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Evaluating the success of a marine protected area: a systematic review approach

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Highlights:

- A systematic review of indicators of success of marine protected areas
- A list of most frequently cited biophysical, socio-economic and governance indicators
- A demonstration of a case study application of evaluation of MPA success using a traffic light system of indicators
- A framework of indicators for application to evaluate success of any MPA

Abstract

Marine Protected Areas (MPAs), marine areas in which human activities are restricted, are implemented worldwide to protect the marine environment. However, with a large proportion of these MPAs being no more than paper parks, it is important to be able to evaluate MPA success, determined by improvements to biophysical, socio-economic and governance conditions. In this study a systematic literature review was conducted to determine the most frequently used indicators of MPA success. These were then applied to a case study to demonstrate how success can be evaluated. The fifteen most frequently used indicators included species abundance, level of stakeholder participation and the existence of a decision-making and management body. Using the indicator framework with a traffic light system, we demonstrate how an MPA can be evaluated in terms of how well it performs against the indicators using secondary data from the literature. The framework can be used flexibly. For example, where no MPA data currently exist, the framework can be populated by qualitative data provided by local stakeholder knowledge. This system provides a cost-effective and straightforward method for managers and decision-makers to determine the level of success of any MPA and identify areas of weakness. However, given the variety of motivations for MPA establishment, this success needs to be determined in the context of the original management objectives of the MPA with greater weighting being placed on those objectives where appropriate.

1.0 Introduction

Marine Protected Areas (MPAs) are areas in which human activity is restricted in order to manage and protect marine and coastal resources against threats such as over exploitation and ecological damage (Eagles, et. al., 2002; Cleguer, et. al., 2015). Once these areas are protected, they could have positive ecological effects (Edgar et al. 2014, Selig and Bruno 2010) such as increasing species abundance and improved habitat quality (Roberts et al., 2001) as well as significant socio-economic effects for coastal communities (Rodriguez et al. 2015, Santo 2013). MPAs, are found all over the globe (Salm et al., 2000), and have demonstrated that they protect endangered habitats from decline, restore food webs, and sustain ecosystem services (Pauly, et al., 2002). MPAs vary in location; however most occur at intertidal or near-coastal waters (Wood et al., 2008). Recent estimates are that between 2.2% (MPAtlas 2014) and 3.4% (Juffe-Bignoli, et al., 2014) of the world's oceans are protected by MPAs . However, regulations and enforcement vary at these sites with some being no more than paper parks (Halpern 2014, Edgar et al. 2014). This impacts the level of protection they provide and so the level of success in meeting management objectives (Hilborn et al., 2004).

Pomeroy et al. (2005) state that at the time of implementation, MPAs must: (1) maintain or restore marine biodiversity and ecosystem function, particularly through marine reserves, also called 'no-take' areas; and (2) also improve the socio-economic conditions by increasing revenues in and around the MPA by increased tourism and improved local commercial fishing outside of the MPA due to an increase in the size and number of fish migrating out of the MPA. Pomeroy and colleagues also suggested that in order to evaluate management effectiveness within a marine ecosystem there is a need to establish specific indicators. These indicators can serve multiple audiences, such as donor agencies, policy makers, management teams, and conservation and development non-governmental organisations. It was concluded that the most frequently cited limitation reported by MPA managers, in measuring the management effectiveness of their efforts, was a lack of technical skill and experience in conducting an evaluation. Evaluation techniques should be improved and conducted more regularly, as regular evaluation can strengthen management action, enhance priority setting and ensure accountability (Pomeroy et al., 2005). Lack of evaluation can be complicated when no clearly defined MPA goals or objectives exist or the management plan for the area of the MPA is unclear.

MPA management effectiveness assessment tools have been developed such as MPA MEAT which was created to assess the effectiveness of MPA management in the Philippines (Alino, 2011). This tool provides managers with a clear indication of where

management improvement can be made but is not broad enough to incorporate socio-economic and biophysical changes as a result of protection to evaluate the success of the MPA as a whole. The aim of this paper is to provide a framework to assess the biophysical, socio-economic and governance success of any MPA based on criteria found in the most recent literature on MPA indicators of success. The framework should be versatile enough to be used in a variety of ways depending on the level of data and expertise available.

The choice of the three broad categories of MPA effectiveness (biophysical, socio-economic and governance) is based on those used in the literature (e.g. CTI NCC (2011)).We use the term governance in the broad sense described by Hufty (2011) and Bevir (2013) where governance refers to "all of processes of governing, whether undertaken by a government, market or network, whether over a family, tribe, formal or informal organization or territory and whether through the laws, norms, power or language" (Bevir 2013). It relates to "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions" (Hufty 2011). The objectives of the research include: the development of a success criteria matrix using a systematic literature review which detailed the indicators used and the sources of data; identification of specific indicators of success based on the criteria matrix; the ranking of indicators according to their frequently of citation; and then demonstrating how the framework of indicators can be used to evaluate the success of any MPA using a traffic light system, by applying it to a case study. An additional objective was to identify how such a framework might be adapted to data and expertise poor scenarios.

