Perceptions of Practitioners: Managing Marine Protected Areas for Climate Change Resilience

Abstract

Climate change is impacting upon global marine ecosystems and ocean wide changes in ecosystem properties are expected to continue. Marine Protected Areas (MPAs) have been implemented as a conservation tool throughout the world, primarily as a measure to reduce local impacts, but their usefulness and effectiveness is strongly related to climate change. MPAs may have a role in mitigation through effects on carbon sequestration, affect interactions between climatic effects and other drivers and be affected themselves as the distributions of protected species change over time. However, to date, few MPA programmes have directly considered climate change in the design, management or monitoring of an MPA network. This paper presents a series of international case studies from four locations: British Columbia, Canada; central California, USA; the Great Barrier Reef, Australia and the Hauraki Gulf, New Zealand; to review perceptions of how climate change has been considered in the design, implementation, management and monitoring of MPAs. The results indicate that some MPA processes have already incorporated design criteria or principles for adaptive management, which address some of the potential impacts of climate change on MPAs. Key lessons include: i) Strictly protected marine reserves are considered essential for climate change resilience and will be necessary as scientific reference sites to understand climate change effects ii) Adaptive management of MPA networks is important but hard to implement iii) Strictly protected reserves managed as ecosystems are the best option for an uncertain future. Although the case studies addressed aspects of considering climate change within MPA networks and provided key lessons for the practical inclusion of these considerations, there are some significant challenges remaining. This paper provides new insights into the policy and practical challenges MPA managers face under climate change scenarios.

Key Words: adaptive management, climate change, conservation, marine protected areas, resilience

1. Introduction

Climate change in the marine environment is having a substantial impact on marine ecosystems, and there is an extensive body of literature evaluating these impacts (see Harley et al., 2006; Hoegh-guldberg, 2010; Pörtner et al., 2014). Climate change as a stressor on the marine environment operates at a global scale and therefore cannot be removed locally (Micheli et al., 2012). Marine Protected Areas (MPAs) as spatially explicit conservation tools cannot directly influence all impacts of climate change affecting species and habitat traits, however, MPAs are still a useful tool in climate change adaptation and mitigation (Côté and Darling, 2010; McLeod et al., 2009).

The predicted climate change impacts on marine ecosystems: temperature increases, rising sea levels, ocean acidification, changing circulation patterns, changes in weather conditions and dissolved oxygen levels (Hoegh-guldberg, 2010; Pörtner et al., 2014), can directly and indirectly affect species distributions and abundances, community composition, habitat quality, and changes in population dynamics (Cheung et al., 2009; Harley et al., 2006; Lawler, 2009). The cumulative effects of climate change and anthropogenic drivers, (e.g. fishing) can lead to complex patterns of change and result in enhanced vulnerability of natural and human systems (Halpern et al., 2008; Pörtner et al., 2014). At an ecosystem level, interactions between climate change impacts and fishing can enhance diversity loss in benthic communities (Griffith et al., 2011) and promote a change in ecosystem structure (Kirby et al., 2009). Additionally, the truncating effect of fishing on age and size structure of populations can lower population recruitment variability and reduce their ability to buffer environmental fluctuations (Perry et al., 2010).

Protection of marine biodiversity from local stressors, such as fishing, can enhance the resilience of species and habitats to climate change impacts (Micheli et al., 2012). Mitigation of global climate change may also be enhanced by protecting habitat areas that contribute to carbon sequestration, including mangroves, seagrasses, and salt marshes (Crooks et al., 2011). However, the low predictability and variability of ecosystems to climate change may undermine the effectiveness of conservation measures (Pörtner et al., 2014). As a result, there have been numerous calls to consider climate change in the establishment of MPAs to ensure marine biodiversity is protected effectively under future climatic scenarios (McLeod et al., 2009; Salm et al., 2006).

MPAs have historically been implemented on an individual basis to address local stressors, more recently, MPA networks have been planned to achieve larger scale conservation by protecting wider ecosystems and being strategically placed (IUCN-WCPA, 2008). An MPA network is intended to operate more effectively and comprehensively than individual MPA sites alone and over various spatial scales (IUCN-WCPA, 2008), however, there is little evidence of MPA sites within a network performing synergistically (Grorud-Colvert et al., 2014). An additional concern is that MPA networks have not been designed with climate change in mind (Gaines et al., 2010), and therefore, are not optimising potential benefits.

Conflict exists between local and national initiatives with differing priorities and differing capacities to implement MPAs or MPA networks. International and regional agreements require a network approach to MPA designation, yet these agreements rely on member states to implement the recommendations (e.g. The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)). Even where legal sanctions are available, there is no clear definition of a "network", against which MPAs could be tested.

Understanding the perceptions of those involved in resource management and conservation is important for understanding the policy process and the success of management action. Yet most research has focused on using the perceptions of end users to inform and improve resource management; a lack of research surrounding perceptions of environmental managers has been identified (Cvitanovic et al., 2014). Exploring the perceptions and opinions of those involved in MPA processes informs of operational and political realities that may not be published the academic literature. The aim of this study was to explore perceptions and experiences in four different case study locations of how climate change is considered in MPA processes and networks. Three key objectives of this study were: i) identify how climate change considerations have been successfully included in these MPA processes thus far ii) explore the perceived barriers to including considerations of climate change in these MPA processes iii) provide insights into best practice advice for climate change resilient MPAs.

2. Materials and Methods

2.1 Case Study Selection

Four case study locations were selected for inclusion in this study: British Columbia, Canada; Central California, USA; Great Barrier Reef; Australia and Hauraki Gulf, New Zealand. All had liberal democratic governments with functioning law enforcement systems, free press, market capitalist economies and well-developed expertise in marine science and conservation. The ecosystems considered varied from coral reefs to cold temperate coasts and coastal to offshore systems (see Table 1).

