Zones in the UK as part of the national strategy to produce an ecologically coherent network of MPAs [4]. Furthermore, the Marine Management Organisation (MMO) recently called for views on MPA site assessments for fisheries to understand how to improve management of protected areas [5]. Agardy [6] broadly defined that MPAs often fail to be effective by having characteristics of: small size, inappropriate planning/management (such as lacking Before, After, Impact, Control design), degradation of surrounding unprotected areas, negative effects of displaced of human activities and lacking enforcement.

MPAs deemed successful usually have five features for a significant protective effect including: no-take, well-enforced, >10 years of age, >100 kilometres scale and sand or depth isolation [7]. However, the magnitude and location of the main drivers behind MPA failings have not yet been identified and the quality of evidence behind these drivers has not been assessed. It is common for papers to identify a failing(s) in one or a few MPAs but there is currently no global assessment of failings [2,8,9]. In the extended timeframe granted from the revised CBD protection targets, it is imperative that these failings are classified to re-evaluate MPA management [3]. This will be done in the current project for Newcastle University by identifying and analysing drivers of failings in order to ensure the long-term viability of ecologically coherent networks of marine reserves.

Identifying drivers of failings allows mitigation to increase MPA effectiveness. Despite numerous MPA reviews, the minority focus on why MPAs fail to be effective. There may be potential literature bias in favour of promoting positive results from protected areas [10]. Furthermore, few studies use a systematic methodology and assess the quality of evidence garnered from the review, which is recommended by the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) framework for systematic reviews [11-14]. Notwithstanding the available comprehensive guidelines on designing and implementing supposedly resilient MPAs, for example Kelleher, IUCN-WCPA [15] and Day [16], there does not appear to be a simple checklist of failing indicators besides the overview provided by Edgar [7] although a request for one has been made [17].

It is difficult to quantitatively assess if and when an MPA has categorically failed and to define what has driven this failure. However, drivers of failure that could cause ineffective protection may be categorised and the evidence in support of the existence of these drivers can be quantified. It is possible that a combination of drivers could lead to the MPA failings. Furthermore, an MPA expressing failing drivers does not automatically mean an outright failure of its primary objective to restore and conserve biodiversity. Simply, it means that potential peak effectiveness is compromised. This project does not aim to categorise failed MPAs, only to identify drivers that could lead to failings within existing MPAs and analyse any patterns in failings.

Aims and Objectives

A_1 –What are the key drivers of failings in MPAs across the world? (See appended literature review).

O_1 –To use a systematic method to review literature on the causes of MPA non-compliance.

A_2 –What is the weight of evidence behind each of these drivers?

O_2 –To assess which drivers are reported more frequently and to assess if there is a correlation between driver frequency and climate, size or age of MPAs.

H_1-Non-compliance drivers will not be affected by MPA size.

H_2 –Non-compliance drivers will not differ between tropical and temperate waters.

H_3 –Non-compliance drivers will not be affected by MPA age.

O_3 –To assess indicators of MPAs not having maximum effectiveness through a ten question checklist.

METHODS PROTOCOL

The appended literature review forms the justification of the 14 drivers of failings identified from running the SR. The protocol method for the current report was adapted from the GRADE framework and from environmental and medical systematic reviews by Hansen [18], Pita [19], Liquete [12], Sciberras [13] and Sciberras [20], to create a systematic search of peer reviewed and grey literature that is as fully comprehensive as possible utilising a series of electronic databases. After performing a series of initial tests on Google Scholar to refine the search terms with the use of Boolean operators, a search term was selected that covered as many aspects of perceived failings in MPAs as possible whilst also returning a manageable number of results. The tests were:

Test One: *Marine protected area failure OR "paper parks" OR protection failure OR marine protected area issues OR marine protected area conflicts OR marine AND "no-take zone" OR "non-compliance"*

Test Two: *"Marine protected area" OR "marine reserve" AND "paper parks" OR protection failure OR conflicts OR "no-take zone" OR "non-compliance"*

Test Three: *"Marine reserve" OR "marine protected area" AND "non-compliance"*

Test one had too low specificity but a high return rate of ~40,000 papers. Refining the search terms in Test two still resulted in a high return with 60,400 papers but many were biological studies rather than non-compliance in MPAs. The final chosen primary search terms had a lower return rate in Google Scholar of 1,080 but allowed more studies targeted to the question asked by the client **(Table 1).**

Articles were screened by checking abstracts and full text against the specific criteria **(Table 2)**; those accepted were imported into an EndNote library for analysis.