2.0 Materials and Methods

In order to begin the process of developing a framework that managers and decision makers can use to evaluate the success of any MPA worldwide, a systematic literature review (based on Pullin and Stewart 2006) was carried out. By analysing evidence from scientific journal articles that address the question, ‘What makes an MPA successful?’ this study aimed to provide stakeholders, policy makers, and management with key indicators of success which are straightforward to interpret and apply for their own specific use. Since new primary data collection is time consuming and costly, a systematic review approach combined with a traffic light system method of evaluation provides a straightforward system for managers to evaluate the success of marine protected areas and update that evaluation as new data become available. The framework also could be adapted for a variety of scenarios of data availability as will be discussed.

2.1 Search engine choice

The Web of Science was chosen as the most appropriate search engine option due to the: high level of reliable cited journal entries; ease of accessibility to third parties; and repeatability of searches. The search range was from the years 2000 – 2015 to gather the most current scientific results. Endnote was used as a repository for search engine results as it is highly compatible with Web of Science.

2.2 Systematic Review and Search Approach

A systematic review is a scientific approach that is a robust and quantitative way of reviewing literature and is the process of searching, selecting, synthesising and reporting evidence on a particular question or topic. It is currently considered the best, least biased and most rational way to organise, gather and evaluate literature (Ng and Peh, 2010). This method allowed for indicators of MPA success to be determined and ranked in order of most commonly used.

The steps of this systematic review are described below:

Step 1: In order to capture all recent papers concerning the evaluation of MPA success a Web of Science search was carried out with 10 primary terms covering the terminology for marine protection commonly found in the literature (Table 1). In addition, 5 secondary terms were added to the search to specify the focus of the search on MPA success or effectiveness. Despite this narrow focus, this process generated a list of 6,941 journal articles.

Table 1: Primary and secondary search terms for systematic review

Primary Terms (n=10)		**Secondary Terms (n=5)**
Marine protected areas	and	Success
Marine reserve		Effectiveness
Marine refugia		Failure
Marine refuge		Benefits
MPA		Indicator
Marine Parks		
Partial closure		
No-take zone		
No trawling		
Marine conservation zone		

Step 2: The large number of papers generated by Step 1 required further refining in terms of the relevance of the paper. The abstract and title of each of the 6,941 articles were read. Based on the identification of relevant articles and common terms used in Step 1, only articles which mentioned one or more of the following tertiary terms were included in the final list of articles: biological, biophysical, environmental, ecological, economic, social, socioeconomic, conflict, governance and stakeholders. These terms were chosen to cover the broad areas under which MPA success would be deemed successful by decision makers and other stakeholders. This process narrowed down the results to 966 papers by removing many papers which did not address the criteria of assessing an MPA's success or effectiveness.

Step 3: Upon reading the full-text of 966 papers from Step 2's results there were still papers, that although they included some of the search terms, did not address the topic of interest. These papers appeared to fit into two broad categories: journals with the search words in text but on an unrelated topic (e.g. Allan et al. 2008; Foster-Smith and Evans 2003; Ye et al. 2011); or those that were related to MPAs but only covered the theory behind the closure, design or implications for specific species (e.g. Alexander and Armitage 2014; Alfonso et al. 2008; Ban et al. 2012). Therefore based on the title and abstracts of the articles, further criteria for inclusion and exclusion were then applied (Table 2). In order to ensure consistency of the process and reliability of the outcome, the application of these criteria were applied by two independent groups of researchers who then agreed a final list of papers. This resulted in a final agreed list of 105 papers.

Table 2: Inclusion and exclusion criteria for systematic review

Inclusion	**Exclusion**
Mention of protected area, case study, area of MPAs, network of MPAs	Models predicting the outcome or impacts of an MPA
Clear outcome of designation/closure	Predictions and no reflections about the MPA
Reflection upon how designation process affected the MPA outcome	Estimations
Quantitative measurement of indicator	Potential of an MPA's effect on stakeholders mentioned with no actual outcome
Review of MPA success/result/indicators of success/outcomes of MPA history	If full text not freely accessible online

Step 4: The final 105 papers (peer reviewed and grey literature) (Appendix 1) were then read fully and inspected for indicators of success. Each indicator present in the literature was recorded in an excel spreadsheet and then ranked according to the number of papers in which it was found. The frequency was taken to represent the significance of the indicator in assessing the success of an MPA. For practical purposes the 15 highest-ranking indicators were used to form the final list of indicators of MPA success.

2.3 Application of indicator framework to a case study

The framework of indicators derived from the literature can be applied to MPA sites with varying degrees of data availability. Where some secondary data are already available in the scientific literature the systematic literature search can be carried out as above focusing on the MPA in question with records of changes to the indicators being made. Where no data are available the indicator framework can be used within a stakeholder workshop or focus group setting to elicit local knowledge about the state of change to those indicators. Here the case of Lyme Bay is described to demonstrate how the framework can be applied to a case study where some secondary data are available.