Table 1 Background on case studies.

Case Study	Planning region extent	Governance	Composition of MPA "network"	Climate change context	Ecological context	Key References
British Columbia, Canada	450, 000km^2 internal and offshore waters; 185 MPAs covering 28% coastline and 2.8% EEZ	First Nations Government, local, provincial and federal government responsible for proposing MPAs	MPAs designated under provincial or federal designations. Varying levels of protection from no-take areas to fisheries management areas	Recognition of climate change impacts in the marine environment in the academic and grey literature. Links between MPA network design and climate change.	Diverse and productive system; planning region incorporates inshore coastal areas and offshore seamounts.	(Ban et al., 2014; Burt et al., 2014; Government of Canada, 2014)
Central Coast California, USA	2,964km^2 of state waters: ocean, estuary, and offshore waters from Pigeon Point south to Point Conception; 29 MPAs covering 18% coastline or 535km^2	CDFW[1] responsible for MPA management, work with MPA Monitoring Enterprise (a programme of California Ocean Science Trust), California Ocean Protection Council and California Sea Grant	MPA classifications from strictly protected State Marine Reserves (SMRs) to areas where select recreational take activities are permitted.	Baseline data from the MPA network monitoring programme intended to be used to inform future climate change adaptation. Clear recognition in policy documents, grey and academic literature.	Temperate, biologically productive, dynamic oceanographic conditions, shallow estuarine habitat to deep sea habitat.	(California Ocean Science Trust and California Department of Fish and Wildlife, 2013; Fox et al., 2013; Saarman and Carr, 2013)
Great Barrier Reef, Australia	344, 400km^2 Great Barrier Reef Marine Park	GBRMPA[2], Federal Government Agency, is responsible for managing the GBR, in addition to the Queensland Government, and numerous advisory groups and stakeholder committees.	Multi-use MPA network, zoning plans set out areas where different types of fishing are allowed. Zones vary in protection from Preservation zones ("no-go" areas; no extractive activities) to General Use Zones (provide opportunities for use)	Climate change identified as one of the greatest threats to the long term health of the GBR. Clear recognition in policy documents, grey and academic literature.	Complex and diverse coral reef system; variety of marine habitats extending over shallow estuarine areas to deep oceanic waters.	(Day and Dobbs, 2013; Great Barrier Reef Marine Park Authority, 2014)
Hauraki Gulf, New Zealand	1.2 million hectares Hauraki Gulf Marine Park, 6 marine reserves	Regional Council, New Zealand Government	Two categories of MPA: Marine Reserves with the purpose of preserving marine life for scientific study and other MPAs established using other management tools and have a broad definition e.g. benthic protection areas	Recognition of climate change impacts in the marine environment in the academic and grey literature. No clear link between MPAs and climate change.	Gulf area extends from deep ocean to bays, inlets. Temperate, diverse and productive system.	(Ministry of Fisheries and Department of Conservation, 2008); (Ballantine, 2014)

[1]CDFW: California Department of Fish and Wildlife

[2]GBRMPA: Great Barrier Reef Marine Park Authority

In British Columbia, Canada, MPAs have so far been implemented on an ad-hoc, site by site basis with little overall co-ordination of protected sites and jurisdictional uncertainties (Ban et al., 2014). Yet there has been progress towards the design of MPA networks (Ban et al., 2014) with some discussion of climate change resilient MPA network design (Burt et al., 2014).

The Marine Life Protection Act (MLPA) (California State Law, enacted 1999) mandated a redesign of California's existing MPAs to create a state-wide MPA network (Fox et al., 2013) and the successful implementation of California's MPA network is often used as an exemplary case for stakeholder involvement in MPA design and planning. The MLPA requires each MPA to have goals and objectives, whilst collectively the MPA network should achieve the overall goals and guidelines of the Act (MLPA, 1999). A clear monitoring framework to evaluate MPA effectiveness was developed and the central California coast was the first region in the state wide network to report on the monitoring results after five years of the network being implemented (see California Ocean Science Trust and California Department of Fish and Wildlife, 2013).

The world's largest coral reef system, the Great Barrier Reef, Australia is managed by the Great Barrier Reef Marine Park Authority (GBRMPA) and is designed as a multiple use park regulating through a zoning plan. There is a clear recognition of climate change in monitoring and management of the Great Barrier Reef Marine Park as demonstrated by the development of a climate change adaptation strategy (see Great Barrier Reef Marine Park Authority, 2012) and the long term sustainability plan (Commonwealth of Australia, 2015) . It is also important to note the highly sensitive political nature of the GBRMP, with recent debates over the UNESCO World Heritage status and the threats posed by continued activities on and around the reef.

New Zealand has a long history of implementing marine reserves, with the first marine reserve, Cape Rodney-Okakari Point, in the Hauraki Gulf, established in 1975 under the Marine Reserves Act, 1971. However, these marine reserves were primarily designated for local protection and were established individually and independently, not considering larger scale processes or wider biodiversity (Thomas and Shears, 2013).

2.2 Data Collection

In-depth interviews were used to explore the range of opinions and experiences surrounding climate change and MPAs. The advantage of in depth interviews in untangling complex topics and exploring experiences and perceptions made this a particularly good method for this study (Qu and Dumay, 2011). Interviews were conducted with MPA managers, academics with experience of climate change and marine conservation interventions, NGO employees with a direct link to MPA processes in each case study region and governmental staff.