Full text articles were accepted meeting the following secondary criteria:

1. Data presented on non-compliance after, or before and after implementation of MPA.

Table 1. Systematic search terms to target literature focussing on failing/failed international marine protected areas.

Online databases	Google Scholar, Scopus, Science Direct.
Additional specific searches	IUCN, Marine protected areas publications NOAA, National Marine Protected Areas Centre (mpa.gov), JNCC, Defra.
Primary search terms	(Marine protected area OR marine reserve) AND (non-compliance)
Secondary search terms	Tropical, temperate, management, effectiveness, enforcement, poaching, illegal.

Table 2. Primary criteria for returned results to be imported into the EndNote library.

Criteria	Required elements
Types of study	Studies written in the English language. Primary and/or grey literature. Quantitative and qualitative studies including but not limited to questionnaire surveys, existing reviews, focus groups and interviews. Circumstantial evidence will also be accepted
Populations and habitat	Stakeholders involved (including officials and any local populations or tourists involved or interacting with MPAs). Broad scale habitats including mussel beds, coral reefs, sponges, worm reefs, estuaries, rocky habitats, littoral chalk communities, tide swept, muddy gravels, sub-tidal chalk, seagrass, burrowing megafaunal communities, peat and clay exposures, maerl beds, native oyster beds, underboulder communities, fish, invertebrates and mammals (JNCC Habitat FOCI, 2016).
Types of intervention	Marine protected area. Gear and/or access and/or fishing restrictions. Enforcement may or may not be present.
Types of outcome (driver)	Size, location, governance regime, level of protection stakeholders who perceived the failing, categories of different drivers possibly contributing to MPA failings.

2. Primary data reported or a meta-analysis of previously collected primary data or anecdotal evidence.
3. Level of enforcement described. *
4. Size of MPA described. *
5. Age/implementation date of the protection given. *

* Due to the nature of some of the published materials, MPA size, enforcement and age are not always described. Articles were accepted if criteria 3-5 could be identified from mpatlas.org. Articles not meeting inclusion criteria one and two were rejected.

If two or more articles on the same MPA were highlighted but they were published in different years or contained different facets of data, both were included. If a paper contained case studies on more than one MPA then the paper was logged individually for each MPA as the perceived drivers may be different. For each MPA identified with a driver of failure and reviewed, its criteria (size, age, enforcement etcetera) were logged manually in a Summary of Findings (SoF) table. A SoF table was chosen as the best method for data representation as it is used by the Cochrane Collaboration to present main findings of medical treatment systematic reviews [14]. The GRADE working group guidelines (Grading of Recommendations, Assessment, Development and Evaluation) provides a framework to rate the quality of available evidence ranking quantitative evidence most robust and circumstantial evidence as the least robust. Using this and answering the reports second aim. A general linear model (R Studio Version 0.99.902 © 2009-2016 RStudio, Inc), was also used to test drivers against size of MPAs.

Chi-square tests for association were used to test for associations between MPA factors such as size and age against drivers. The observed values were the frequency of MPA citations of a particular named driver for example, local illegal fishing. A Chi-square contingency table further satisfied objective two of aim two and was used for Tests 1 and 2 (Table 3). For Test 1 (Table 3), the observed (O) frequency of each driver was input into the table. The expected value (E) was 16.9, as out of 236 non-compliance citations from the 127 papers, each driver was expected to be equally represented (236/14=16.9). The X^2 statistic was then calculated from these values. For Test 2, the drivers were grouped under the three non-compliance foci of enforcement, management and stakeholder absence. O was the sum of the different drivers under each focus, for example, for *stakeholder absence*, the combined frequency of MPA citations for lack of stakeholder participation and lack of alternate income were input into the contingency table. As there were seven drivers under *enforcement*, five under *management* and two under *stakeholder absence*, the expected ratio was 7:5:2, which gave E values of 118, 84.5 and 3.8, respectively. The X^2 was then again calculated using these values.

