MARINE PROTECTED AREA NETWORK DESIGN FEATURES THAT SUPPORT RESILIENT HUMAN-OCEAN SYSTEMS

Applications for British Columbia, Canada,

December 2014

Jenn M. Burt | Phillip Akins | Erin Latham
Martina Beck | Anne K. Salomon | Natalie C. Ban

MARINE PROTECTED AREA NETWORK DESIGN FEATURES THAT SUPPORT RESILIENT HUMAN-OCEAN SYSTEMS

- APPLICATIONS FOR BRITISH COLUMBIA, CANADA -

Authors

Jenn M. Burt^{1,3*}, Phillip Akins², Erin Latham², Martina Beck², Anne K. Salomon^{1,3}, Natalie C. Ban²

1 - School of Resource & Environmental Management, Simon Fraser University, Burnaby, B.C., Canada

2 - School of Environmental Studies, University of Victoria, Victoria, B.C., Canada

3 - Hakai Institute, Tula Foundation, Quadra Island, B.C., Canada

* Corresponding author - jenn.burt@gmail.com

Report section lead authors: (1) JMB, (2) JMB, (3) PA, (4) JMB, (5) EL, (6) JMB

Citation

Burt, J.M., Akins, P., Latham, E., Beck, M., Salomon, A.K., Ban, N.C. 2014. Marine protected area network design features that support resilient human-ocean systems - Applications for British Columbia, Canada. Simon Fraser University. British Columbia, Canada. 159 pp.

Web location

<http://www.sfu.ca/coastal/research-series/listing/marine-protected-area-network-design-features-that-support--resi.html>

Disclaimer

This first version of this document was prepared for the Kitasoo/XaiXais First Nation and the Great Bear Initiative Society in July 2013. The contents are the responsibility of the authors and do not necessarily reflect the views of the Kitasoo/XaiXais First Nation or the Great Bear Initiative Society.

Funding

Funding for this report was provided by the Kitasoo/XaiXais First Nation and Coastal First Nations-Great Bear Initiative Society. Additional support for J.M. Burt's time was provided by NSERC and through the Hakai Institute as a Hakai Scholar. A.K. Salmon was supported by NSERC and the Hakai Institute, and N.C. Ban by NSERC and SSHRC.

Acknowledgements

We would like to thank the following persons who provided inputs and assisted with review: Dr. Dana Haggarty, Dr. Katie Lotterhos, Dr. Jeff Marliave and Jan Freiwald kindly reviewed our Adult Species Movement and Larval Duration tables. Jennfier Carpenter (Heiltsuk Integrated Management Resource Department) provided valuable information on culturally important species. Dr. Sam Gilchrist (Seabass Studios) produced Figure 3 showing species movement patterns, and Andy Lamb and Gloria Snively provided the fish and invertebrate illustrations. Karin Bodtke, Dr. Katie Lotterhos, Sabine Jessen, and Dr. Mark Carr reviewed the 'Ecological Design Principles' section of the report. Dr. Phillip Dearden and Sabine Jessen reviewed the Governance section. Sabine Jessen reviewed the 'Social Goals' section. Dr. Nancy Turner, Dr. Jonaki Bhattacharyya, and Dr. Valentina Savo kindly reviewed the 'Knowledge Integration' section. General support, guidance and feedback was provided throughout by Ken Cripps and Steve Diggon. Any errors and omissions in this report are those of the authors and not of the reviewers listed above.

Report layout and production by Alison Harwood of Boldfish Creative (www.boldfishcreative.com)

Cover photo: Lisa Williams (marina), Lynn Lee (kelp forest)

© 2014 Simon Fraser University. All rights reserved. Reproduction and dissemination of material in this report for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holders provided the source is fully acknowledged. Reproduction of material in this information product for resale or other commercial purposes is prohibited without written permission of the copyright holders. Applications for such permission should be addressed to Jenn Burt via jenn.burt@gmail.com.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	I
List of Tables	II
List of Figures	II
Acronyms and Abbreviations	III
1. INTRODUCTION: MPAS IN HUMAN-OCEAN SYSTEMS	1
2. ECOLOGICAL DESIGN PRINCIPLES FOR MPA NETWORKS	2
2.1. Introduction	2
2.2. Literature Review	2
2.2.1. Approach and methods	2
2.2.2. Discussion - Ecological design principles and their potential application in B.C.	4
2.3. Applying Ecological Guidelines to Review MPA Policy Documents	10
2.4. Review of Species Movement and Dispersal to Inform MPA Design	12
2.4.1. Approach and methods	12
2.4.2. Results: Adult movement and larval duration for BC fish and invertebrate species	13
2.4.3. Applying species movement and dispersal to size and spacing MPA guidelines in B.C.	18
2.5. Summary, Limitations, Conclusions	21
3. MPA GOVERNANCE AND MANAGEMENT EFFECTIVENESS	24
3.1. Introduction	24
3.2. Literature Review	25
3.2.1. Approach and methods	25
3.2.2. Governance principles relevant to MPAs and MPA networks	25
3.2.3. Discussion	31
3.3. Applying Governance Principles to Review MPA Policy Documents	32
4. SOCIAL GOALS FOR MPAS: SYNERGIES AND TRADE-OFFS IN DESIGN AND ESTABLISHMENT	38
4.1. Introduction	38
4.2. Literature Review	38
4.2.1. Approach and methods	38
4.2.2. Key themes underlying the social goals of MPAs and MPA network design	41

5. KNOWLEDGE INTEGRATION: INCORPORATING TRADITIONAL ECOLOGICAL KNOWLEDGE INTO MPA PLANNING	45
5.1. Introduction	45
5.2. Literature Review	45
5.2.1. Approach, methods, and terminology	45
5.2.2. Knowledge integration and TEK in marine planning	46
5.2.3. Incorporating TEK to better understand the marine system	47
5.2.4. Incorporating TEK into marine monitoring	48
5.2.5. Incorporating TEK to guide management strategies and options	50
5.2.6. Challenges in knowledge integration	51
5.2.7. Concluding remarks	55
6. SUMMARY AND RECOMMENDATIONS	56
REFERENCES	60
APPENDICES	75
Appendix A	A1 - A8
Ecological principles and guidelines for designing MPA networks.	
Appendix B	B1 - B6
Assessment of MPA policy document using ecological design guidelines.	
Appendix C	C1 - C14
Adult movement and depth information for select B.C. fish and invertebrate species.	
Appendix D	D1 - D10
Larval characteristics for select B.C. fish and invertebrate species.	
Appendix E	E1 - E12
Guiding principles and practices/strategies for governance of MPAs and MPA networks.	
Appendix F	F1 - F17
Assessment of marine planning policy documents using governance principles and guidelines.	
Appendix G	G1 - G10
Examples of social goals that complement, supplement or present trade-offs with desired ecological outcomes of MPAs.	

EXECUTIVE SUMMARY

In this report, we synthesize the overarching principles and general guidelines that underpin the establishment of marine protected area (MPA) networks designed to meet ecological, governance, social and cultural objectives, based on the peer-reviewed literature. These guidelines are supported by scientific research, institutional experience and global case studies, and take a social-ecological systems approach to marine conservation.

Information reviewed in this report suggests that the design of MPAs and MPA networks require the simultaneous consideration of ecological features and processes, governance arrangements, economic costs and benefits, as well as social and cultural values. Planners, managers and decision-makers can use the guidelines synthesized in this report to support the process of MPA network design in their local contexts. We discuss how several of the design guidelines apply to the Pacific region of British Columbia (B.C.), Canada, given the federal and provincial governments have committed to establishing a bioregional network of MPAs (Canada and British Columbia, 2014).

In this report we reviewed and synthesized:

- › Ecological principles and guidelines for MPA network design, with discussion and recommendations on how each of these principles could be applied in B.C.;
- › Species-specific movement and larval duration estimates for a selection of marine species of ecological, economic, cultural and conservation importance in B.C., with recommendations on how this can inform guidelines on the size and spacing of MPA networks in B.C.;
- › Overarching principles from global literature on good governance of MPAs and MPA networks;
- › Design goals and strategies for achieving different social objectives in MPA and MPA network planning; and
- › Opportunities and challenges for integrating local knowledge systems (focus on Traditional Ecological Knowledge) into marine planning and MPA design.

Lastly, we assessed relevant B.C. policy documents using the ecological and good governance guideline frameworks.

According to our synthesis of the literature, successful establishment and effective management of MPA networks depend on legitimate and effective governance arrangements that can accommodate ecological criteria while considering the perspectives and input of local resource users and stakeholders. Furthermore, policy makers should specify MPA objectives as this will guide design priorities, assessment and monitoring, and ensure that trade-offs are transparent.

Overall, the principles and guidelines synthesized in this report support an approach to MPA design that incorporates biodiversity and ecosystem resilience objectives while recognizing human uses and values. Our compendium of information is most relevant to MPA planning processes in B.C., but can be applied and adapted to MPA and MPA network design in any other region.