Interviewees were identified from a review of the academic literature and grey literature including government and NGO reports. Further participants were identified through snowball sampling. The interviews were conducted using a semi structured format which allowed for an open, flexible question order and discussion format (Bryman, 2008; Rubin and Rubin, 2012). The semi-structured format allowed the researcher to narrow the discussion topics, but the interviewees' responses determined the information produced about those topics and the relative importance of each of the topics (Green and Thorogood, 2014). After reviewing the literature regarding MPAs and climate change, five key topics were defined: i) MPA network design ii) policy structure iii) management of MPAs/networks iv) stakeholder considerations v) barriers to including considerations of climate change.

2.3 Data Analysis

Each interview was fully transcribed using QSR International NVivo software (QSR International Pty Ltd, 2010), which facilitated organisation, coding and retrieval of the data (Bazeley and Jackson, 2013). Coding is the process of data naming or labelling (Miles and Huberman, 1994). An inductive grounded theory approach to coding was chosen (as demonstrated in Alexander et al., (2013) to ensure that the codes generated remained "grounded" in the data (Corbin and Strauss, 2015). However, as this study did not aim to create theory, rather as an exploratory study it aimed to explore the key issues surrounding MPAs in the context of climate change in the four case studies, the grounded theory method was only used as a coding strategy (as demonstrated in Alexander et al., (2013)). The first step is to intensely code the data through a line-by-line analysis(Corbin and Strauss, 2015; Green and Thorogood, 2014) generating open codes or conceptual labels. These “open codes” were then grouped into focused codes by gathering those that appeared to relate to similar phenomena. The third step, more selective coding, builds relationships between categories from which the core categories or themes emerge (Figure 1.). Analytical memos were written throughout the analysis, which allowed the researcher to document emerging relationships between the codes and categories (Green and Thorogood, 2014).

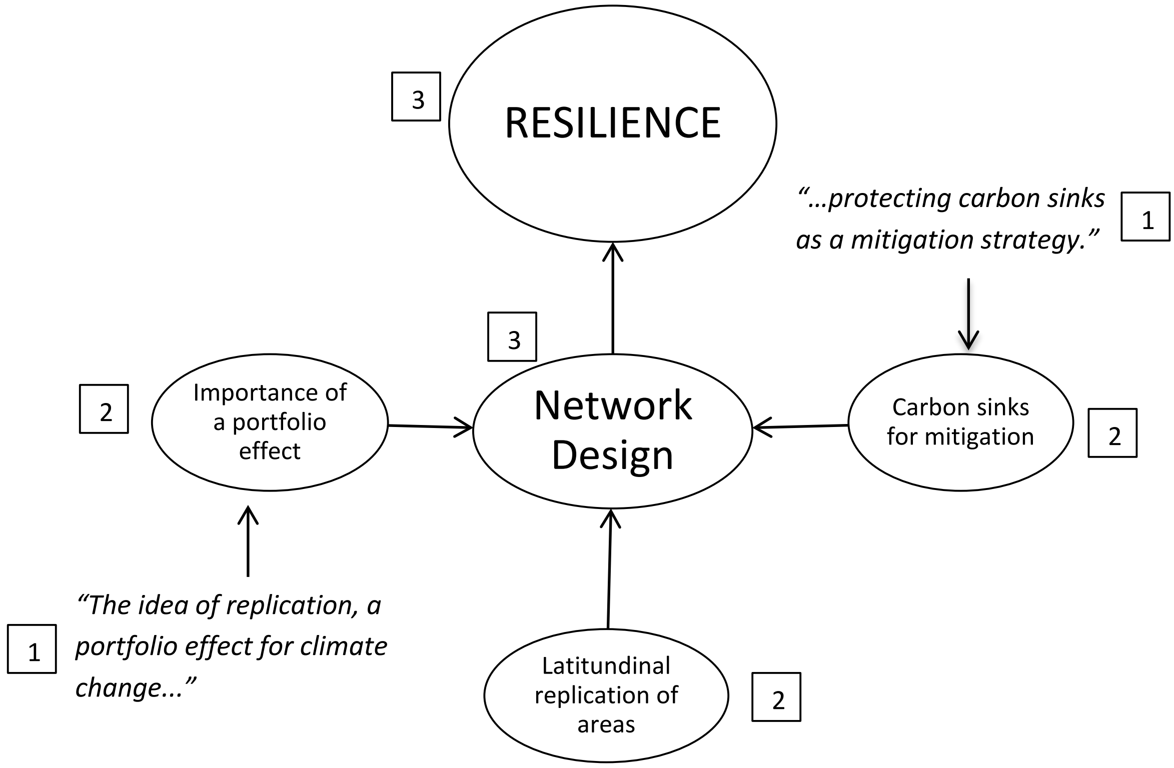

Figure 1 Diagram representing the coding process: (1) line by line analysis given a conceptual label or “open code”; (2) grouping “open codes” into focused codes; (3) linking focused codes into core categories and themes. Modified from Alexander et al. (2013).

3. Results

Twenty in depth exploratory interviews were conducted between February and April 2013, either face-to-face or using Skype software. Interviews were conducted with a mix of MPA managers, academics, NGO employees and governmental staff in each of the case study locations (Table 3). The type of participants in each location is indicative of those involved directly in the MPA process or having expert knowledge of climate change in the marine environment with reference to MPAs, The results are presented as follows: a description of the key themes identified in each case study with illustrative quotes followed by a cross-case study comparison for which conceptually-clustered matrices (as described in Miles and Huberman (1994) have been produced.