A Chi-square test for association was used for tests 3, 4 and 5 (Table 3). For Test 4, 500 km^2 was used as a size boundary to test smaller MPAs against very large MPAs. Test 5 used 20 years as the age boundary to test for differences between newer and older MPAs as the average age of MPAs was 20-30 years. For Test 3, divided the tropical and temperate MPA citations with local illegal fishing and visitor illegal fishing combined so that O>5 as they were similar drivers. Weak governance was discarded as O <1 and could not be suitably combined with another driver. The X^2 value for Test 4 was determined by calculating the O values of driver citations split into two MPA size categories (<500 km^2, >500 km^2). For Test 5, which tested the assumption that there was no association between driver frequency and MPA age, the drivers were grouped into the three foci (*enforcement, management,* *stakeholder absence*) to ensure O>5. The X^2 value for Test 5 was determined by calculating the O values of driver citations split into two MPA age categories (< 20 years, >20 years).

RESULTS

Running the systematic review resulted in an output of 127 papers that could be used for statistical analysis **(Figure 1)**. Of 127 papers, 74% were qualitative, 19% circumstantial and 7% quantitative, although in regards to quality of evidence, qualitative data were expected to be most frequent to answer the proposed question [21].

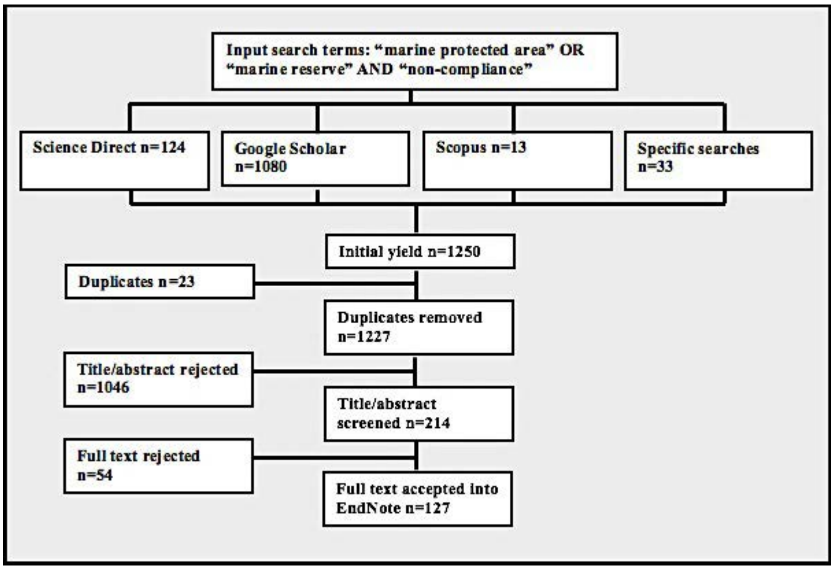

Figure 1. Flowchart of results synthesis. Search terms were inputted in April 2016. None of the returned results from the specific website searches (Table 1) were eligible for inclusion. Articles accepted into the EndNote library included: 25 results from Science Direct, 94 results from Google Scholar, and eight results from Scopus.

Statistical analyses were carried out in R Studio Version 0.99.902 © 2009-2016 RStudio, Inc software for Mac. For all drivers, frequency of mentions was greater in tropical than temperate MPAs, with less than 40% of reported drivers in temperate countries **(Figure 2).** This suggested a potential study bias favouring reporting of tropical over temperate MPAs. The drivers insufficient monitoring, accidental harm, perceived poor legitimacy and lack of alternative income were only recorded in tropical countries. Lack of adaptive management appeared most frequently cited than the other drivers, with insufficient enforcement and visitor illegal fishing also appearing prominent as MPA failings. Lack of funding had few citations and lack of stakeholder participation had the lowest frequencies for both temperate and tropical MPAs, suggesting they were not one of the key drivers for MPAs failing in their protective objectives.