LIST OF TABLES

Table 1.	Overarching principles and general guidelines to achieve ecological objectives in MPA networks	3
Table 2.	Examples of guidelines for determining the optimal size of MPAs	6
Table 3.	Examples of MPA network spacing recommendations from the scientific literature, science-based MPA guideline reports, and case examples where guidelines have been implemented in practice	8
Table 4.	Summary of how ecological guidelines are articulated in the Canada-BC Marine Protected Area Network Strategy (Canada and British Columbia 2014)	11
Table 5.	Guiding principles synthesized from a global literature on good governance of MPAs and MPA Networks. Principles are organized under six thematic headings	26
Table 6.	Assessment of key policy documents against governance principles	34
Table 7.	Examples of social goals for MPAs and MPA network design synthesized from a global literature	39
Table 8.	Potential contribution of Traditional Ecological Knowledge to the MPA ecological design principles outlined in Section 2.0	40
Table 9.	Common challenges and sources of conflict between Indigenous knowledge systems and Western scientific knowledge or management	53

LIST OF FIGURES

Figure 1.	Distribution of available data for reported home range or movement category for adult fish and invertebrate species of commercial, recreational, conservation or cultural importance in B.C.	13
Figure 2.	Number of adult fish and invertebrate species of commercial, recreational, conservation and cultural importance in B.C. within assigned movement categories	14
Figure 3.	General movement ranges and common depth occurrence for adult fish and invertebrate species of commercial, recreational, conservation, and cultural importance in British Columbia, Canada	15
Figure 4.	Distribution of average pelagic larval duration for B.C. fish and invertebrate species of commercial, recreational, conservation and cultural importance	16
Figure 5.	Visual summary of pelagic larval duration (PLD) of fish larvae (black diamonds), invertebrate larvae (open diamonds) and algal spores (grey circles) for B.C. species of commercial, recreational, conservation or cultural importance	17
Figure 6.	Key figures from other studies showing information on larval dispersal distance	20
Figure 7.	Components of traditional ecological knowledge and wisdom of aboriginal peoples of northwestern North America	46

ACRONYMS AND ABBREVIATIONS

B.C.	British Columbia
BCMCA	British Columbia Marine Conservation Analysis
MLPA	Marine Life Protection Act (California)
CBD	Convention on Biological Diversity
CBNRM	Community Based Natural Resource Management
CDFG	California Department of Fish and Game
CFN	Coastal First Nations
CHN	Council of the Haida Nation
COSEWIC	Committee On the Status of Endangered Wildlife In Canada
CPAWS	Canadian Parks and Wilderness Society
DFO	Department of Fisheries and Oceans / Fisheries and Oceans Canada
EBSA	Ecologically and Biologically Significant Area
FEK	Fishers Ecological Knowledge
FLNRO	Department of Forests, Lands, and Natural Resource Operations
FSC	Food, Social and Ceremonial (harvest or fishery) - A term with legal and political importance referring to constitutional rights of Aboriginal peoples in Canada to harvest fishery resources.
GBRMPA	Great Barrier Reef Marine Park Authority
ICCA	Indigenous and Community Conservation Areas
IUCN-WCPA	International Union on the Conservation of Nature - World Commission on Protected Areas
LEK	Local Ecological Knowledge
LOI	Letter of Intent
MaPP	Marine Planning Partnership
MOU	Memorandum of Understanding
MPA	Marine Protected Area
NCSFNSS	North Coast-Skeena First Nations Stewardship Society
NMCA(R)	National Marine Conservation Area (Reserve)
NOAA	National Oceanographic and Atmospheric Administration
NRM	Natural resource management
OAG	Office of the Auditor General
OSPAR	The name of the mechanism by which fifteen governments of the western coasts and catchments of Europe, together with the European Union, cooperate to protect the marine environment of the North-East Atlantic. OSPAR refers to the 1992 OSPAR convention, which was so named because of the original Oslo ("OS") and Paris ("PAR") Conventions.
PLD	Pelagic Larval Duration
PNCIMA	Pacific North Coast Integrated Management Area
RCA	Rockfish Conservation Area
TAC	Total Allowable Catch
TEK	Traditional Ecological Knowledge
TURF	Territorial Use Rights for Fishing
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
WCA	West Coast Aquatic
WWF	World Wildlife Fund for Nature

1. INTRODUCTION: MPAS IN HUMAN-OCEAN SYSTEMS

Mounting evidence suggests that marine protected areas (MPAs) are important spatial management tools for achieving ecological conservation objectives (Halpern 2003; Lester et al. 2009; Stewart et al. 2009). These objectives include species and habitat protection, biodiversity conservation, and the maintenance of ecosystem function and resilience in the face of natural or anthropogenic disturbances (Sobel 1996; Allison et al. 1998; Lubchenco et al. 2003; Salomon et al. 2006; Lester et al. 2009). Evidence further suggests that networks of MPAs are able to fulfill ecological aims more effectively and comprehensively than single MPAs (IUCN-WCPA 2008; Groud-Colvert et al. 2014). As such, a substantial body of scientific literature has emerged to address different aspects of a key question: How do we best design MPAs and MPA networks to achieve desired ecosystem objectives?

Marine Protected Area (MPA)

A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IUCN-WCPA 2008).

MPA network

A collection of individual marine protected areas that operates cooperatively and synergistically, at various spatial scales, and with a range of protection levels, in order to fulfill ecological aims more effectively and comprehensively than individual sites could alone (IUCN-WCPA 2008).

While ecological MPA design principles are crucial for achieving ecosystem objectives, the importance of their integration with social and governance considerations are increasingly being recognized (Salomon et al. 2001; Salomon et al. 2002; Ostrom 2009; Cinner et al. 2012; Ban et al. 2013a). This is because of growing acknowledgement and documentation of the benefits that MPAs provide to humans, including fisheries benefits, cultural benefits, education benefits, non-consumptive benefits, health benefits, among many others (Angulo-Valdes and Hatcher 2010). The social-ecological systems approach views humans as part of ecosystems, and recognizes that reciprocal interactions between humans and the environment lead to ecological and social outcomes (Folke 2006; Folke and Gunderson 2006). This approach is particularly relevant in marine systems where humans have interacted with, modified and managed the seascape for millennia, such as coastal British Columbia, Canada, which has a long history of indigenous communities (Fedje et al. 2001; Turner and Turner 2007; Szpak et al. 2012).

The goal of this report is to provide a synthesis of scientifically-sound ecological, social and governance principles and guidelines used in MPA and MPA network design that have been vetted by peer reviewed literature and synthetic documents derived from scientific panels and expert working groups. First, we summarize the overarching design principles, general guidelines and specific strategies/practices for achieving ecological objectives in MPA network design. To tailor general ecological guidelines to a regional context, we summarize life history characteristics of key fished or culturally important species in B.C. and discuss how this information may be applied to MPA size and spacing in B.C. Following this, we describe governance principles that present the scope of good practices in marine protected areas around the world. We apply our ecological and good governance design frameworks by examining how well guidelines are articulated in MPA planning policy documents from British Columbia (B.C.), Canada. Next, we discuss social goals in MPA network planning and provide examples of the synergies and trade-offs that can be involved in addressing both societal and ecological objectives. Finally, we discuss the role of traditional knowledge in MPA planning and highlight that knowledge integration is a potentially powerful way of integrating ecological, governance, and social considerations in MPA design.

2. ECOLOGICAL DESIGN PRINCIPLES FOR MPA NETWORKS

2.1. INTRODUCTION

As the number of MPAs and MPA networks continues to grow, several core principles and guidelines for achieving ecological objectives in MPA network design have emerged. The ecological effects of MPA size, shape, spacing and complementary management regulations outside protected areas have been measured based on both empirical evidence and theoretical models (e.g. Airame et al. 2003; Botsford et al. 2003; Friedlander et al. 2003; Halpern 2003; Roberts et al. 2003; Shanks et al. 2003). Furthermore, a number of scientific reviews (McLeod et al. 2009; Foley et al. 2010) and synthetic reports by international agencies (IUCN-WCPA 2008; Brock et al. 2012) and interdisciplinary working-groups (Jessen et al. 2011; Fernandes et al. 2012) have summarized these results and formulated scientific guidelines to be applied by managers and policy makers to regional MPA planning processes. Given our limited knowledge of marine ecosystem function and connectivity, and the extent to which human activities influence these processes, the principles and guidelines described here are designed to help reduce and spread risk spatially across the seascape (Roberts et al. 2003; Gaines et al. 2010).

Despite the ubiquity of broad design principles, scientists and managers are challenged with synthesizing, tailoring and implementing region-specific guidelines that match regional ecological, social and institutional contexts. For example, the marine environment of B.C. may share some commonalities with other temperate regions that have implemented MPA networks (Stewart et al. 2009), but it also has a unique combination of geographical, oceanographic, ecological, social and cultural features. Here, we provide a summary of general principles and guidelines to achieve ecological objectives in MPA networks globally, and discuss how these guidelines might apply in B.C. We also compile species-specific data from a selection of priority species and discuss how this information can inform size and spacing guidelines for MPA networks in B.C.

2.2. LITERATURE REVIEW

2.2.1. *Approach and methods*

To synthesize key ecological MPA design principles we examined the primary, peer-reviewed literature and five science-based synthetic reports. The latter were selected because they provide comprehensive summaries of MPA network design guidelines from a global context (IUCN-WCPA 2008), a North American context (Brock et al. 2012), a European context (OSPAR 2007), a multi-nation South Pacific context (the Coral Triangle; Fernandes et al. 2012) and a Canada-wide context (Jessen et al. 2011). We organized our review and resulting MPA network guidelines into five overarching and widely recognized conceptual design principles: (1) Representation, (2) Unique, Important and Vulnerable Areas, (3) Replication, (4) Size, Shape and Connectivity, and (5) Mitigating human impacts (Table 1). Under these overarching principles we assembled a list of “General Guidelines” that we define as having sufficient support in the academic literature (Table 1 and Appendix A). In Appendix A we provide rationale for each General Guideline, as well as several “Specific Targets or Strategies” from the science-based reports which illustrate a range of options available for achieving the general guidelines. We discuss our summary of ecological guidelines in relation to their rationale and support in the primary literature as well as their potential application to MPA network planning in B.C.