Table 2 Characteristics of interview participants

Interviewee	Job Role*	Case Study Location	Identification Method
Interviewee 1	NGO Employee	British Columbia	Grey literature
Interviewee 2	Academic	British Columbia	Academic literature, referral
Interviewee 3	Academic	British Columbia	Academic literature, referral
Interviewee 4	NGO Employee	British Columbia	Grey literature
Interviewee 5	NGO Employee	British Columbia	Grey literature
Interviewee 6	NGO Employee	British Columbia	Grey literature, referral
Interviewee 7	MPA Planner[1]	Central California	Academic literature
Interviewee 8	MPA Manager[2]	Central California	Grey literature
Interviewee 9	Governmental Staff	Central California	Referral
Interviewee 10	NGO Employee	Central California	Referral
Interviewee 11	MPA Manager	Great Barrier Reef	Referral
Interviewee 12	MPA Manager	Great Barrier Reef	Referral
Interviewee 13	Academic	Great Barrier Reef	Academic literature
Interviewee 14	Governmental Staff	Hauraki Gulf	Referral
Interviewee 15	NGO Employee	Hauraki Gulf	Referral
Interviewee 16	Academic	Hauraki Gulf	Academic literature, referral
Interviewee 17	Academic	Hauraki Gulf	Academic literature, referral
Interviewee 18	Academic	Hauraki Gulf	Referral
Interviewee 19	Academic	Hauraki Gulf	Academic literature
Interviewee 20	Academic	Hauraki Gulf	Academic literature, referral

*This refers to the job role category held at the time of the interview
[1] MPA planner: Active role in planning stage of MPA development
[2] MPA manager: Role in current management (at the time of interview) of MPA/MPA network

3.1 British Columbia, Canada

3.1.1 Future conservation values

How the marine environment is perceived and how marine services or biodiversity are valued under climate change scenarios was mentioned by several participants. One participant suggested that in current MPA processes, there is a need to consider how marine biodiversity will change in the future.

"I think another barrier probably is that we haven't yet had clear conversations about what values we want to see into the future… But those are the types of conversation that need to happen for us not only to adequately manage the current suite of values that we have, but to understand what is the value or the service that we desire so that we can

successfully manage a transition where a transition may be starting to occur." ***NGO Employee 6***

This relates to the setting of clear objectives and how these objectives might change in the future depending on how we view the marine environment and services we expect MPAs to deliver under climate change scenarios. There was recognition that as species and habitats change within MPAs, there will need to be a rethink about how we view biodiversity.

"So you might get different species there, some species might go extinct, other species, we don't call them invasive anymore, you have to call them climate refugees" ***NGO Employee 1***

By viewing species and habitat shifts due to climate change as part of an inevitable process, this could change the management of MPAs as fixed sites, with fixed species or habitat assemblages.

3.1.2 Design criteria for climate change resilience

A large amount of discussion was in reference to the scientific and ecological principles for good MPA network design. Some interviewees suggested that potential design criteria could ensure marine biodiversity was protected under scenarios of climate change.

"The idea of replication, a portfolio effect for climate change, we don't really know what's going to happen but if we have representivity and replication then that's our way of safeguarding against climate change." ***NGO Employee 5***

Specific ideas were proposed, such as selecting sites that have a direct link to climate change impacts. There was general agreement for protecting areas that will perhaps be more resilient to climate change, ones that are biodiversity rich, areas of high productivity or specific habitats that can act as climate change mitigation.

"I think the best thing that I've seen so far, which is climate change specific, is the idea of protecting carbon sinks as a mitigation strategy. Most of the carbon sinks are critical habitats anyway, so there's overlap there with the regular ecological principles." ***NGO Employee 5***

"So I think one way to resolve that would be to set up bigger MPAs than previously and actually encapture the area that would potentially be changing or affected under climate change." ***Academic 3***

There was some uncertainty regarding how the impacts of climate change would affect MPAs and therefore, incorporating good ecological principles was considered important. Some of strategies such as moveable MPAs were considered scientifically appropriate but politically unfeasible.

3.1.3 The slow process of implementation

The majority of respondents commented on the slow process in British Columbia of implementing marine protected areas. This was closely related to suggestions that incorporating climate change into network design is practically very difficult because the capacity or political will to do so is limited.

"To think about designing MPAs and thinking about how things might change and how that is incorporated into the network design is going to be a huge challenge…how [governments] are going to deal with something that's going to be dynamic and changing, we just don't seem to have things set up in a way that will make that easy to do." ***NGO Employee 4***

Concerns were raised that the slow pace and jurisdictional complexity of the MPA process was generating confusion and that incorporating considerations of climate change would add to a general feeling of process exhaustion. Several participants emphasised the close relationship between Canadian NGOs and the establishment of MPAs. It was explained that the various NGOs have different roles; some have an important role in providing and coordinating scientific advice for the establishment of MPAs and others have a strong lobbying role. It was viewed by some participants that NGOs and the First Nations Government were a driving force for implementation of MPAs along the BC coast.

3.2 Central California, US

3.2.1 Clear objectives

There was a consensus that clear objectives were needed in order to evaluate whether an MPA was successful. Several respondents mentioned the difference between site level, MPA objectives that often relate to stakeholder views of success, objectives that can inform monitoring effort and the overall goal of the Californian MPA network to protect marine biodiversity.

"In more recent years there's been more emphasis on the value of PAs, not just for productivity increases, but for resilience. They do harbour greater biodiversity and that is an important hedge against climate change impacts. Biodiversity and protecting the functions of ecosystems is one of the primary goals of the MLPA, so indirectly, there's a goal that related very strongly to climate change." ***NGO Employee 10***

Monitoring objectives for climate change were thought to be needed although there was recognition that climate change specific monitoring objectives had not been explicitly stated, instead objectives for protecting functioning whole ecosystems were acting as a proxy for resilience.