Case study - Lyme Bay

Lyme Bay is a southerly facing stretch of the South West coast located in England, at the border of Devon and Dorset. In July 2008, a 60nm^2 area of seabed in the bay was closed to scallop dredging and trawling creating the largest MPA in British waters (Figure 1) (Rees et al 2010a, 2010b; Sheehan et al, 2013a). The aim of the closure was to protect benthic diversity within the area, maintain the reef structure and enable the recovery of the benthos (Attrill et al., 2011). Although towed gear has been banned, the MPA still remains open to static gear fishers using pots and nets, recreational users, sea anglers, and scuba divers (Mangi, et al., 2011). The bay has also become a candidate Special Area of Conservation (cSAC) under the Habitats Directive; Regulation 35(3) of The Conservation of Habitats and Species (Amendment) Regulations 201 (McLeod et. al, 2005). The impacts of the MPA have been researched since the time of closure in 2008. For these reasons Lyme Bay is a

valuable case study to evaluate in terms of success against the most frequently cited indicators of MPA success.

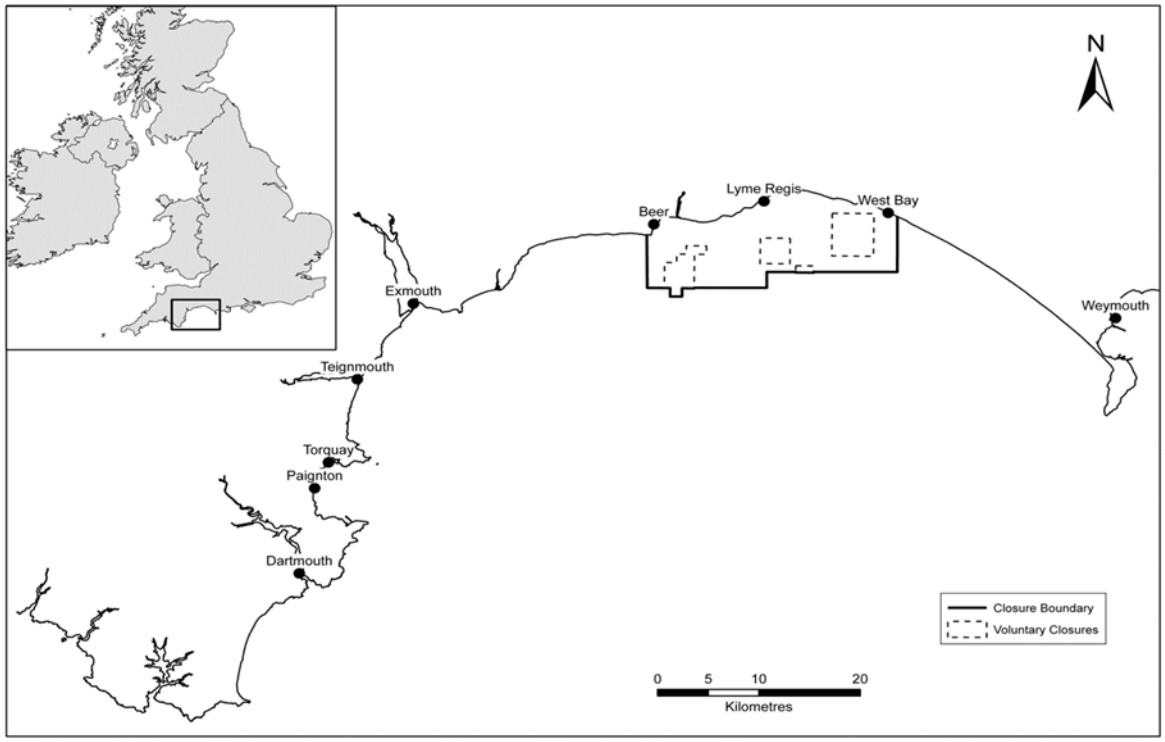

Figure 1: Map of the Lyme Bay MPA. The solid line represents the closure boundary and the dashed lines represent the voluntary closures (Cousens, 2015).

The method for the systematic review was replicated but using Lyme Bay as a specific case study resulting in a slight difference in the methods by using different terms in the review.

The steps of the case study specific systematic review are described below:

Step 1: The term “Lyme Bay” was included in this step to make sure this search is case study specific. This still resulted in 50 permutations (10x5x1) searched using Web of Science. This process resulted in 11 articles being found.

Step 2: The same systematic review method was used for the Lyme Bay MPA in order to demonstrate how the method can be applied to any case study for which some data are available. In this case there were only 11 articles found from the search, however, the process followed could be applied to case studies where far more data are available. The title and abstracts of the all 11 articles were read, further criteria for inclusion and exclusion were then applied (Table 2). This was carried out by two independent groups of researchers

to ensure consistency of the process and reliability of the outcome. This resulted in a final agreed list of 6 peer-reviewed articles (Appendix 2).

Step 3: The final 6 articles were then read fully and inspected for the final indicators of success. Each indicator present in the literature was recorded against the 15 highest-ranking indicators of success found in the general search.