Table 1. Overarching principles and general guidelines to achieve ecological objectives in MPA networks.

OVERARCHING PRINCIPLE	GENERAL GUIDELINES
REPRESENTATION: <i>Protect the full range of biological diversity and the associated oceanographic environment.</i>	<ul style="list-style-type: none"> › The MPA network includes adequate representation of each habitat type found within each bioregion.
UNIQUE, IMPORTANT AND VULNERABLE AREAS: <i>Protect areas and features that are biologically/ecologically unique, vulnerable or of high functional importance.</i>	<ul style="list-style-type: none"> › Ensure areas or features that are unique (1 per bioregion) or rare (few per bioregion) within the bioregion are captured within the network. › Protect areas of special importance to certain life history stages. › Protect areas characterized by high biological diversity. › Protect areas characterized by high productivity. › Protect species or habitats that are threatened, vulnerable, or declining.
REPLICATION: <i>Provide redundancy to safeguard against unexpected (natural or anthropogenic) habitat loss or population collapse.</i>	<ul style="list-style-type: none"> › Include spatially-separated replicates of representative habitat types or features.
SIZE, SHAPE AND CONNECTIVITY: <i>Maintain the integrity and viability of protected features and processes by ensuring MPA sites are adequate in size/shape and are ecologically connected within the network.</i>	<ul style="list-style-type: none"> › Individual MPAs within the network are large enough to provide adequate protection for the feature or ecological process they are meant to protect. › Individual MPAs within the network have an optimal shape. › Individual MPAs are adequately spaced to ensure functional connectivity (have ecological linkages) between individual MPAs within the larger network.
MITIGATING HUMAN IMPACTS: <i>Increase ecological resilience of desirable ecosystem states in the face of human-induced change and stressors.</i>	<ul style="list-style-type: none"> › Sufficient area within the network is encompassed in no-take marine reserves › Areas with reduced/minimal human impact are targeted for protection. › Areas and features that exhibit characteristics associated with ecological resistance/resilience to climate change are targeted for protection. › Ensure long-term protection. › Sustainable use of marine resources is promoted beyond the boundaries of the MPA network.

2.2.2. Discussion - Ecological design principles and their potential application in B.C.

Representation

Different marine habitat types encompass distinct species assemblages; therefore, MPA networks have a greater chance of conserving regional biodiversity (across multiple levels - genetic, species, habitats, ecosystems) if all broad-scale habitat types and embedded communities are protected to some degree (Roberts et al. 2003; Palumbi 2004; IUCN-WCPA 2008; McLeod et al. 2009; Gaines et al. 2010). Ideally, achieving representation in an MPA network includes having a classification system for a full range of habitat types, information on their spatial distribution, targets to guide how much of each habitat type should be protected, and a defined spatial scale within which to assess representation (Airame et al. 2003; Fernandes et al. 2005).

The scientific literature offers different approaches for determining what percent of available habitat types should be included in an MPA network to achieve adequate representation. The most commonly cited is Roberts et al. (2003) who suggest that the total amount of each habitat type to be protected in an MPA network should reflect both the relative prevalence of that habitat type within a region, as well as the overall target for regional protection (i.e. if there is a national or regional target to protect 20% of the marine environment, then 20% of the area of each habitat type should be included in the network). However, the challenge of applying this principle lies in deciding on how much total area of a region should be protected. For example, Gell and Roberts (2003) suggest that maximum fisheries benefits occur when between 20-40% of areas open to fishing are put into reserves (i.e. in no-take areas), although this depends on regional conditions and the state of relevant fisheries. Other studies that use theoretical models based on maintaining a threshold reproductive output for species (to ensure species replacement) suggest that at least 35% of a given coastline would have to be within connected MPA reserves to sustain exploited fish populations (Botsford et al. 2001; Fogarty and Botsford 2007). The National Research Council (2001) summarized science-based estimates for levels of adequate MPA coverage and showed that the recommended area to protect in MPAs can range from 8-80% depending on the management goal (i.e. risk management, maximizing fisheries yields, or conserving biodiversity). Gaines et al. (2010) state that “in the face of poor fisheries management, a conservative estimate of minimum proportion of a region to be placed in reserves lies at approximately one-third, a value comfortably within the maximum proportion estimated to maximize fishery prosperity for a number of species” (p. 18289).

The recommended guidelines from the five science-based synthetic reports we reviewed all suggest that the proportion of each habitat type to be protected should fall between 20-35%, with some reports emphasizing this should be within no-take reserves (Jessen et al. 2011; Fernandes et al. 2012). Fernandes et al. (2012) summarize the available science on overall protection targets and recommend that between 20-35% of each habitat type should be protected if the MPA network is designed to optimize fisheries benefits, but that 35% should be a minimum target if the overall goal of the network is to conserve biodiversity. The European (OSPAR 2007) guidelines state it is “unrealistic to expect agreement on any single network percentage” (p.18) but suggest the MPA network would be considered “ecologically coherent” if the spatial protection of targeted features fell within a 10-50% range determined from the reviewed scientific literature (Ballantine 1991; Carr and Reed 1993; Ballantine 1997; National Research Council 2001; Rodwell and Roberts 2004). Consistent with the ranges recommended by IUCN-WCPA (2008), OSPAR (2007), and Fernandes et al. (2012), Canadian scientists recommend that for MPA networks within Canada, at least 30% of the area of each broad-scale habitat type within a bioregion¹ should be in no-take reserves (Jessen et al. 2011). Overall, despite convergence on adequate MPA coverage ranging from 20-35%, the question of “how much is enough” will always be met with MPA targets that vary based on local contexts (e.g. state of fisheries, existing fishing pressure, life history of species of concern, etc.) and guiding management goals.

¹ The Government of Canada (2011) states the spatial scale for planning a national network of MPAs is defined by 13 ecologically delineated “bioregions” that cover Canada’s oceans and Great Lakes. There are four bioregions on the B.C. coast.

In B.C., some research has already begun to identify representation targets. The B.C. Marine Conservation Analysis (BCMCA, 2011) project (www.bcmca.ca) compiled data for marine features and used workshops to solicit expert opinions on appropriate targets, or ranges of targets, for achieving conservation objectives. These were then translated into options for low, medium and high levels of representation (BCMCA 2012; Ban et al. 2013b). Combined with the recommended target for Canada to represent 30% of all broad-scale habitat types within each marine bioregion (Jessen et al. 2011), the BCMCA targets could be used as a starting point for planning and evaluating proposed MPA network configurations and regional spatial plans in B.C.

Unique, important and vulnerable areas

The scientific literature and the synthetic reports commonly state that MPA networks should target areas of high biological diversity, and habitats or species that are threatened, vulnerable, or declining. Similarly, guidelines recommend protecting unique (1 per bioregion) or rare (few per bioregion) areas, as well as areas of special importance to certain life history stages, including breeding grounds, spawning sites and nursery areas (see references within Appendix A synthesis reports; see also Roberts et al. 2003; Green et al. 2007; McLeod et al. 2009). The rationale for these guidelines with respect to achieving MPA network goals differs: unique and rare sites are important because their loss would impact biodiversity, whereas protecting areas critical for life history stages contributes to enhancing or maintaining viable and persistent populations of particular species. For example, many reef fish aggregate when spawning, and efforts to protect known sites of spawning aggregations can assist the recovery of vulnerable populations (Hamilton et al. 2011). In the California Channel Islands, habitats such as seagrass meadows, eelgrass beds and surfgrass beds were considered particularly vulnerable to human activities and were explicitly targeted in the reserve network siting process (Airame et al. 2003).

Some efforts have attempted to identify unique and important areas in B.C. “Important Areas” and “Ecologically and Biologically Significant Areas (EBSAs)” were identified by the Department of Fisheries and Oceans (Clarke and Jamieson 2006a, 2006b), and the BCMCA collated spatial data for features (species or habitats) designated as “special features” (BCMCA 2012). Understanding where unique and vulnerable areas are may be further aided by efforts led by local residents and First Nation communities who have been involved in mapping ecologically and culturally important areas (e.g. Parks Canada 2009; Council of the Haida Nation 2011; Heiltsuk Nation Traditional Use Study).

Replication

The design principle that recommends including spatially-separated replicates of representative habitats within MPA sites is well supported in the scientific literature and all the science-based synthesis reports we reviewed. The primary reasons to replicate representative habitat types and other special features (e.g. vulnerable sites, special life history areas) are: 1) to safeguard against local disturbance or environmental disaster, 2) to help ensure that natural variation in representative habitats and features is encapsulated in the MPA network, and 3) to address the uncertainty in identifying and fully encompassing representative habitats and features in individual areas (Airame et al. 2003; Roberts et al. 2003; McLeod et al. 2009; Gaines et al. 2010).

Although there is no agreement on how many replicates are needed, the recommendation for having at least three spatial replicates appears most frequently in the literature (e.g. Fernandes et al. 2005; IUCN-WCPA 2008; McLeod et al. 2009; Fernandes et al. 2012). In B.C. an important aspect to consider is what ecologically meaningful scale should be considered to meet this general replication guideline (e.g. bioregional vs. more local scales). Canada is taking a “bioregional MPA network planning approach” (Government of Canada 2011, p. 10) which defines four bioregions within B.C., however, other finer-scale ecologically-based classifications exist, including 12 B.C. marine “ecosections” (BCMCA 2002; BCMCA 2011) and 24 “oceanographic regions” (BCMCA 2011; Robinson and McBlane 2013). While adequate replication of representative habitats as well as special or vulnerable features should be ensured at the bioregional scale, additional ecologically viable habitat replicates within MPAs should be encouraged within

smaller classification units. For example, smaller coastal regions may also want to consider replication of habitats or key marine features within protected areas at their own planning scales (e.g. Central Coast, Haida Gwaii, etc.).