3.2.2 Strong monitoring framework

The connection between setting clear objectives in order to be able to evaluate the success of an MPA network and a strong monitoring framework was discussed. There was an acknowledgement that resources for monitoring are often limited, which therefore made the setting of very clear objectives that were measurable and realistic, a priority. Respondents discussed the value of citizen science for monitoring in relation to maximising resources and the huge task of monitoring, not only to ascertain success, but to also monitor for climate change impacts.

One participant suggested that monitoring would need to be adaptive; there may be other stressors or issues to monitor for in the future that will need to be incorporated into a monitoring framework.

"One of the things that we recognised early on is that if we're thinking about monitoring towards broad goals like those in the MLPA, that talk about protecting ecosystems, surely

*we should be able to have some pieces that we can add onto the core monitoring framework that address other issues whether it's fisheries or invasive species or climate." **NGO Employee 8***

There was also the recognition that in terms of climate change impacts, monitoring will have to be coordinated across the state, such that monitoring of individual MPAs should feed into broader scale monitoring of large-scale impacts. One participant mentioned that there is one entity for managing the network state wide, therefore the capacity for monitoring impacts should be in place.

3.2.3 An adaptive approach

The importance of having an adaptive approach to the overall management of an MPA network was emphasised in the context of climate change, yet more work to understand how adaptive management would work in an MPA context was needed.

*"I think the major knowledge gap is how do we manage these things and then how do we monitor them with good questions and good metrics and answer the right questions and then based on that monitoring, how do we know how to change the network how it needs to be changed. I think that is a major area that we really need to think about more and it's going to be really tough and it's going to be critical to the network's success." **MPA Planner 7***

Adaptive management was discussed in relation to monitoring and how monitoring should look at *what* elements are changing, but also should be attempting to answer *why* things are changing.

3.3 Great Barrier Reef, Australia

3.3.1 Clear recognition of climate change

There was a clear recognition that to manage the GBR, climate change must be recognised and be at the forefront of management and monitoring.

"…really up front recognition of climate change right from the start in as many places as possible. As in all the aspects of the planning. It's not the only consideration but it has an influence of so many aspects of what marine park management and design is all about. If

it's one of the things that's on the table at the start, it will just naturally be part of the conversations and the decisions and it's not something that has to be overlaid later." ***MPA Manager 11***

Two respondents noted that climate change was specifically addressed in reporting on the state of the network and also is recognised in relation to business and users along the GBR. Respondents also gave specific examples of adaptive management and highlighted the importance of such approaches in the face of climate change. One respondent noted the possible need for an "interventionist approach".

3.3.2 Multiuse MPA network

There was some discussion of the zoning approach to the GBR, particularly in relation to the importance of preservation "pink" zones as scientific baselines; one participant suggested that there should be more of these areas. Also, that for "green" no-take areas to be effective long term they would need to be integrated into broader scale management.

"I'm really worried when I talk to people around the world about MPAs that there seems to be a real focus on just the no-take part of it. And what I've seen is people setting up these really small no-take areas, which are really resource intensive and are set within a sea of unmanaged, overfished and polluted, and these aren't going to be viable in the long term." ***MPA Manager 12***

It was suggested that there should be an allowance for users in an MPA network, but there should be a core of strict protection that integrates into other management. There was a sense that users should be "stewards of the reef" and large-scale impacts such as climate change would require collaborative management.

3.3.3 Managing for climate change impacts

One participant related managing for climate change impacts to providing refugia from disturbance events, and protection of recolonisation sources to minimise the chances of losing a whole system or MPA through a single disturbance event.

"Thinking about risk based approaches, that is something we're starting to do a lot of in the way we think and some of the projects looking at cumulative impacts and multiple scale, geographically and otherwise of multiple impacts and accumulations of impacts." ***MPA Manager 11***

There was an emphasis on cumulative impacts and minimising these through integrated management on land and sea. However, one respondent stated that although work had begun to understand cumulative impacts, there was still a knowledge gap in terms of how impacts may interact synergistically.

3.4 Hauraki Gulf, New Zealand

3.4.1 Marine reserves

Strong opinions were given in reference to the importance of strictly protected marine reserves (as compared to multi-use MPAs where some extractive activities are still permitted). It was suggested by the majority of respondents that marine reserves are important for climate change resilience.

"I guess one of the big things about marine reserves in relation to climate change is it's been shown that marine reserves are more resilient to change, and perturbations of various sorts. If there is a problem they tend to recover quicker than fished areas." ***Academic 18***

In addition to the importance of marine reserves for resilience, the importance of marine reserves as reference areas was also discussed in relation to climate change.

"The other thing is that by having [marine reserves], you also provide for monitoring, so that you can actually monitor the response of ecosystems and the populations of species to a changing climate and ocean acidification in the absence of confounding factors such as human impacts." ***NGO employee 15***

Several participants commented on the importance of being able to monitor in undisturbed areas, free from extractive activities in order to understand changes without confounding effects.

3.4.2 Importance of monitoring

Several participants mentioned the importance of monitoring in order to understand whether the management action is effective. There was some discussion that in the context of long-established marine reserves, monitoring objectives have changed over time, and this should be recognised as part of an adaptive monitoring approach. Newly established reserves were monitored for initial changes resulting from protection, however, now they can form part of a long term monitoring programme to identify climate change impacts across a network. Several issues relating to the lack of monitoring and the resulting problems were raised by respondents.