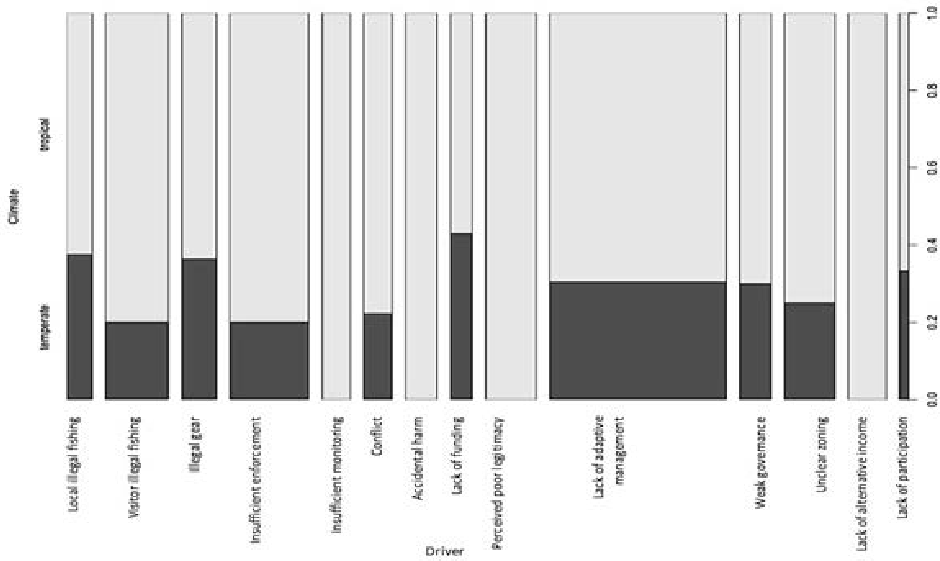

Figure 2. Driver frequency against climate, with width of bars representing proportional frequency of driver mentions. Pale grey represents tropical MPAs, dark grey represents temperate MPAs.

Size of recorded MPAs varied greatly from <1 km^2 to 333,000 km^2, so a log scale was used in the R Studio *ggplot* statistical package and any duplicate entries were removed prior to analysis **(Figure 3)**. There was only one mention of weak governance/coordination in temperate MPAs. It appeared that the majority of MPAs were ~≤ 30 years of age, with only a few outlying MPAs **(Figure 3a)**. Initially, use of illegal gear appeared to be reported in a greater age range of temperate MPAs in comparison to tropical MPAs and the other drivers. This suggested that the use of illegal gear was apparent in numerous temperate MPAs, regardless of how many years the area had been protected for. In contrast, size of MPAs varied significantly more than age did, although the majority appeared ≥ 100 km^2 **(Figure 3b)**. Smaller, (<100 km^2) tropical MPAs appeared to have greater size frequencies for lack of adaptive management but no significant association was found between any driver and size of MPA (general linear model, t =4.311, SE = 4.8, p >0.05,). No significant association was found between any driver and age of MPA (general linear model, SE =4.867, t =4.212 p >0.05). This suggested that although the weight of evidence was greatest behind a few of the aforementioned drivers (lack of adaptive management plan, insufficient enforcement and visitor illegal fishing), no correlation between any of these and MPA size and age was found.