Size, Shape and Connectivity

Peer-reviewed literature consistently supports the need for MPAs to be an adequate size to protect viable populations and/or ecological processes within their boundaries. However, there is no ideal size applicable to all MPAs, as the appropriate size will vary with respect to the life history characteristics of the species targeted for protection (Palumbi 2004), specific habitats targeted for protection (see Representation and Unique/Important/Vulnerable Areas), species interactions (Baskett et al. 2007), the management objectives of the MPA or network (Fernandes et al. 2012), and management regulations outside of MPAs (Walters et al. 2007; Moffitt et al. 2009; White et al. 2010b). Despite this understanding, the best available science suggests that to ensure the persistence of populations within an MPA, the size should at least be as large as the average larval dispersal distance of targeted species (Table 2) and encompass the adult home range² or neighbourhood size³ (Table 2). This line of thinking suggests that short distance dispersers are likely to persist in smaller (e.g 4-6 km diameter; Shanks et al. 2003) no-take areas, but that larger MPAs (10 - 100 km in the smallest dimension) are necessary to accommodate longer dispersers and more mobile species (Palumbi 2004; Botsford et al. 2009; Gaines et al. 2010). In a global review by Edgar et al. (2014) targeting 87 well-known and well-regarded MPAs worldwide, “large MPA size (> 100 km²)” was found to be one of five key features that contributed directly to the conservation effectiveness associated with a MPA site (the other four features were “no-take”, “enforced”, “old”, and “isolated”).

Table 2. Examples of guidelines for determining the optimal size of MPAs.

MPA SIZE GUIDELINES	REFERENCE
PEER-REVIEWED LITERATURE	
The neighbourhood size of a species should be less than about twice the size of the marine reserve. Species with adult home ranges larger than a reserve's size will be protected for only part of the time.	(Botsford et al. 2001; Botsford et al. 2003; Palumbi 2004)
The size of the MPA should be at least as large as the average dispersal distance of the larvae (and home range of adults) to ensure viable populations can persist within its boundaries.	(Hastings and Botsford 2006)
Modelling based on observed larval characteristics in nearshore temperate environments suggests that a reserve 4 - 6 km in diameter should be large enough to contain the larvae of short-distance (< 1 km) dispersers.	(Shanks et al. 2003)
MPAs should have a diameter greater than the average dispersal distance of the species of interest	(Botsford et al. 2009; Gaines et al. 2010)
Reserves should be no larger than about twice the target species' dispersal scale to ensure that enough larvae are exported to offset fishery squeeze.	(Pelc et al. 2010)
A global network of MPAs to provide optimum coverage of the world's coral reefs would include MPAs at least 10 km ² in area to protect the neighbourhood of a broad group of vagile species.	(Mora et al. 2006)

² Home range is defined as the area an animal uses on a regular basis for its routine activities (Mace et al. 1983 as cited in Moffitt et al. 2009)

³ Neighbourhood size refers to the area that is large enough to encompass species movements during their adult life stage as well as the offspring of those adults (Palumbi 2004)

Ideally for planning, it is helpful to have specific MPA size recommendations. The five science-based synthesis reports reflect this need, but their size guidelines reflect different approaches. The IUCN-WCPA (2008), Jessen et al. (2011) and Fernandes et al. (2012) all cite relevant science to conclude that larger MPAs (i.e. 100s - 1000s of km²) are most appropriate to achieve overall network resilience and biodiversity conservation (Palumbi 2004; Hastings and Botsford 2006; McLeod et al. 2009; Gaines et al. 2010; Moffitt et al. 2011). The IUCN-WCPA (2008) highlight the size guidelines from the California Marine Life Protection Act which recommended MPAs should have an alongshore span of 5-10 km, and preferably 10-20 km (CDFG 2008). In the Coral Triangle, Fernandes et al. (2012) recommend applying a combination of large (considered 4 - 20 km across) and small (0.4 km²) protected areas within the network, acknowledging that in some cases, particularly for species with smaller movements and dispersal, small MPAs can provide benefits to nearshore fisheries (Alcala and Russ 2006; Samoilys et al. 2007; Lester et al. 2009). The OSPAR (2007) guidelines do not provide specific size guidelines, but emphasize that the size of individual MPAs within the network should be individually assessed for adequacy based on whether they can sustain viable target populations or communities (accounting for species life-history, population structure, habitat quality, management outside of the MPA, and connectivity to other sites). Overall, both the science and associated MPA guidelines point to the fact that a greater understanding of species-specific movement, dispersal patterns, and population parameters provides valuable information to develop and assess size-related recommendations for MPA network design. Since this information was not available for B.C. species, we compiled and summarised data for a selection of species and discuss how this information may apply to B.C.-specific MPA guidelines (details in Section 2.4 below).

The shape of individual MPAs influence both the ratio of edge to volume (this affects the degree of species retention vs. spillover) and the ease of compliance and enforcement (based on ease of navigating around MPA boundaries). The more perimeter edge a reserve has, the more it will export larvae and adults to the surrounding area (Roberts et al. 2003). Therefore, the fisheries benefits of MPAs will be greatest if MPAs have shapes with a greater edge to volume ratio, whereas biodiversity objectives are better served by MPAs that have higher volume and minimized edges (IUCN-WCPA 2008; McLeod et al. 2009; Gaines et al. 2010; Fernandes et al. 2012). It is also important that the shape of an MPA facilitates ease of enforcement. As such, MPA boundaries should be easily identifiable (e.g. demarked by obvious landmarks), navigable (e.g. straight lines over curved lines), and well communicated (e.g. resource users are made aware of new boundaries). All of these guidelines are important in the B.C. context, with large MPAs, minimized edges, and effective compliance most likely to help achieve the stated vision for an “ecologically comprehensive and resilient network that protects the biological diversity and health of the marine environment” (Canada and British Columbia 2014, p. 9).

Individual MPAs will benefit from one another if they are linked by a flow of dispersing eggs and larvae or migrating juveniles and adults. Evidence based on empirical data and simulation models emphasizes the importance of connectivity between MPAs (Botsford et al. 2001; Kaplan and Botsford 2005; Botsford et al. 2009; White et al. 2010a; Grüss et al. 2011), however recommended spacing guidelines vary in the scientific literature, in the science-based synthesis reports, and in practice (Table 3). Despite differences in recommended spacing, the specific MPA guidelines all reference the importance of considering the scale at which a species’ larva disperses. Estimated larval dispersal distances vary in orders of magnitude among species and depend on larval behaviour as well as local and regional oceanographic patterns (Shanks 2009). Furthermore, despite efforts to measure larval duration and dispersal distances, these parameters are not known for most species, or for any species with great certainty (Shanks 2009; Moffitt et al. 2011). Regardless, rules of thumb based on average dispersal distances for species with available information have been used both to inform MPA planning (Gleason et al. 2010; Moffitt et al. 2011; see other examples in Table 3) and assess the degree of connectivity between existing MPAs (e.g. Andrello et al. 2013; Lotterhos et al. 2014). Connectivity between MPAs has only briefly been assessed in B.C. (Robinson et al. 2005; Lotterhos et al. 2014) and information on the larval dispersal of key B.C. species is lacking. As such, we have summarized larval duration of select B.C. species and discussed how these data may apply to MPA spacing recommendations (details in Section 2.4 below).

Table 3. Examples of MPA network spacing recommendations from the scientific literature, science-based MPA guideline reports, and case examples where guidelines have been implemented in practice.

MPA NETWORK SPACING RECOMMENDATIONS	REFERENCE
PEER-REVIEWED LITERATURE	
Distances between reserves ranging from 10 - 100 km enhance both conservation and fishery benefits because they approach mean larval dispersal distances estimated for many fished coastal marine species.	(Gaines et al. 2010)
Reserves spaced 10 – 20 km apart should be close enough to capture propagules released from adjacent reserves.	(Shanks et al. 2003)
The spacing of reserves should reflect larval neighborhood scales, which range from 10 - 200 km .	(Palumbi 2004)
SCIENCE-BASED MPA GUIDELINE REPORTS	
All MPAs should generally be within 20 to 200 km from the nearest MPA in the network.	(Jessen et al. 2011)
The spacing between individual MPA sites should range from 10 - 20 km up to 50 - 100 km (depending on the habitat type and region).	(IUCN-WCPA 2008)
When specific data [on larval dispersal] is lacking, nearshore MPA sites should be spaced not further than 50 km apart to maintain connectivity of most short to moderate larval dispersing species.	(OSPAR 2007)
Apply a variety of spacing of individual no-take areas (from 1 to 20 km apart) throughout the entire management area. Inshore areas should be located closer together (more towards ≥ 1 km apart) than the more offshore areas (more toward ~20 km apart).	(Fernandes et al. 2012)
Consider how larval dispersal may shift as a result of climate change (e.g. changing temperature and current patterns) and adjust MPA boundaries accordingly.	(Brock et al. 2012)
CASE EXAMPLES	
California, Marine Life Protection Act Based on currently known scales of larval dispersal, MPAs should be placed within 50 to 100 km of each other.	(CDFG 2008)
Indonesia, Berau Marine Conservation Area Larval dispersal was considered along with other ecological parameters to inform recommended spacing of no-take zones: between 500 m - 40 km	(Green et al. 2009)
Australia, Great Barrier Reef Distances between no-take zones vary from a few km to 100 km apart when re-zoning was implemented in 2004.	(Fernandes et al. 2005)
Philippines 94% of MPAs in the Philippines are within 1 – 20 km of at least one other reserve, and more than 70% of MPAs are located within 5 km of another reserve.	(Weeks et al. 2010b)

Mitigating human impacts

The level of protection that MPAs provide, their location, the extent to which they limit human activities, and the effectiveness of their enforcement, determine whether MPAs are able to mitigate against human disturbances. As such, the academic literature and science-based reports we reviewed identify a number of guidelines that strive to maximize the ecological resilience of desirable ecosystem states in the face of human-induced change (see Appendix A for details):

- › Ensure sufficient area within the network is encompassed in no-take marine reserves;
- › Target areas with reduced/minimal human impact for protection;
- › Target areas and features that exhibit characteristics associated with ecological resistance/resilience to climate change for protection;
- › The network should offer long-term protection; and
- › Promote the sustainable use of marine resources beyond the boundaries of the MPA network.