"The concern is that the monitoring that's been done, isn't been done well enough; with the right methods, the right experimental design, the right replication to detect an effect, to really know if there is an effect. And also, without information prior, it's quite hard to know how effective an MPA has been". ***Academic 17***

A concern, however, was that there are always limited resources, and therefore the monitoring task for a large scale network is huge, and incorporating more factors (including climate change) adds to this large monitoring load.

3.4.3 Limitations of the process

The majority of respondents reported on the limitations of the Marine Reserves Act for establishing MPAs for any other purpose than for scientific research. Respondents considered that for an MPA network to be effective into the future, New Zealand should build on the foundation of marine reserves and include conservation of biodiversity as an objective for new MPAs, in line with international policy.

"It's interesting because in New Zealand, you've got the history of setting up reserves under scientific use and most countries now, have moved to the idea of biodiversity conservation for their MPAs." ***Academic 16***

There was criticism of the MPA process in New Zealand, which most respondents felt was politically stalled with no momentum to drive forward the implementation of a functioning network of MPAs. One respondent commented that there was no "strategic oversight" for an MPA network to be created, and another respondent commented that any policy documents produced were vague and scientifically lacking.

3.5 Cross Case Study Comparison

Comparisons between case studies yielded emergent themes of characteristics of MPAs for climate change resilience (Table 4) and the perceived barriers to including considerations of climate change in MPA processes (Table 5). Through the cross-case study analysis four key issues emerged and were identified which are presented in the Discussion.

Table 3 Conceptually clustered matrix: characteristics for climate change resilient MPA networks. The characteristics in italics are discussed further in the text.

Characteristics (Based on participant responses)	**British Columbia, Canada**	**Central California, US**	**Great Barrier Reef, Australia**	**Hauraki Gulf, New Zealand**
Design				
Effective protection/Marine reserves	X	Y	Y/X– consensus for the need of them but debate around their effective inclusion	Y/X– consensus for the need of them but debate around their effective inclusion
Moveable MPAs	X			X
Adequate size	Y	Y	Y	
Forecasting resilient sites	X		-	
Buffer zones	X			-
Mitigation sites (e.g. carbon sinks)	Y	Y	Y	X
Replication/Portfolio Effect	Y	Y	Y	-
Representative	Y	Y	Y	-
Connectivity	Y	Y	Y	X
Clear, measurable objectives	X	Y	Y	-
Protecting ecosystem functions		Y	Y	-
Specific recognition of climate change in design	Y- discussions in the NGO community	X	Y	-
Coherent network		Y		X
Monitoring				
Climate change indicators	X	Y	Y	Y
Citizen science	Y	Y	Y	
Baseline data	X	Y	Y	Y
Long term monitoring	X	Y	Y	Y
Strong framework	X	Y	Y	
Monitoring coordinated as a network	X	Y	Y	
Reference sites for monitoring		Y	Y	Y
Management				
Adaptive approach	X	Y	Y	X
Incorporating updating scientific information	Y	Y	Y	-
Long term commitments		Y	Y	-
Co-operation between agencies	X	Y	Y	-
Enforcement	Y	Y	Y	-
Flexible activities management	Y	Y		

Proactive versus reactive	X	Y		
Additional management measures	X	Y	Y	-
Leadership			Y	X
Integrated planning land and sea		-	Y	-
Other				
Reviewing gaps in protection	X	Y	Y	-
Considering future values for biodiversity	Y-discussions in the NGO community			
Communication with users/stakeholders	Y		Y	-
Public engagement		Y	Y	X
Facilitating policy environment	X	Y	Y/X- consensus for the need of but debate around effective inclusion	X
Independent scientific advice	X	Y	Y	Y
Long term vision		Y	Y	-
Vulnerability assessment			Y	
Recognition of climate change in all aspects of the process		X	Y	X

Y- Characteristic referred to by respondents and considered to be included (or intended to be) in the MPA process

X- Characteristic referred to by respondents, but not considered to be included in the MPA process/not explicitly referred to in the process

- Discussed by respondents but no reference to the specific case study MPA network/process

Table 4 Conceptually clustered matrix: analytical codes concerning perceived barriers to including considerations of climate change in MPA process. The barriers in italics are discussed further in the text.

Characteristics (Based on participant responses)	British Columbia, Canada	Central California, US	Great Barrier Reef, Australia	Hauraki Gulf, New Zealand
Design				
Ability to adapt the network design over time	X		Y	X
Understanding ecosystem connectivity			Y	X
Counterproductive targets		Y		
Lack of scientific guidelines				X
Lack of effective protection	X		Y/X	Y/X
Different objectives for or perceptions of a successful MPA				X
Monitoring				
No clear questions for monitoring		Y		-
Resources			Y	
Need for long term monitoring				-
Management				
How climate change affects the activities being managed		Y	Y	
Bad relationships with network users		Positive relationships described	Y	-
Decision making for changing the network			Y	
Understanding cumulative impacts			Y	
Communicating scientific advice to managers			Y	
Lack of resources	X	Y		X
Lack of adaptability	X		Y	X
Other				
Scientific understanding of impacts		Y	Y	
Inflexible policy environment	X		X	X
Understanding socioeconomic impacts		Y		
Lack of communication/public engagement			Y	X
Shifting baselines			Y	
No political will			Y/X	X
Slow process	Y/X		Y	X

Understanding how to engage stakeholders	X	-
Conflict between policy departments		X

X perceived as a barrier by respondents
Y perceived as a barrier but also recognise there is capacity to overcome the barrier
Y/X perceived as a barrier but some debate from respondents as to the capacity to overcome the barrier
- Discussed by respondents but no reference to the specific case study MPA network/process

4. Discussion

Four key issues for incorporating climate change considerations into MPA processes emerged through in-case study analysis and cross-case comparisons and are presented below. The aim of this study was to document specific perceptions and opinions in the context of each case study location, as such, the results presented are not intended to be generalised. Indeed, the success and effectiveness of MPA processes is highly context dependent. However, the key issues that emerged were comparable across case studies and are in agreement with the wider literature concerning MPAs and climate change.