Step 4: Rather than provide quantitative measures of success, the traffic light system uses colours to give a general indication of the level of success given the research findings to date. If the colour green is selected then this shows that the literature reported only positive improvements in this indicator (in this case for Lyme Bay). An amber colour suggests that both positive and negative aspects of change were reported. This would reflect for example that there were winners and losers amongst the stakeholders. Yellow was used to indicate that no significant change has been recorded. Red was used if the literature reported that the impacts overall were negative. The frequency of reports were recorded for each indicator mentioned.

3.0 Results

3.1 Indicators of MPA success

The systematic review determined 15 of the most frequently used indicators of success for evaluating the success of an MPA from three broad categories – biophysical, socio-economic and governance (Table 3) were consistent with previous studies such as MPA MEAT (CTI NCC, 2011). Of the generated indicators of success 4 were biophysical, 5 socio-economic and 6 were governance. The geographical range of the MPAs reported was global ranging from tropical to temperate regions.

Table 3: 15 most frequently cited indicators of MPA success (ranked in order of citations)

Rank	Indicator Type	Indicator of Success	Data requirements	Total number of papers (N=105)	Peer Reviewed articles	Grey literature
1	Biophysical	Area under no or reduced human impact	Quantify area closed	61	58	3
2	Governance	Level of stakeholder participation and satisfaction in management process and activities	Quantify stakeholders groups involved and satisfied with the management of the MPA through surveys	55	51	4

3	Socio-economic	Level of understanding of human impacts on resources	Survey stakeholders about their environmental awareness	52	51	1
4	Socio-economic	Local values and beliefs regarding the marine resources	Survey non-economic stakeholder groups about their perceptions on how marine resources are and should be used.	52	49	3
5	Governance	Level of resource conflict between stakeholders	Quantify conflicted stakeholder groups to find percentage of stakeholder groups who are in conflict	50	48	2
6	Socio-economic	Type, level and return of fishing effort	Catch per unit effort	48	46	2
7	Governance	Local understanding of local rules and regulations	Survey stakeholders about their understanding of the management regulations belonging to the MPA	48	46	2
8	Governance	Degree of interaction between managers and stakeholders	Number of attended meetings & workshops, other outreach including: emails, flyers, visiting local schools/stakeholders.	47	44	3
9	Governance	Existence and activity level of community organisation	Number of community members involved in MPA and what positive impacts are created from authority and organisation involvement.	47	44	3
10	Socio-economic	Local marine resource use patterns	Marine planning (spatial, economic, social, environmental) in place and updated as the MPA develops, Decision making body surveyed to reflect on their policies	46	43	3
11	Biophysical	Species abundance	The total number of species present in a MPA	45	43	2
12	Socio-economic	Community infrastructure and businesses	Percentage increase in employment and income for economically dependent stakeholders on the MPA	45	42	3
13	Governance	Existence of decision making and management body	Legal enforcement of MPA guidelines (e.g. number of prosecutions)	44	42	2
14	Biophysical	Protection of critical habitats such as coral reefs, mangroves, sea grass	Total area of critical habitats protected within the closed area (MPA)	39	37	2
15	Biophysical	Composition and structure of the community	Survey the species within the MPA	38	37	1

Governance indicators were most frequently cited with 6 out of the most frequent 15 indicators in this category (Table 3). However, the most frequently cited indicator of success

was a biophysical one, perhaps unsurprisingly, the 'area under no or reduced human impact'. This implies the importance of an MPA fulfilling its mandate of physically reducing human impacts. The most frequently used socio-economic indicator of success is 'local marine resource use patterns' in the MPA. This indicator implies the engagement by management in marine spatial planning of the local area is an important factor in the success of an MPA. The most common governance indicator of success was found to be the 'level of resource conflict'. This indicator focuses on the importance of keeping any animosity at a low level between various stakeholders.

3.2 Traffic Light System: Case study application

The systematic review of the Lyme Bay literature (n=6) showed that Lyme Bay has been a success based on the biophysical parameters with 3 out of 4 indicators (species abundance, composition and structure of the community, protection of critical habitats) showing positive changes since the closure. Based on socio-economic indicators, Lyme Bay's success was less distinct for two indicators (community infrastructure and business and type and level of return for fishing effort) which showed both positive and negative impacts from the closure in these areas (Table 4). Other socio-economic indicators (local marine resource use patterns, local values and beliefs and the level of understanding of human impacts on resources) showed positive changes. Most governance indicators were positive. However, the level of resource conflict showed both positive and negative impacts.

Table 4: Results of traffic light system of indicators specific to Lyme Bay.