The academic literature provides strong support for ensuring a proportion of the MPA network is managed as no-take reserves to maintain ecological processes and meet ecological recovery and biodiversity goals (Halpern 2003; Roberts et al. 2003; Lester and Halpern 2008; Stewart et al. 2009; Edgar et al. 2014). Comprehensive studies that compare data from multiple protected areas have shown that no-take reserves result in higher ecological benefits (e.g. fish density and biomass) compared to partially protected areas, although partially protected areas still offer benefits compared to open access areas (Lester and Halpern 2008; Sciberras et al. 2013). Four out of the five science-based guideline reports we reviewed specifically recommend that a proportion of the MPA network (~30%, see Appendix A) should be zoned as no-take reserves (the fifth report uses the term protected area and is not explicit about no-take reserves; Brock et al. 2012). If the recommendations by Canadian scientists are applied to B.C. (Jessen et al. 2011), then 30% of the total area of each four B.C. bioregions should be encompassed in no-take MPAs. In a study by Robb et al. (2011), it was found that less than 1% of B.C.'s waters receive full protection status; 160 out of 161 MPAs allow commercial fishing in all or portions of their boundaries, including 95 MPAs assigned IUCN categories that imply the highest level of protection.

MPA planning processes around the world have resulted in MPA networks with varying proportions of no-take reserves. The Great Barrier Reef rezoning plan was guided by targets to represent at least 20% of reef and non-reef habitats in no-take areas within each bioregion (Fernandes et al. 2005). The final configuration met that target and resulted in 33% of the total Great Barrier Reef Marine Park (344,400 km²) in no-take areas (Fernandes et al. 2005). The Scientific Advisory Panel for the Channel Islands National Marine Sanctuary (4294 km²) recommended that 30-50% of the overall planning region should be protected in no-take areas to achieve conservation and fisheries objectives (Airame et al. 2003). The final design resulted in 11 no-take reserves comprising 21% of the Channel Island National Marine Sanctuary (Airame and Ugoretz 2008). In another example, the MPA network design process in North Central California (planning area of 1976 km²) had a Science Advisory Team that identified key and unique habitats that needed to be represented within network MPAs, but they did not identify an overall regional target for the amount of area that needed be in no-take zones (Gleason et al. 2010). MPA proposals were evaluated by the Science Advisory Team for habitat representation (along with other ecological criteria), which showed that each network proposal had 10-30% of each habitat represented in high protection MPAs (Gleason et al. 2010). After stakeholders and other forums reviewed the proposals, the final configuration resulted in 22 MPAs (most in high protection conservation areas with minimal take of selected species) that cover 20% of the region, with ~11% of the region protected in no-take marine reserves (Gleason et al. 2010). These examples demonstrate the utility of having science-based conservation targets to guide MPA network planning, but they also illustrate that the final designated networks may stray from original targets as a result of complex processes that involve multiple

objectives (access right, food security, economic benefits etc.), negotiation of stakeholder and local community values, and trade-offs between conservation and fisheries/economic/social objectives. These considerations will be particularly relevant to Canada, for example, where First Nations have a constitutional right to fish for food, social and ceremonial purposes in their territories (see sections 3 and 4 below; MPA Governance, Social Goals for MPAs).

A growing literature reflects MPA design considerations specific to addressing anticipated climate change impacts (reviewed in Salm et al. 2006; McLeod et al. 2009; Brock et al. 2012; Fernandes et al. 2012; Magris et al. 2014). Predicted temperature increases, sea level rise, ocean acidification, changes in dissolved oxygen levels, and changes in marine weather conditions can all directly and indirectly affect species distributions and abundance, reproductive timing, habitat quality, and patterns of population connectivity (Harley et al. 2006; Lett et al. 2010; Lotterhos and Markel 2012). In turn, these metrics influence MPA design and performance (McLeod et al. 2009; Brock et al. 2012). Design principles that are intended to reduce and spread the risk of potential disturbance, such as representation and replication (discussed above) are emphasized as important to accommodate climate change (Allison et al. 2003; McLeod et al. 2009; Magris et al. 2014). Furthermore, it is recommended that MPAs should be larger in an MPA network designed for climate change objectives than would be for fisheries or biodiversity conservation objectives alone (IUCN-WCPA 2008; McLeod et al. 2009; Fernandes et al. 2012). Other climate-change specific recommendations include siting the appropriate locations for MPAs, for example, protecting sites that are more resistant to, more able to recover from, or help mitigate climate change effects (e.g. physical features that reduce temperature stress such as cold water upwellings and high tidal exchange areas) (Ban et al. 2012; Magris et al. 2014). In a science-based guidelines report focused on designing MPA networks in a changing climate, Brock et al. (2012) emphasize the importance of protecting coastal carbon sink features, which are recognized for their carbon sequestration potential (Laffoley and Grimsditch 2009). These marine areas or features (e.g. eelgrass beds, tidal salt marshes, kelp beds) are prevalent in B.C., which suggests this guideline, along with the others mentioned above, are relevant if MPA network objectives include mitigation of, and adaptation to, climate change impacts.

2.3. APPLYING ECOLOGICAL GUIDELINES TO REVIEW MPA POLICY DOCUMENTS

The ecological guidelines assembled from our literature review can be useful as a framework to assess MPA planning or policy documents. Here, we assess the degree to which our ecological guidelines are articulated in the Canada-British Columbia Marine Protected Area Network Strategy (Canada and British Columbia 2014). We reviewed the text of this document against our General Guidelines (Table 4), and noted instances where guidelines were mentioned, whether the description of the guideline was clearly defined, and whether the document provided an elaboration or strategy for how particular guidelines might be implemented (results in Table 4). Although this assessment is limited to simply identifying whether general guidelines are included and articulated in the document, it provides a useful overview that reveals where ecological MPA design principles are well addressed, weakly addressed, or absent. Our assessment only examines the written content of the draft strategy document and makes no assumptions about approaches that may have been or will be implemented. Details of our review of the text from the Canada-British Columbia MPA Network Strategy are provided in Appendix B.

The purpose of the Canada-BC MPA Network Strategy (Canada and British Columbia 2014) document is to outline a vision and goals for the MPA network design, and the design process, in B.C. Thirteen of our 15 general ecological guidelines were mentioned in the document, the majority of which were reasonably well-defined. The most notable gap was that there was no mention of how an MPA network might be designed to accommodate or mitigate against climate change impacts. This could be seen as a considerable shortfall, given the document does specifically acknowledge that changes in species assemblages, species survival and condition, marine productivity, habitat ranges, and depth strata, are possible outcomes of ongoing climate change and ocean acidification in the

Table 4. Summary of how ecological guidelines are articulated in the Canada-BC Marine Protected Area Network Strategy (Canada and British Columbia 2014). For each ecological guideline, a checkmark indicates whether it was mentioned in the document, well-defined or described, and whether there was detail provided on specific strategies for how that design aspect would be achieved. Dark green (✓) checkmarks indicate that the mention, definition or strategy was clearly addressed and articulated. Light green (✓) checkmarks indicate that the guideline was not fully or clearly articulated. Refer to Appendix B to see the full review in detail.

ECOLOGICAL GENERAL GUIDELINES	MENTION?	DEFINED?	STRATEGY?
REPRESENTATION:			
The MPA network includes adequate representation of each habitat type found within each bioregion.	✓	✓	✓
UNIQUE, IMPORTANT AND VULNERABLE AREAS:			
Ensure areas that are unique (1 per bioregion) or rare (few per bioregion) within the bioregion are captured within the Network.	✓	✓	✓
Protect areas of special importance to certain life history stages.	✓	✓	✓
Protect species or habitats that are threatened, vulnerable, or declining.	✓	✓	
Protect areas characterized by high biological diversity.	✓	✓	✓
Protect areas characterized by high productivity.	✓		
REPLICATION:			
Include spatially-separated replicates of representative habitat types or features.	✓	✓	✓
SIZE, SHAPE AND CONNECTIVITY:			
Individual MPAs within the network are large enough to provide adequate protection for the feature or ecological process they are meant to protect.	✓	✓	✓
Individual MPAs within the network have an optimal shape.	✓	✓	✓
Individual MPAs are adequately spaced to ensure functionally connectivity (have ecological linkages) between individual MPAs within the larger network.	✓	✓	✓
MITIGATING HUMAN IMPACTS			
Sufficient area within the network is encompassed in no-take “marine reserves” - self-sustaining, viable areas that are free from extractive and habitat-altering activities that may be stressful to marine habitats and/or organisms.	✓	✓	
Areas with reduced/minimal human impact are targeted for protection.			
Areas and features that exhibit characteristics associated with ecological resistance/resilience to climate change are targeted for protection.			
Ensure long-term protection.	✓	✓	✓
Sustainable use of marine resources is promoted beyond the boundaries of the MPA network.	✓	✓	✓

Pacific Region (Okey et al. 2012). Climate change is increasingly being considered in MPA network design globally (refer to section Mitigating human impacts above), and future B.C. MPA network planning documents, technical guidance, and dialogue should consider focusing more effort on this issue.