4.1 Effective protection is needed for climate change resilience

Discussions of how MPAs could still be effective in the face of climate change centred on the concept of marine reserves; protected areas of strict protection with no extractive activities. Nearly all respondents proposed that reduction of other anthropogenic stressors (e.g. fishing pressure) through the use of marine reserves, may contribute to reducing the impacts of such a major climatic disturbance by enhancing local resilience of populations and ecosystems.

Studies suggest the most resilient populations and communities to climatic change are those that are stable and intact and protection of such areas may reduce the risk of biodiversity loss (Harley et al., 2006; Hughes et al., 2003). Known spatial and temporal refuges may act as buffers against climate-related stress (Harley et al., 2006; Keller et al., 2009) and protected, less degraded coral reefs have been shown to return to their original state more rapidly after perturbations (e.g. bleaching) when compared to unprotected, damaged or degraded reefs (Côté and Darling, 2010; Halpern and Warner, 2002). However, some studies argue this may be fundamentally incorrect and such resilience-focused management may in certain cases result in greater vulnerability to climate change impacts. For example, Graham et al., (2008) demonstrated little difference between no-take zones (NTZs) and fished areas in coral cover declines following a bleaching event; indicating isolated, small scale marine reserves surrounded by exploited areas are not effective for climate change resilience.

Not only was the need for strictly protected reserves discussed in relation to increasing resilience, but it was also suggested that reserves were needed as an integral part of MPA networks to function as reference sites. In New Zealand, the original purpose of many of the marine reserves was to allow scientific research to proceed in the absence of factors such as fishing or other types of extraction. In the face of climate change, these reference sites will be critical for monitoring broad scale climatic impacts in the absence (or near absence) of human impacts.

Most interviewees stated the importance of strictly protected areas in safeguarding biodiversity under climate change scenarios and that marine reserves should be the "backbone" of an MPA network surrounded by buffer zones of management fully integrated into marine spatial planning and other conservation interventions. Yet, there are criticisms of processes that establish no take areas as in Australia (see Devillers et al., 2014), or "benthic protection zones" as in New Zealand, which are already in areas where anthropogenic impacts are minimal to non-existent. These areas add little if any extra protection for biodiversity, and therefore little in the way of climate change resilience; unexploited areas also tend to be different ecosystems (Devillers et al., 2014). Additionally, the use of these areas for reference sites is limited if the goal is to understand how an area can recover from extractive activities or to disentangle the effects of fishing and climate change if they are different from fished areas in other ways.

4.2 Why monitoring for effectiveness is key

Realistic and achievable objectives for an MPA and the measurement of their achievement are a crucial aspect of long-term management (Syms and Carr, 2001). Whilst some respondents saw the setting of climate change specific objectives as important, others suggested that it adds a level of uncertainty or complexity that would be difficult to measure. Studies have highlighted that where the vision for an MPA network or objectives are not clear or apparent, the MPA process is ineffective (Guénette and Alder, 2007). Several concerns were raised regarding the setting of clear objectives for individual MPAs/MPA network and many saw unclear objectives as a potential barrier to assessing whether an MPA was successful in the face of climate change. However, these objectives should recognise that biodiversity values under climate change may change, for example, if an MPA is designated for a particular species, which undergoes a range shift and is no longer present within the MPA, the MPA may be seen as ineffective. Participants suggested that discussions are needed as to how marine biodiversity is valued, either in terms of services, or species and habitats and whether these will be preserved under climate change.

The challenge is to develop targets and evaluation protocols that are robust to the many sources of uncertainty inherent in managing natural systems. Effectiveness targets must be established with the understanding that the natural world is variable, and there is a degree of uncertainty at every level of inquiry and management action (Syms and Carr, 2001). A structured approach can incorporate variability into setting targets and evaluating performance, which can in turn be explicitly incorporated into management plans (Syms and Carr, 2001). Stakeholders may also hold very different views to management as to what constitutes success (Himes, 2005). Indeed the results of this and other studies suggest that there may be a mismatch between different stakeholder and MPA practitioner groups as to what contributes success at the level of the individual MPA and at a network scale, which must be addressed.

4.3 An adaptive approach

Respondents noted the need for adaptive management in the face of climate change, which corresponds to other studies of MPA managers (e.g. Cvitanovic et al., (2014)) that suggest adaptation would allow decision makers to develop proactive management measures. However, the results of this study suggest that there is a perception of a need for MPA processes to be adaptive, whilst in reality few can demonstrate current adaptive management or the legal or scientific capability to carry it out in the future.

New Zealand has a long history of implementing marine reserves, yet the ad hoc approach to designation of small scale reserves has not resulted in an ecologically coherent network (Thomas and Shears, 2013), which could leave isolated marine reserves vulnerable to the impacts of climate change (Cicin-Sain and Belfiore, 2005). Incorporating these reserves into a connected and functional network has been a priority for New Zealand for some time, yet the process is stalled and at present the singular reserves could be left vulnerable. A lack of political will or foresight in MPA management is a barrier for an adaptive approach.