Indicator Type	Indicator of Success	Traffic Light	Number of Papers (n=6)
Biophysical	Area under no or reduced human impact		5
Socio-economic	Type, level and return of fishing effort		4
Socio-economic	Local marine resource use patterns		4
Biophysical	Species abundance		3
Biophysical	Composition and structure of the community		3
Governance	Level of resource conflict		3
Socio-economic	Community infrastructure and businesses		3
Biophysical	Protection of critical habitats such as coral reefs, mangroves, sea grass		2

Governance	Local understanding of local rules and regulations		2
Governance	Degree of interaction between managers and stakeholders		2
Socio-economic	Local values and beliefs regarding the marine resources		2
Governance	Level of stakeholder participation and satisfaction in management process and activities		1
Governance	Existence and activity level of community organisation		1
Governance	Existence of decision making and management body		1
Socio-economic	Level of understanding of human impacts on resources		1

3.2.1 Biophysical

As a general trend the literature indicates in Lyme Bay closed area species have increased in abundance and biomass between 2008 and 2013, i.e. King Scallops, Ross Coral and Pink Sea Fans (Table 4). Sheehan et al. (2013b) and Rees et al. (2013) attribute this to the ban on detrimental fishing practices in the Lyme Bay MPA (Table 5). The existence of other stakeholder activities in the area such as diving, angling and potting explains the amber colour for the 'area under reduced or no human impact'.

Both the indicators of 'protection of critical habitats such as coral reefs, mangroves, sea grass' and 'composition and structure of the community' were reported to have been positively affected by the closure. The MPA resulted in increased area closure specifically to protect internationally important species such as ross coral (*Pentapora fascialis*), dead man's fingers, (*Alcyonium digitatum*) and pink sea fans, (*Eunicella verrucosa*). It also resulted in positive changes in assemblage composition (Sheehan et al. 2013b).

3.2.2 Socio-economic

Towed gear fishermen have experienced negative socio-economic impacts due to the Lyme Bay closure (Table 5). Towed gear fishermen spent longer at sea to maintain catch levels and some have found a general decline in the quality of their catch, resulting in a decline in their profits (Hattam et al., 2014). The findings suggested, however, that there may also be a positive outcome. Due to an increase in species abundance in the protected area the angling and potting fishing return is likely to increase hence the type, level and return on fishing effort was given an amber traffic light.

By assessing stakeholder satisfaction with Lyme Bay MPA the indicators 'level of understanding of human impacts on resources' and 'local values and beliefs regarding marine resources' were found to be positive due to reflection upon previous years research and stakeholder support of Lyme Bay (Rees et al., 2013; Sheehan et al., 2013 a, b). Sea anglers hold the highest amount of support for the MPA closure, while trawlers held the lowest (Rees et al., 2013). 'Community infrastructure and business' experienced a positive and negative impact with a reported decline for demersal trawling vessels and positive changes for sea anglers, single pot fishers and divers who have reported an increase in the quality of their experience in the closure area, which has strengthened the local economy and generated additional revenue (Rees et al., 2013).

Local marine resource use and patterns were evaluated as positive since all stakeholders, known by the management and their consultants, have been recorded and considered (Rees et al., 2013).

3.2.3 Governance

The number of stakeholders in conflict is low, as only towed gear fishermen have had cause to complain (Table 5). As their traditional fishing grounds shrink, towed gear fishers are now moving into historically static gear fishers' areas, causing damage to fishing gear and conflicts over catch rights (Rees et al., 2013). Findings, however, suggest that the longer the MPA has been in place the less conflict there has been between the stakeholders (Rees, et al., 2013). This indicator was given amber to reflect a transition to lower levels of conflict. The management at the Lyme Bay MPA can be judged as successful based on the mostly effective exclusion of mobile gear fishers from the protected area. This success is due in part to the increased community and stakeholder participation, understanding and satisfaction with regards to the management of the MPA (Rees et al, 2013). Rees et al., (2013) imply that the management of the MPA (the responsibility for which lies with the local Inshore and Fisheries Conservation Authorities IFCAs and ultimately the Marine Management Organisation) tries to provide for all stakeholder groups, through interaction with these groups. This management can be seen to be a success since the diving and angling community have experienced an improvement in their activities and some stakeholder groups have expressed an interest in being involved in management plans and activities. This increase in the activity level of community organisation suggest that the level of stakeholder satisfaction is increasing as all stakeholder groups, such as conservationists, businesses, mobile gear fishermen, are now included in the management process. Any discrimination felt by some stakeholder groups such as mobile gear fishermen just after the

closure have been improved. The increase in local understanding of rules and regulations with regards to the MPA suggest that the stakeholders have begun to recognise the importance of the closure to protect benthic diversity within the area; to maintain the reef structure and the recovery of the benthos. Although, just after the closure, the tensions were high for mobile gear fishermen, with the increased participation in management this conflict has started to decline. Stakeholders that can continue their activities within the MPA. For example, static fishers and divers have little conflict with each other. Rees et al., (2013) also suggest that the perceived economic and environmental benefits of the closure are greater than the costs.