While reference to most ecological guidelines (excluding climate change) was made, details on proposed strategies or approaches for how each guideline would be achieved appeared lacking or poorly articulated (light green checkmarks) in some cases. For example, “protect unique and vulnerable habitats” is explicitly stated under Ecological Network Design Principle #2 (pg. 14), but no definition of “vulnerable” is provided, nor are there any details or examples of habitats that would be considered vulnerable (i.e. habitats that are sensitive to human disturbance such as eelgrass or sponge reefs? Critical habitat areas associated with Species-at-Risk?). Overall the lack of specific details, strategies or targets may be due to the fact that this document is a high-level strategic framework to guide MPA establishment and thus design remains focused on broad visions, goals and general principles. It is possible that further guideline details, definitions, and specific recommendations (e.g. conservation targets, specific size/spacing guidelines) will be articulated in future technical documents or perhaps through regional planning processes. This is alluded to through statements such as: “those involved in the planning process may also wish to define conservation targets that specify how much of each habitat, feature, function or value requires protection to achieve goals, relevant design principles and bioregional objectives.” (Canada and British Columbia 2014, pg. 26).

2.4. REVIEW OF SPECIES MOVEMENT AND DISPERSAL TO INFORM MPA DESIGN

2.4.1. Approach and methods

MPA guidelines provide broad recommendations for achieving ecological objectives, but are rarely species-specific. We filled this gap by collating information on adult movement and pelagic larval duration (PLD) for marine fish and invertebrate species in B.C. that have been identified as having commercial, recreational, ecological, or cultural importance. Specifically, we included those species targeted by B.C. commercial fisheries (including most species of quota and non-quota rockfish), recreational fisheries (in Creel survey reports; Zetterberg and Carter 2010), and those ‘at risk’ (based on COSEWIC reporting; www.cosewic.gc.ca). For culturally important species, we included those currently or traditionally harvested by coastal First Nations (J. Carpenter, Heiltsuk Marine Use Planning Coordinator, pers. comm., April 2013). Together, these species are a focused selection of B.C. coastal fishes (59 species) and invertebrates (32 species), and are not intended to be comprehensive (e.g. only 20 of 40 common families of fish found in B.C. are included; Lamb and Edgell 2010).

We assembled species-specific adult movement information by reviewing the scientific literature, and whenever possible, studies that were conducted in, or made reference to, B.C. marine systems. We compiled information on adult home range, general movement patterns, depth distribution and critical habitat for the selected species (Appendix C). Home range is defined as the typical area that an individual animal uses on a regular basis for its routine activities (Mace et al. 1983 as cited in Moffit et al. 2009). In our review, we list home ranges as the mean and maximum range that individuals have been observed to move in various tagging and survey studies. We also include available adult movement information for migratory and wide-ranging species. Data permitting, we recorded the minimum, maximum and mean observed distances travelled, along with additional notes on movement patterns. We then assigned species to a movement category (0, <0.05 km, <1 km, 1-10 km, 10-50 km, 50-1000 km, >1000 km, or unknown) based on the interval that best fit our reported home range or movement values. When species-specific home range or movement information was not available, we assigned a movement category based on other reported observational information and made note of the rationale for assigning a specific movement category. We also compiled the maximum and commonly observed depth (e.g. depth range where the highest abundance of individuals are caught or observed during tagging studies). Finally, we noted habitat associations with each species.

We compiled information on the pelagic larval duration (PLD; the time larvae spend as plankton in the water column) of select B.C. fish and invertebrates (Appendix D). Here, we also included three species of marine algae (*Macrocystis pyrifera*, *Nereocystis luetkeana*, *Pterygophera californica*) and glass sponges (*Hexactinellid spp.*) because they are key habitat-forming species. We grouped species based on the spatial area in which they generally release their larvae/spores: intertidal (area between high and low tides), nearshore-subtidal (0-60m depth), nearshore-to-offshore (spawn across a broad spatial and/or depth range), or offshore (larvae released offshore or at deeper depths > 60 m). To best capture the degree of uncertainty associated with PLD values, wherever possible we reported the range for a species' PLD. Pelagic larval durations were listed as a single value if a range was not provided in the literature. We also marked species with a "S" or "m" if reports stated 'significant' or 'moderate' data gaps and/or uncertainties for a species' PLD value or early life history information in general. Finally, we noted modes of adult spawning (demersal, pelagic, live birth, broadcast spawner, other) and the months during which larvae are thought to enter the plankton (e.g. time of larval release, birth, hatch).

2.4.2. Results: Adult movement and larval duration for BC fish and invertebrate species

We found reported home ranges, for 27 out of 59 fish species, and 12 out of 20 mobile invertebrate species (Appendix C). We were able to infer a movement category for an additional 23 fish and seven mobile invertebrate species based on reported observations of species behaviour and mobility. Nine fish and one invertebrate species had limited information regarding movement and were classified as 'unknown'.

We were able to assign movement categories and commonly observed depth categories to 80 species (50 mobile fish, 19 mobile invertebrates, 11 invertebrates with "minimal to no movement") (Fig. 1 and 2, details in Appendix C). Fifty percent of the species we reviewed were limited in their movements (categories "no or very limited movement", < 0.05 km, or < 1 km) and 38 % were highly mobile with movements from over 50 km to 1000s of km (Fig. 1 and 2). Species that fell into the intermediate movement categories (1-10 km or 10-50 km) were mostly invertebrates, apart from three fish species (Fig. 2 and 3). Many species with limited or very limited mobility fell within the shallow depth class (0-20 m), and were typically associated with nearshore rocky reef habitats (e.g. greenlings, red Irish lords, cabezon, wolf eel, sea urchins, large chitons and abalone) (Fig. 3). Most rockfish species were also very limited in their movements, but were found at a range of depths (Fig. 3). The majority of very mobile species were pelagic with distributions that encompassed greater depths. Many of these species make long-distance, or regular on-shore-off-shore migrations (see notes in Appendix C).

Figure 1. Distribution of available data for reported home range or movement category for adult fish and invertebrate species of commercial, recreational, conservation or cultural importance in B.C. These data represent the maximum reported home range for species (27 fish and 12 invertebrates), and the upper limit of an assigned movement category (23 fish and 7 invertebrate species) when no home range was available. Species with upper limits greater than 1000 km were capped at 1000 km. These data exclude species that were classed in the “no or minimal movement” category. Data available in Appendix C.

Figure 2. Number of adult fish and invertebrate species of commercial, recreational, conservation and cultural importance in B.C. within assigned movement categories. Species are placed in movement categories based on empirical data from tagging studies or based on observational information when specific movement data was not available (see Appendices C for details).

Figure 3. General movement ranges and common depth occurrence for adult fish and invertebrate species of commercial, recreational, conservation, and cultural importance in British Columbia, Canada. Species are placed in movement categories based on empirical data from tagging studies (marked by *) or based on observational information when specific movement data was not available (see Appendix C for species details). Depth class demarcations reflect the B.C. Marine Ecological Classification (0-20m = Shallow, 20-50m = Photic, 50-200 = Mid-depth, 200-1000 = Deep, BCMEC 2002). Species were placed in the depth class that best captured their commonly observed depth range (many species may be found in shallower or greater depths). Fish illustrations are provided with permission from Andy Lamb (Lamb and Edgell 2010) and invertebrate illustrations provided with permission from Gloria Snively (Snively 1978). Four additional illustrations were obtained from open-licensed sources or are otherwise left blank. Illustrations are not to scale.

We found information for pelagic larval duration for 40 out of 59 fish species (the other 19 species either spawn in freshwater or do not give birth to larval young), 31 out of 32 invertebrate species, and two out of three algae species (Fig. 4 and 5, details in Appendix D). Larval durations ranged from 32 hours to over one year, with a wide range of values across phyla and within each spatial “larval release zone” grouping (intertidal to offshore) (Fig. 5). The majority of species we reviewed (55 species, 73%) had an average PLD over 30 days/720 hours long, with 18 species (24%) having an average PLD of over 100 days/2400 hours.

A large proportion (54%) of the species we reviewed were noted to have either ‘moderate’ (37%) or ‘significant’ (17%) uncertainty or data gaps regarding their PLD value or information on their early life history (see * and ** symbols in Fig. 5). Eighteen out of 40 fish species were noted as having ‘moderate’ uncertainty (45%), while 9 fish species had ‘significant’ uncertainty (23%). Nine out of 32 invertebrate species were noted as having ‘moderate’ uncertainty (34%), while 2 invertebrate species had ‘significant’ uncertainty (6%).

Figure 4. Distribution of average pelagic larval duration for B.C. fish and invertebrate species of commercial, recreational, conservation and cultural importance. (Left) Larval duration distribution for fish species. (Right) Larval duration distribution for invertebrate species (data available in Appendix D).