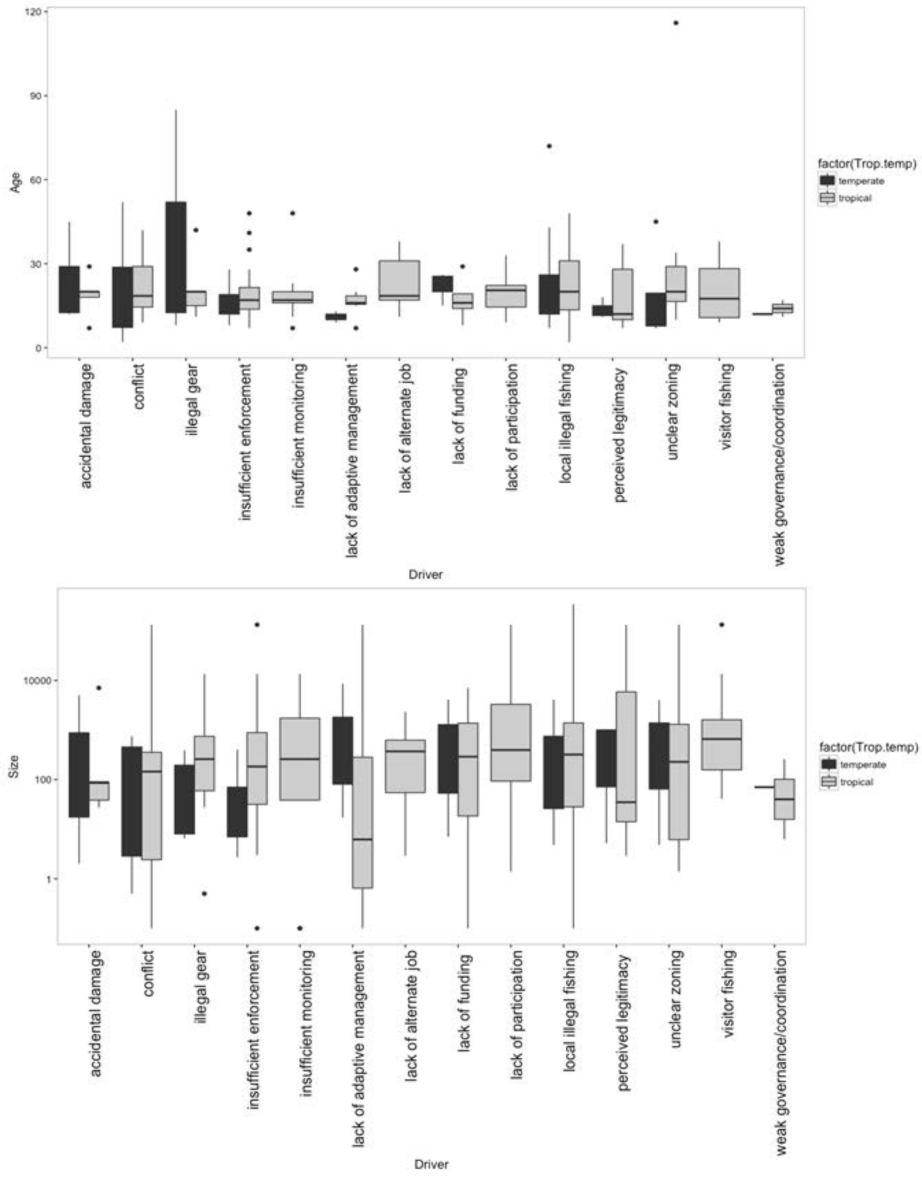

Figure 3(a). Frequency of reported driver against MPA log age (years), sorted by climate. (b). Frequency of reported driver against MPA size (km^2) sorted by climate.

Test 1 analysed whether the observed frequency of drivers was significantly different from the expected frequency.

The null hypothesis of Test 1 that drivers would have equal frequency of mentions and found a higher frequency of local illegal fishing, insufficient enforcement, conflict and lack of stakeholder participation was rejected. Test 2 rejected the null hypothesis that the *enforcement*, *management* and *stakeholder participation* would have the ratio of 7:5:2. Test 2 found a higher frequency of *enforcement* drivers (local illegal fishing, visitor illegal fishing, conflict, insufficient enforcement, insufficient monitoring, illegal gear and accidental harm) reported than expected, with a lower than expected frequency for *management* (lack of adaptive management plan, unclear zoning, lack of funding, lack of perceived legitimacy) and *stakeholder absence* (lack of participation, lack of alternative livelihoods) drivers. Test 3 accepted that there was no association between the proportion of MPA citations in each of the driver categories was the same for each of the two climates. Tests 4 and 5 did not find an association between size or age of MPAs and frequencies of drivers cited.

DISCUSSION

This seems to be the first SR of its kind to assess the drivers behind non-compliance in MPAs around the world. The novel quality of this study is further enhanced by the minimal emphasis that previous socio-ecological studies have placed upon stakeholder compliance [21]. The true justification for using an SR protocol is that it can be easily and cost-effectively updated in the future as more information becomes available and does not rely upon author-selected evidence [22]. Furthermore, SRs provide an evidenced-based approach to objectively bridging information gaps between MPA practitioners and researchers [23]. It was unsurprising that the majority of returned papers from the SR were qualitative in nature, because the forms of non-compliance were generally assessed through social surveys and interview techniques as a standard practice in research. Quantitative information mainly stemmed from illegal catch data and available fisheries records of local and national institutions. Since one-fifth of papers returned from the SR involved circumstantial evidence, it seems common for non-compliance to not be a main research priority or simply be too challenging to quantify. Furthermore, fishers anecdotes are often the only way to quantify illegal harvest in data-poor regions, increasing reporting errors and the risk of bias [2].

The frequencies of the drivers behind non-compliance in temperate MPAs appeared to be underreported in comparison to tropical MPAs, suggesting a possible reporting bias, the presence of fewer MPAs in temperate climates or that temperate MPAs have fewer instances of non-compliance. The last could be correct because temperate MPAs are generally in wealthier, more developed countries that theoretically, can often better afford enforced regulation and stronger, more adaptive management plans. However, the difference in reporting between the two climates is most likely to be a combination of factors, including others not aforementioned in the current report and should have further investigation.