Table 5: Examples of evidence of indicator changes

Indicator Type	Indicator of Success	Details
Biophysical	**Area under no or reduced human impact**	The Lyme Bay MPA, in south west UK, has excluded towed demersal fishing gear from 206 km2 of sensitive reef habitat using a Statutory Instrument since July 2008. Diving and potting activities still occur in the area (Hattam, et al., 2014, Sheehan et al., 2013a, b, Rees et al., 2010a,b and 2013)
	Species abundance	Within three years evidence of recovery was noted for species abundance (Sheehan et al., 2013b)
	Protection of critical habitats such as coral reefs, mangroves and seagrass	Protection was brought into force following concerns about the impact that towed benthic fishing gear has on marine habitats, especially mudstone reefs, as the designated area is home to a number of nationally and internationally important marine species (e.g. ross coral (*Pentapora fascialis*), dead man's fingers, (*Alcyonium digitatum*), erect branching sponges, pink sea fans, (*Eunicella verrucosa*) and the sunset cup coral (*Leptopsammia pruvoti*)) and is considered a marine biodiversity hotspot. (Hattam, et al., 2014, Sheehan et al., 2013b)
	Composition of structure of the community	Within three years following the cessation of towed demersal fishing, there were positive responses for assemblage composition (Sheehan et al., 2013b)
Socio-economic	**Level of understanding of human impacts on resources**	Without the support of key stakeholder groups whose user rights have been affected by the creation of an MPA, human impacts cannot be reduced (Rees et al., 2013)
		Over the past two decades, studies have increasingly attempted to understand the wider effects of fishing and other human activities on the marine environment (Sheehan et al., 2013a)
	Local values and beliefs regarding the marine resources	Sea anglers showed the highest amount of support for the Lyme Bay closure, followed by static gear fishermen. Mobile gear fishers held the lowest amount of support three years after closure (Rees et al., 2013).
	Local marine resource use patterns	There are sectors of the marine leisure and recreation industry (sub-aqua diving, sea angling and wildlife watching), which depend on the presence of natural marine resources in order to carry out their activity (Rees et al., 2010a)
		Stakeholder groups comprise of commercial fishermen, sea anglers, dive businesses, divers and charter boat operators (Rees et al., 2013)
	Community infrastructure and businesses	The MPA may have a negative impact on a business resource as a result of displacement of fishing vessels e.g. Diving companies (Rees et al., 2013)
		Sea angling in the south west region of the United Kingdom as a whole generates expenditure of £165 million each year (reported in Rees et al., 2010a)
	Type, level and return of fishing effort	By closing the area it has affected other areas. Small boats have been pushed into an ever small area (Rees et al., 2013)

		It has been said that some fishermen will benefit in the future from the overspill from the MPA (Rees et al., 2013)
		Mobile gear fishermen have experienced longer travel times to areas, which support the amount and quality of scallops they require to support their businesses. They have also seen costs increase and a decline in income due to time spent at sea, time spent fishing and fuel costs (Hattam et al., 2014, Rees et al., 2010b, 2013).
		Static gear fishermen who fish inside the closed area have seen changes in terms of increased fishing effort, mostly because they have been able to increase the number of crab and whelk pots they deploy (Mangi et al., 2011).
Governance	**Level of stakeholder participation and satisfaction in management process and activities**	Social costs are felt most by the mobile gear fishermen who feel a strong sense of unfairness and discrimination from the policy aimed at their traditional user rights (Rees et al., 2013)
		The mobile gear fishermen are the stakeholder group that provide the most feedback on the economic costs of MPA. As this group have the potential to impede the biological recovery of the site, effort has been made to ensure that they are involved in the MPA management process (Rees et al., 2013)
		Conservationists have had the main control over MPA designation, having recommended the closure to Marine Management Organisation (MMO) and DEFRA (Rees et al., 2010b).
	Level of resource conflict	Mobile gear fishers perceive they suffer the worst from the impacts of closure, unfairly discriminate and violate user rights. Mobile gear fishermen and the mixed gear fishermen have borne the brunt of this policy instrument as they are no longer free to make a living from a section of their traditional fishing grounds (Rees et al., 2013).
		Social tensions have increased, according to mobile gear fishermen, due to encroachment of mobile gear into stationary gear areas (Rees et al., 2013, Mangi et al., 2011)
		Perceived economic and environmental benefits of the Lyme Bay closure are greater than perceived economic and environmental costs (Rees et al., 2013).
		Static fishers and divers have benefitted as their activities are not impacted by mobile gear fishermen within the closure. Less conflict between practising stakeholders within the MPA (Rees et al., 2010b).
	Local understanding of local rules and regulations	Leisure and recreation stakeholders support the MPA closure (Rees et al., 2013).
		There has been an increase in angler time spent in closure area, angler catch and a reported higher quality experience and understanding of closure impacts for these stakeholders (Rees et al., 2013).
		Fishers and recreational stakeholders recognise the potential of the closure to provide a nursery ground for fish and larvae and protect rare national sea fan species (Rees et al., 2013).
	Degree of interaction between managers and stakeholders	Management of MPAs has tried to provide for all stakeholder groups. The issue of fair representation of stakeholder groups proves to be difficult in providing for all opinions. (Rees et al., 2013)
	Existence and activity level of community organisation	All leisure and recreational stakeholders support the MPA closure (Rees et al., 2013).
		Angler, divers, static and mobile gear fishermen have varying levels of support for the closure (Rees et al., 2013).
	Existence of decision making and management body	The diving and angling community have experienced an improvement in recreational activities quality (Rees et al., 2013, Rees et al., 2010a). Stakeholders have expressed interest in being involved in the management plans and activities (Rees et al., 2013) Lyme Bay MPA is now using ecosystem management approach (Sheehan et al., 2013a).