Figure 5. Visual summary of pelagic larval duration (PLD) of fish larvae (black diamonds), invertebrate larvae (open diamonds) and algal spores (grey circles) for B.C. species of commercial, recreational, conservation or cultural importance. Species are grouped based on the spatial area and depth where larvae/spores are released: intertidal (area between high and low tides), nearshore-subtidal (within roughly 0-60 m depth), nearshore-to-offshore (across a broad spatial and/or depth range), or offshore (released offshore or at deeper depths >60 m). For species that have a range reported for pelagic duration (horizontal error bars), the symbol simply represents the centre point between the upper and lower values. An asterix next to a species number demonstrates that either 'moderate' (*) or 'significant' (**) data gaps or uncertainty were mentioned in the early life history or larval information available. Refer to Appendix D for larval duration values and more species detail.

2.4.3. Applying species movement and dispersal to size and spacing MPA guidelines in B.C.

Information about adult species movement patterns and larval dispersal is relevant to MPA effectiveness and design (Gaines et al. 2010; Grüss et al. 2011). As such, an important part of the MPA planning process is to gather movement and dispersal information for species found within the planning region (e.g. Coral Triangle, Maypa et al. 2012; California, CDFG 2008; Oregon, Heppell et al. 2008). These data help inform whether existing and/or proposed MPA networks are protecting key species or critical life stages, what MPA sizes might be most suitable to protect target species, and what spacing distances provide adult and larval connectivity between MPAs in a network.

MPA Size

Individual animals will gain the most benefit from spatial protection if all of their routine movements (home range) are encompassed within an MPA. Accordingly, species with limited movement or smaller home ranges will benefit most from MPAs (Gell and Roberts 2003; Palumbi 2004; Moffitt et al. 2009). Our results reveal that a number of valued fish and invertebrate species in B.C. ($n = 29$, Fig. 2 and 3) move within a range of less than 1 km. Our results are similar to those of Freiwald (2012) who found that among 26 species of temperate reef fish in the northeast Pacific, 80% had a maximum movement distance less than 1.5 km. These limited movement species (e.g. rockfish, greenling, perch, mobile invertebrates, etc.) are most likely to directly benefit from spatial protection, assuming MPA boundaries overlap with their distribution and/or habitat.

A network of MPAs will also benefit exploited species with intermediate and larger movement patterns, if overall individuals are spending less time exposed to fishing mortality. As such, species with greater movement patterns are better served by larger MPAs (Palumbi 2004). Wide-ranging species are also likely to benefit if MPAs cover habitats where individuals spend a lot of time or are particularly vulnerable (e.g. migration bottlenecks or critical life stages such as breeding, feeding, or nursing areas) (Hyrenbach et al. 2000; Fernandes et al. 2012). Both of these design recommendations would apply to protecting many of the highly mobile species in B.C. (e.g. salmon, herring, eulachon, halibut, sablefish, hake; see Fig. 2). While MPAs represent one conservation strategy, highly mobile exploited species also require sustainable harvest policies to be implemented outside of reserve boundaries (Allison et al. 1998; Walters et al. 1999; Salomon et al. 2002).

In addition to adult movement, the effectiveness of MPAs also relies on successful recruitment into the protected area (Botsford et al. 2001; Botsford et al. 2003; Botsford et al. 2009; Shanks 2009). For this reason, it is ideal to inform MPA size recommendations with information on larval dispersal (Botsford et al. 2001; Botsford et al. 2003; Hastings and Botsford 2006; Botsford et al. 2009). In California, modelling the dispersal of the larval stages of nearshore species suggested that a reserve size of 4–6 km in diameter should contain the larvae of short-distance (i.e. < 1 km) dispersers, and reserves spaced 10–20 km apart should be close enough to capture propagules released from adjacent reserves (Shanks et al. 2003). The coastline of B.C. however is very different from that of California; B.C. is influenced by different oceanographic currents, has many long fjords and inlets, is highly articulated, and has many islands and archipelagos characterized by high tidal activity. In one simulation study investigating oceanographic connectivity among B.C. MPA sites, Robinson et al. (2005) showed that local, regional, and seasonal currents, as well as eddies, greatly influence the movement of particles among different areas of the B.C. coast. Although we have summarized larval durations for a number of B.C. species (Appendix D), without further modeling studies and empirical estimates of larval dispersal and transport within B.C., it is not possible to incorporate larval dynamics into recommendations for MPA sizing.

MPA size recommendations for B.C. could be informed by the fish and invertebrate movement information we summarized and rules of thumb established in the peer-reviewed literature (see Table 2: MPA Size Guidelines). The overall wide range in movement distances we observed are well aligned with the spatial management recom-

recommendations of Palumbi (2004): a variation in reserve sizes from 10 to 100 km in diameter (i.e. 80 to 7854 km²) may be appropriate to accommodate the neighbourhood sizes of a large fraction of species important in commercial harvest and ecosystems dynamics. Given that many of the species in B.C. are similar to those in California, recommendations that were based on species movements in the California Marine Life Protection Act (MLPA) are also applicable: MPAs should have an alongshore span of at least 5 to 10 km (3 - 6 miles) of coastline although 10 to 20 km (6-12.5 miles) is preferable, and larger MPAs are required to fully protect wide ranging marine birds, mammals, and migratory fish (CDFG 2008, pg. 37). The MLPA size guidelines do not stipulate recommendations for offshore boundary distances except to recommend that MPAs “should extend from the intertidal zone to deep waters offshore” to accommodate movements over the life history of individuals (CDFG 2008, pg. 34). Given that California state waters extend to 3 nautical miles offshore, the Science Advisory Team considered MPAs that extended to the state boundary as meeting the intertidal-to-offshore guideline. For the purposes of evaluating proposed MPAs, the Science Advisory Team combined the alongshore size guideline and state boundary distance to give a minimum size threshold of 9 square miles (i.e. 3 miles alongshore, and ~3 miles offshore) (California MLPA Initiative 2008; 2009). Overall, MPAs with areas 9 - 18 square miles (23-47 km²) were considered to fall within the minimum size range, and those 18-36 square miles (47-93 km²) were within the preferred size range (California MLPA Initiative 2008, 2009).

Our review of species movement information suggests that the adult stage of many nearshore coastal species of economic and cultural importance, particularly reef-associated species with limited mobility (e.g. 20 fish and 25 invertebrate species in the no, very limited, limited, and small movement categories, Fig. 3), could be protected within an MPA area as small as 10 km² (based on a circle with a 1.8 km radius). However, an MPA of this size would have to be placed directly in the appropriate species habitat, and would not necessarily be large enough to ensure population level protection. As such, an alternative minimum size range between 23-80 km², based on the MLPA and Palumbi (2004) guidelines may be appropriate. Large MPAs (100 to 1000s of km²)⁴ will be needed to protect intermediate and more mobile species (e.g. movements between 10 - 1000+ km), encapsulate representative habitats or unique features, protect large-scale ecological processes, and serve many of the wide-ranging species that were not reviewed here (e.g. other fish and invertebrate species, marine birds, marine mammals, etc.). These rules of thumb could serve as initial guidelines until better information becomes available, however ultimately, the appropriate size of MPAs should be determined by the MPA management objectives.

MPA Spacing

MPAs should be spaced far enough apart to maximize the length of coastline replenished by larvae produced within MPAs, but close enough that larvae have the potential to be exported from one MPA to another. The MPA network guideline for spacing in California of having MPAs within 50-100 km of each other, was based on models of larval transport and syntheses of larval dispersal distance estimates for marine fish, invertebrate and seaweed species (Kinlan and Gaines 2003; Shanks et al. 2003). These studies provided data to show that larval movement of 1-100 km was typical of marine invertebrates and larval movements for fishes were typically between 50-200 km (Fig. 6).

The data reviewed here show that a majority of priority fish and invertebrate species in B.C. have very long larval durations (most between 720 - 4800 hours or 30 - 200 days). Assuming that larval duration can be used as a crude indicator of dispersal potential (Shanks et al. 2003, 2009), these long larval durations potentially imply long dispersal distances (100 - 1000 km). However, it is acknowledged that realized larval dispersal distance is only partly explained by larval duration (variation in PLD accounts for ~ 50% of variation in dispersal distance; Shanks et al.

⁴ In a global review by Edgar et al. (2014) targeting 87 well-known and well-regarded MPAs worldwide, “large” MPAs were considered to be >100 km².

Figure 6. Key figures from other studies showing information on larval dispersal distance. (Left) Modified from Shanks et al. (2003), this plot shows the relationship between larval duration (propagule duration) and mean realized dispersal distance for fish and invertebrates (open circles), as well as plant species (filled circles) from the intertidal and nearshore environment. (Right) Graph from Kinlan and Gaines (2003) showing the distribution of mean dispersal distance estimates based on a literature compilation of genetic-by-distance slopes for different macroalgae, invertebrate and fish taxa.

2009), and that larval behaviour, oceanography and current regimes, as well as environmental conditions (e.g. temperature, local sources of entrainment) can significantly influence dispersal distance (Shanks 2009). Overall these parameters have not been extensively examined in the context of larval dispersal within B.C., although some studies provide relevant information. Marliave (1986) conducted ichthyoplankton transects in the rocky intertidal environment and concluded that the larvae of most intertidal fish families (Cottidae, Stichaeidae, Pholidae, Gobiesocidae, Gasterosteidae) remain very restricted to inshore environments with little offshore and possibly longshore dispersal, while some intertidal fish taxa did show greater offshore larval transport. Robinson et al. (2005) used oceanographic particle dispersion models and assumptions of typical larval durations and dispersal distances to show potential patterns of larval transport to, from and within the Gwaii Haanas National Marine Conservation Area Reserve. These authors conducted model simulations using a mean particle dispersal rate (2 km/day), two dispersal release depths (2 m, 30 m), and two dispersal durations (30 days for invertebrates, 90 days for fish), to show that Gwaii Haanas likely contributes particles to other northern MPA sites (~100 km away), receives particles from regions several 100s of km to the south, and likely can retain particles within its 100 km north to south boundary. Finally, Lotterhos et al. (2014) used genetic techniques to estimate the average dispersal distance for black rockfish in B.C. (6 - 184 km per generation) and concluded that the distance between Rockfish Conservation Areas (RCAs) to facilitate connectivity should be no greater than 100 km. Overall, compared to many studies that examine transport patterns of larvae around coastal California (detailed in Shanks et al. 2009), little is known about how the larvae of B.C. fish and invertebrate species are influenced by oceanographic currents, seasonal wind-patterns, upwelling, tidal influences, and larval behaviour and adaptations.