Cvitanovic et al., (2014) found that Australian MPA managers considered adaptive management critically important in a climate change context, yet felt they did not have enough knowledge regarding adaption to make informed assessments. This is line with suggestions made in this study by respondents in California, proposing a possible barrier in implementing adaptation was a lack of understanding of how adaptation would work in practice. A resistance to adaptation by governments (Cvitanovic et al., 2014) and also by stakeholders (Mills et al., 2015) is another barrier. The slow process to establish an MPA, and a policy structure that would require any changes to boundaries or specific management measures, to go through an application process for a new MPA in Canada, would result in a long and complex process to make slight alterations. Adaptation is recognised in the management of the Californian MPAs, but respondents also stated that the whole concept of adaptive management would need to be more clearly defined if it was to be successful.

Tracking changing conditions through the use of moveable MPAs was suggested as an adaptive approach and the concept has had some attention in other studies (see (Game et al., 2009; Pressey et al., 2007). However, tracking rapidly shifting species ranges may not be appropriate; MPAs designated for single species may also be deemed ineffective if a species moves beyond the protected boundaries. Most respondents in this study suggested that although moveable MPAs was scientifically feasible, it would be politically impractical.

4.4 When to incorporate climate change considerations?

Throughout this study MPA practitioners suggested considerations of climate change should be included in the early design stage of the MPA process. Perceptions of what design criteria would be important in a climate change context closely resemble the guidelines developed for climate change resilient MPA networks (see Brock et al., 2012; Burt et al., 2014) and are based on general ecological principles for MPA network design (see McLeod et al. (2009), Foley et al. (2010), Fernandes et al. (2012)). Key points raised in this study for climate change resilience were: ensure key ecological principles for good MPA network design are followed; the inclusion of strictly protected reserves is critical for resilience; and the inclusion of areas already showing signs of climate perturbation or areas having a mitigation role e.g. blue carbon stores. Several issues were raised relating to “selling” MPAs to stakeholders on the basis of requiring them for climate change resilience and whether stakeholders would understand or consider this an important reason for their designation. However, by addressing climate change resilience in terms of protecting the full suite of biodiversity and ensuring ecological principles are met, it was thought that this conflict could be avoided.

Although it was wholly considered important to address climate change in the design phase, some MPA network processes are now moving past initial designs, therefore it will be important to assess if climate change considerations can be included retroactively. Gaines et al., (2010) recommended considering whether networks designed under prevailing environmental conditions will be effective under projected spatial and temporal variation in climate impacts. Potentially, networks could be designed using forecasting methods selecting areas for protection that would safeguard biodiversity into the future (Johnson and Holbrook, 2014). The difficulty in this approach is the inherent uncertainty; forecasting suitable areas would not work for a species-based approach where the presence of a species is required now, not at some point in the future (e.g. Scotland’s MPA process). Therefore, it is likely that MPA networks will need to be adaptively managed (McCook et al., 2010)

Key principles and design criteria for good network design and management can still be incorporated through an adaptive approach. Reviewing an MPA network will allow MPA managers to fill-in the gaps in protection for climate change vulnerable habitats. However, in the context of British Columbia, there was strong recognition for good design, yet the process to establish new MPAs was extremely long and complex. Therefore, the capacity for reviewing and including new information at a network scale needs to be increased.

MPA processes should not be seen as reaching a static endpoint; adaptive management is the ability to continually incorporate new knowledge through a process of monitoring, review and redesign (Day, 2008). As the scientific knowledge regarding climate change impacts, resilience and adaptation/mitigation improves, it will be imperative for the success of MPA networks that new scientific information actively informs the MPA process. Studies have shown that some MPA managers may be unaware of the breadth of scientific information, which could inform decision making (Cvitanovic et al., 2014), and participants in this study reported policy documents in New Zealand to be scientifically lacking. Therefore it will be important to improve the uptake of MPA and climate change science into policy.

There is a strong theoretical basis for including climate change considerations within current MPA networks, whether from a design starting point or retroactively adding in design or management considerations through network review or including climate change related criteria in a monitoring programme. However, most respondents in this study suggested there is only limited evidence of these lessons actively being implemented. A unifying idea here is that MPAs are seldom designed like experiments with fair controls, so evaluating their success or failure (or whether trends within them are caused by climate change) is inherently very difficult.

5. Conclusions

The respondents in the four areas studied considered strictly protected marine reserves essential when considering climate change in MPA networks, given that complete and healthy ecosystems are thought to be more resilient to climate change. Reference areas will be critical to understand climate change impacts and effects supported by monitoring over medium to long term timescales. Adaptive management of MPAs is an idea that is good in theory, but difficult to implement due to legal or political barriers and realities. Further exploration of how adaptive MPA management occurs in different contexts is warranted. MPAs should be designed and implemented as a network using an ecosystem based approach; single species may move with climate change meaning MPAs sites designated under a single-species approach may be ineffective in the future. By following an ecosystem-based approach, you may not need to move MPAs, but more strictly protected ones may be required. The less strictly protected the MPAs are, the more monitoring data will be required to ensure the MPAs are effective (depending on their criteria for success) and the more management would need to be adaptive. Therefore, given the uncertainty under climate change scenarios, the difficulties of adapting MPA networks once they are in place, limited resources for monitoring and for reiterating the policy cycle, the key question is that to protect biodiversity, do reserves with strict protection make sense?

Understanding perceptions of how climate change knowledge has been included in MPA network processes will help inform best practice advice for decision makers in the future design, monitoring and management of MPA networks. Resolutions over how marine biodiversity is to be valued in the future and an understanding of how MPAs will contribute to these future values is needed. Finally, a restating of clear hierarchical objectives, which include climate change relevant objectives, and integration of these into a strong monitoring framework should be of importance. Critically these ideas need to be actively implemented through active and adaptive policy design not passively acknowledged.

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