4.0 Discussion

4.1 A framework of indicators for evaluating MPA success

The framework of indicators of MPA success developed here from a systematic review of the literature provides a cost-effective method of evaluating MPA success by directing attention towards the key indicators of success. The framework can be applied in a variety of ways depending on the levels of data and expertise available to managers. Where data on these indicators are unavailable the framework provides a focus for discussion with stakeholders to elicit local knowledge on the changes in the state of these key indicators. It also provides a focus for future monitoring and attention should research and funding opportunities become available. Where data are available the framework focuses attention towards the research findings on key indicators of success. The traffic light system can provide either a qualitative approach (as demonstrated with the case of Lyme bay) where general indications of positive or negative changes in the indictors can be recorded and an amber light given for cases of ambiguity or, where good quality quantitative data are available, the framework can be taken a step here by calculating percentage changes recorded or mean levels of change over periods of time for these indicators.

Unsurprisingly, the most frequently cited indicator of success was a biophysical one. Before the initiation of the systematic literature review, it could be assumed that this was going to be a main indicator of success for MPAs. However, the process followed with the systematic review produces an objective view of assessing MPAs, which is not just based upon assumptions. By developing a success criteria matrix using a systematic literature review and showing that this can be applied to a case study, it is possible for this method to be used on other MPAs. It can provide a practical approach for managers facing similar questions about evaluating MPA effectiveness and a useful tool for any governing bodies under pressure from stakeholders to provide evidence for the progress of the MPA.

This framework complements efforts such as Marine Protected Area Management Effectiveness Assessment Tool (MPA MEAT) in Philippines which aims to help managers of locally managed MPAs evaluate their management effectiveness (rather than MPA effectiveness) (CTI NCC 2011). Our findings support ideas in the toolkit developed in terms of highlighting the governance indicators as amongst the most frequently cited indicators of MPA success or effectiveness.

4.2 Case study application

Using Lyme Bay as a case study demonstrated how the developed framework can be used to assess the biophysical, socio-economic and governance success of an MPA when some secondary data are available in the literature. It showed that a systematic review of the current literature, looking for the indicators developed in this methodology, would be a suitable way of assessing the success of any MPA worldwide. As MPAs are in place to manage and protect marine and coastal resources, and because a systematic literature review reduces bias, this method could be used to evaluate conservation goals at national, regional and global levels.

Many scientists, agencies, and governments have stated the potential benefits of MPAs, including the preservation and enhancement of marine communities for future generations (Eagles, et. al., 2002; Cleguer, et. al., 2015), although according to Hilborn et al. (2004) these potential benefits are rarely realised or quantified. If governing bodies continuously assess the success of their MPA, with this proposed framework of indicators and traffic light system, the full potential can be identified efficiently. Roberts et al. (2001) state that potential benefits of an MPA include: increased abundance and biomass of species within the MPA; notable increased age/size composition; an increased spawning stock biomass; and an overall increase in spill-over and larval supply, all of which are evident in our case study MPA, Lyme Bay. Once an MPA has been created, however, environmental success may not result in full socio-economic success (Roberts et al., 2001). This is also reflected to some extent in the case of Lyme bay where biophysical success in almost all the top indicators was met along with partial success in both socio-economic and governance indicators, the majority of indicators being positive.

4.3 Limitations and sensitivity

Like any study of this nature there are a number of shortcomings which should be acknowledged. Firstly, when evaluating the level of success there can be some subjectivity due to them time scale on which the success is being evaluated. To ensure a more robust conclusion of whether an MPA was successful or not , it would be useful to undertake a sensitivity analysis to reduce subjectivity. This would involve using different stakeholder groups to carry out the assessment and would, therefore, account for the different opinions. For example, the socio-economic impact on towed gear fishermen was given an amber colour in the case of Lyme Bay suggesting both positive and negative impacts. However, a different evaluator/group of evaluators may not have considered the potential future benefits from the implementation of the MPA and only considered the negative current situation, and

therefore given it a red colour. The results from the different sensitivities can then be compared to conclude whether the MPA was a success with regards to the initial objectives.

Furthermore, with a systematic review methodology, any number of terms could be used in the search terms. In this case some terms were based on the best knowledge of the authors according to prior knowledge of the literature and the initial steps taken in the process. Other methods of determining the best terms could be also used such as an expert panel.

In the case where very few articles are written on the MPA of interest all papers could be included in the process rather than undertaking a systematic review for that case study. In the case of Lyme bay few studies exist reporting on changes to the key indicators. Including all Lyme Bay papers rather than using the systematic review approach could have yielded different results in the traffic light system. However further consideration of articles previously omitted for Lyme bay did not alter the outcome.