Considering that numerous tropical countries hosting MPAs often have relatively low GDP in comparison to their temperate counterparts, it was interesting that lack of funding was cited so infrequently as a driver of MPA failings. If a secondary study was to investigate the reasons as to why the most commonly cited drivers such as lack of adaptive management plan and illegal catch existed, it may be that funding was an underlying driver contributing to this and other failures. However, caution must be applied when interpreting the prevalence of non-compliance due to the possibility of a false-consensus effect where perceived non-compliance is over-estimated by individuals surveyed, particularly in data-poor regions [21].

The 14 drivers of failings identified and the frequency of their citations supported the earlier study by Agardy [6]. The current study found that lack of an adaptive management plan, lacking enforcement and lack of alternative income/displaced livelihood to be some of the most frequently cited drivers, particularly in tropical areas. This aligns with the focus of coral reef managers who often prioritise research on monitoring and adaptive spatial management [22,24]. However, addressing the second aim of the current project, no correlation was found between driver frequency and either MPA age or size. This suggests that drivers of non-compliance could be correlated to human and social rather than physical factors of the sites, for example possibly national GDP, population size or main exports. The results of the current SR have justified a secondary study to compare drivers against these social factors, to test for such a correlation as the findings may further explain why only certain types of non-compliance are only reported in certain areas, for example, the four drivers only reported in tropical MPAs **(Figure 2)**.

Lack of funding had few citations, yet financial support is often what hinders sufficient planning, management and enforcement of protected areas [2,7] The average age of MPAs was ~20 years **(Figure 3a),** which in terms of protected species with long k-selected life histories such as marine mammals and elasmobranchs, as well as slow-growing organisms such as corals, is relatively young. It would be interesting to see if the frequency of drivers and the dominant drivers changed once the majority of these MPAs had reached 50 or 100 years of age. It could be that age is correlated with driver frequency but that the MPAs studies here do not have a great enough range to display the trend. A future investigation into this would also improve upon the theory by Edgar [7] that MPAs need to be older than ten years of age in order to be successful. It is very likely from these results that generally speaking, MPAs need to have been established for much longer than a decade to discern any noticeably significant protective effect. However, other factors, such as size and level of isolation, likely also play a significant role in determining the success of an MPA as well as age [7].

The current SR highlighted a lack of evidence behind potential failings of temperate MPAs and has justified further future investigation into why there are fewer papers on temperate areas [25,26]. This would also be pertinent in the continual monitoring and implementation of the UKs ecologically coherent network of MPAs and in a wider sense, in regards to meeting CBD targets [1,3]. It could be argued that from this that perhaps temperate MPAs were performing to a better standard than their tropical counterparts and succeeding to a greater extent in their protective and restorative objects. However, underreporting of issues was also possible and would be exacerbated by the smaller number of studies conducted in temperate versus tropical MPAs and the fewer number of MPAs there. Historically, there has been an increase in skewing towards favouring the positive outcomes of MPAs in the literature [27]. Due to the high volume of studies initially found from the SR it was not possible to have greater discrepancy between the 14 drivers, and in a future study, the causes for MPA failings could be analysed in greater detail, with a greater emphasis on discerning between proximate and ultimate drivers of non-compliance. Although the current report highlights the common failings of MPAs, this should not discourage their careful and considered implementation. The creation of MPAs in itself reinforces the statement that biodiversity is worth restoring and preserving for current and future generations [28].

CONCLUSION

This SR could only describe frequency of the 14 drivers most commonly described in the literature but there are likely to be many more causes for MPAs to fail in satisfying their primary objectives of ecological restoration and protection [29]. This was the first SR on perceived drivers of MPA failings of its kind, and therefore, an important first step in understanding and combatting the issue of failings inherent in so many MPAs. The results of this study as well as the methods protocol used, partially satisfy the call for further evidence regarding protected areas from the Marine Management Organisation and the Convention on Biological Diversity [3,5]. Furthermore, the data gained will help bridge the information gap identified between researchers and managers of MPAs [23]. Globally, the majority of MPAs are relatively young, often having been formally established for less than 20 years, suggesting that they might not yet have had sufficient time to take maximum effect for slow-growing species. The current results suggest that MPAs require an adaptive management plan with good enforcement and opportunities for income alternatives to former widespread destructive practices. Out of the 14 most common drivers identified, these aforementioned factors appeared most frequent, evidencing their importance in ensuring a healthy and functional MPA. Without a continually evolving management plan, MPAs are likely to stagnate and be prone to failings as evidenced here, especially if physical, human or environmental conditions change within the area.

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