The indicator framework developed here was based on the literature from 2000-2015 in order to get a current view of indicators of success. This period could be extended to get a complete view of the MPA literature. This would involve vastly more papers to analyse and may yield other indicators.

4.4 The applicability of framework using local knowledge

Though there may be limitations in the applicability of the method of systematic review due to lack of technical expertise in some countries, this limitation can be either mitigated by the international research efforts on MPAs or by the accumulation of local knowledge on the state of key indicators of success identified by this study. An accurate evaluation of MPA evaluation can be achieved regardless of data availability by focussing on these key indicators.

The local stakeholders involved in the design and maintenance of marine protected areas are likely to have significant levels of local ecological knowledge and this local knowledge can provide a valuable source of evidence and information for protected areas (Cook, et al., 2014) (Anadon, et al., 2009). Studies on fishermen in tropical developing countries found that their local knowledge was useful in improving the design and acceptance of MPAs (Bunce, et al., 2008). McKenna et al. (2008) also found that fishermen of Lough Neagh fishery were able to accurately able to draw a mental map of the entire lough suggesting that local knowledge is reliable.

Silvano & Begossi (2012) looked at using a ‘data less’ approach (use of local knowledge) when managing coastal fisheries in tropical developing countries, as these places lack

scientific information and sometimes local knowledge may be the only source of information. For example, at Buzios Island 61% of fishermen interviewed could report on the migration of H. balao and Seriola however there are no scientific surveys on these migratory patterns (Silvano & Begossi, 2012). Their study found that most of the local fishermen's knowledge agreed with biological data e.g. 92% of the fishermen reported that Kyphosus spp. browse algae which corresponded to scientific surveys.

When applying local knowledge, however, it needs to be considered that, in the evaluation of an MPA, the different stakeholders involved in monitoring and reporting, including managers and scientists, may have different priorities (Rogers, 1998), different personal outlook (e.g. optimism and pessimism), more knowledge about certain attributes or taxa than for others (Cook, et al., 2014), or incentives to distort the results that they report (Anadon, et al., 2009). For example if a poor condition of the MPA meant it would reflect badly on an individual's job performance, the individual may distort the results (Cook, et al., 2014). When evaluating an MPA it would be ideal to use a variety of knowledge sources, from lay to expert, as it has been found that local knowledge can be accurate but there are factors which could influence the accuracy (Yli-Pelkonen & Kohl, 2005).

A recommendation from this study is that for the many MPAs in the world which have not had the benefit of scientific studies being carried out, nor have the funds or expertise to carry out those studies, the framework developed here could be applied through stakeholder workshops and focus groups. The 15 indicators can be presented to stakeholders in their three broad categories (biophysical, socio-economic and governance) with open and closed ended questions to elicit the opinions of a broad range of stakeholders in terms of the direction of change, the degree of change and their confidence level of their own opinion. They can also be asked their perspective of success through their qualitative comments, in the same way that comments were recorded in the Lyme Bay case study based on the literature. The answers to these questions can then facilitate the population of a traffic light system indicating MPA success/failure in each category. Furthermore, stakeholders could agree a weighting system to prioritise the indicators. In this way, this framework can be seen as a broad and flexible tool for evaluating MPA success.

5.0 Conclusion

In this study a systematic review of the literature has led to a framework of the 15 most frequently cited indicators which can be used to assess the success of any MPA globally. This framework was applied to a case study to demonstrate how it can be used where some secondary data are available for the MPA in question. Despite potential limitations in the full application of the framework to some areas where expertise is lacking, the framework can be used flexibly and adapted to help guide decision makers at a variety of levels. For example, for those MPAs where no data are currently available the indicators can act as a focus for stakeholder evaluation of the success of a local MPA highlighting areas in which improvements are needed. This evaluation can be achieved through stakeholder workshops and focus groups where stakeholders use their experience and local knowledge to populate the data gaps. The framework can also offer managers a focus for future scientific monitoring and evaluation efforts over time subject to the availability of funds. For those MPAs where some primary and secondary data already exist a traffic light system can be applied directly to these indicators in order to evaluate the overall success of an MPA. The systematic review and traffic light approach employed in this study offers managers and decision-makers alike a cost-effective and time efficient method of gathering secondary data to evaluate MPA success. It should be noted, however, that MPAs are established to meet a variety of objectives and therefore the success of each MPA should be judged on the basis of their intended purpose with greater weighting being placed on those objectives. In the case of the Lyme Bay MPA the objectives were primarily to improve biophysical conditions in the area. On these grounds the MPA can currently be considered to have succeeded in almost all biophysical criteria as well as the majority of the top socio-economic and governance criteria. Further research findings can be applied to this indicator framework and any other case study to update the evaluation of an MPA's level of success. Furthermore, where more detailed quantitative data are available additional analysis can be added to the process to indicate the degree to which changes in the indicators have occurred. Ideally further data sources could be used in each case study to verify the changes in indicators, however, the framework can be adapted to suit varying levels of data and expertise levels.

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Appendix 2. Lyme Bay References

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