Connectivity and optimal MPA spacing are some of the least understood aspects of MPA network design (Palumbi 2001). As it stands, a better evaluation of MPA connectivity in B.C. waters will require further integration of data

on larval characteristics with more detailed oceanographic models, in addition to more data on the genetic and demographic connectivity of different B.C. species. In the absence of this information, based on the above findings of Lotterhos et al. (2014), the connectivity recommendation (spacing 20 - 200 km) for Canadian MPA networks described by Jessen et al. (2011), and the spacing guidelines used for evaluating potential MPA network configurations in California (CDFG 2008; IUCN-WCPA 2008), we recommend that MPAs should be placed within 20-100 km of each other as a starting point for network design within B.C.

2.5. SUMMARY, LIMITATIONS, CONCLUSIONS

Five broad principles emerged from the literature as key directives to designing MPA networks to achieve ecological objectives. A MPA network should 1) represent all habitats, 2) protect unique, important and vulnerable areas/species, 3) replicate the protection of habitats and features within spatially-separated MPAs, 4) facilitate the connectivity of populations between MPA sites through appropriate size and spacing and 5) mitigate human disturbances and impacts. While these broad principles and associated general guidelines are consistently mentioned in the literature, specific recommendations, targets and strategies for how best to achieve them vary (e.g. (OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012).

Using our guideline framework for assessment, we show that the Canada-British Columbia Marine Protected Area Network Strategy (2014) describe 13 out of 15 ecological design guidelines to guide MPA network design in B.C. The 13 guidelines mentioned vary in the degree to which they are defined and articulated, and there are some notable gaps such as reference to climate change considerations. This Network Strategy document is a high-level strategic framework and therefore lacks specific details, strategies and targets specific to each guideline. Through our review of the science literature and comparison of specific recommendations from different planning contexts, we have provided some suggestions for approaches on how these ecological guidelines could be applied in B.C.

We provide adult movement patterns and larval durations for a selection of B.C. fish and invertebrate species and show that this information can be useful to guide size and spacing recommendations for MPAs within a B.C. MPA network. Through this process, we also illustrate the uncertainties and thus limitations of these data. For example, this report only includes information on fish or invertebrate species deemed to be of commercial, recreational, conservation or cultural importance, whereas MPAs are often implemented with the desire to benefit a much wider array of species across different taxa (e.g. marine birds, marine mammals, and many species of algae and invertebrates were not considered here). We also demonstrate that our knowledge of many valued species is limited, for example, we had to infer movement categories for several species (Appendix C) and we identified moderate and significant knowledge gaps for most species' early-life history and larval characteristics (Appendix D). Few existing empirical or theoretical studies in B.C. exist that have measured or modelled patterns of larval dispersal or species connectivity. This information, combined with a greater understanding of oceanographic and environmental influences, will be needed to better assess connectivity (demographic or genetic) between existing MPAs in B.C. and establish more region-specific rules of thumb for future MPA spacing considerations.

Lack of information should not preclude moving forward in implementing MPA networks (IUCN-WCPA 2008; Jessen et al. 2011; Fernandes et al. 2012). Moreover, Fernandes et al. (2012) state, "even if complete information were available on every species of interest, the likelihood of one set of design principles perfectly serving the needs of all of them would be close to nil" (pg. 100). In spite of all the species-specific information and modeling analyses that California had available, the ecological guidelines that were selected to evaluate and compare alternate MPA network configurations were fairly simple (Saarman et al. 2013). These simple, scientifically robust and objective-driven guidelines helped to productively engage non-scientists in MPA planning and contributed to the overall success of the MPA planning process (Saarman et al. 2013). The guidelines developed for California were further recommended for MPA network planning in Oregon (Heppell et al. 2008), and we think these many of these guide-

lines are appropriate for B.C. also. Acknowledging the limitations of available information, the following general recommendations can be drawn from the information we have summarized:

1. Combined with the recommended target for Canada to represent 30% of all broad-scale habitat types within each marine bioregion (Jessen et al. 2011), information and representation targets from the BCMCA (2012) could be used as a starting point for planning and evaluating proposed MPA network configurations and regional spatial plans in B.C.
2. Information on unique, important and vulnerable areas in the B.C. marine environment can be drawn from Important Areas and Ecologically and Biologically Significant Areas (Clarke and Jamieson 2006a; 2006b), along with special features identified by the BCMCA (2012) and local/regional mapping efforts led by First Nations, the province and local communities.
3. Replication of representative habitats as well as special or vulnerable features should be ensured at the bioregional scale (at least 3 replicate MPAs per habitat type or feature recommended). Similarly, ensuring replication of habitats is achieved across MPAs within smaller ecologically-defined classifications or coastal planning regions will allow representation objectives to be met at the smaller spatial scales at which marine planning in B.C. is typically conducted.
4. Our review of species movement information suggests that the adult stage of many nearshore coastal species of economic and cultural importance, particularly reef-associated species with limited mobility, could be protected within an MPA area as small as 10 km². However, MPAs of this size would have to be placed directly in the appropriate species habitat, and would not necessarily ensure population level protection. Guidelines supported by academic literature and implemented in California recommend a minimum size range of 23-80 km². Ultimately, the appropriate size for individual MPAs should be determined by the MPA management objectives.
5. Large MPAs (100 to 1000s of km²) will be required to protect intermediate and more mobile species, encompass representative habitats or unique features, protect large-scale ecological processes, and serve many of the species that were not reviewed here (e.g. other fish and invertebrate species, marine birds, marine mammals). Highly mobile species will also benefit from MPAs that are strategically placed in critical life history areas (e.g. migration bottlenecks and areas for breeding, feeding, or nursing). Because many of these species migrate and shift between habitats and depth classes during their life history, some MPAs should to be large enough to encompass both nearshore and offshore regions.
6. Conservation of highly mobile exploitable species will require sustainable management strategies to be implemented outside of reserve boundaries.
7. The lack of movement information and/or spatial distribution data for most B.C. fish and invertebrate species (i.e. species not reviewed here) emphasizes the importance of having a variety of MPA sizes that capture representative habitats within the network as proxies for different fish and invertebrate assemblages.
8. The B.C. species we reviewed show a wide range in pelagic larval duration times (30 days to >1 year), but overall information on larval transport and estimated dispersal distances for B.C. species is limited. Based on the network recommendations for Canada (Jessen et al. 2011), one study that evaluates Rockfish Conservation Area connectivity in B.C. (Lotterhos et al. 2013), and the California MPA network spacing recommendations, we suggest that having MPAs spaced within 20 - 100 km (or closer) of each other provides a good initial guideline for network design and evaluation within B.C.

9. In order to maximize ecological resilience of desirable ecosystem states in the face of human-induced stressors, sufficient area in the network should be in no-take reserves (science-based guidelines suggest ~30%, including recommendations for Canada), MPA network designations should be designed for long-term protection, and sustainable use of marine resources should be promoted beyond the boundaries of the network.
10. The Pacific region is vulnerable to ongoing and future impacts linked to climate change. MPA network planning in B.C. should consider these impacts by ensuring representation and replication of habitats and special features, including large MPAs, and protecting sites that are more resistant to, more able to recover from, or help mitigate climate change effects (e.g. protecting coastal carbon sinks, cold water upwellings, areas of high tidal exchange, etc.)

Ultimately, the performance of an MPA network cannot be evaluated until several years after implementation and performance will be based on its ability to meet ecological (i.e. population & ecosystem persistence), social (i.e. equity, quality of life, food security) and economic (i.e. maintain commercial viability) objectives. Consequently, network design must also consider community values, cultural norms, access rights, monitoring of effects, etc. in order to create incentives that facilitate high levels of compliance. Therefore, considering governance guidelines, social goals, and the incorporation of traditional ecological knowledge (see following sections) as equal priorities to ecological objectives is important for MPA network design in B.C.

3. MPA GOVERNANCE AND MANAGEMENT EFFECTIVENESS

3.1. INTRODUCTION

“By definition, an MPA is a governance tool. It limits, forbids or otherwise controls use patterns and human activity through a structure of rights and rules.”

(Pomeroy et al. 2004, pg. 163)

Governance encompasses the structures, processes and traditions that shape how power, responsibility, and decision-making are exercised in a society (Christie and White 2007; Fennell et al. 2008; Lockwood et al. 2010). In the context of MPAs, governance includes the rights and rules, as well as shared social norms that determine how marine resources are used (Pomeroy et al. 2004). Governance structures can include laws, agreements, customs, financing mechanisms, and other formal and informal institutional arrangements (Fennell et al. 2008; TNC et al. 2008). Within these structures occur processes for learning and problem-solving, decision-making (or planning), conflict management, monitoring and enforcement, and other activities (Fennell et al. 2008; Lockwood et al. 2010). As well as public (government) actors, private individuals and groups (e.g. local resource users), NGOs, and business owners, may participate in governance.

The International Union for the Conservation of Nature (IUCN) and Convention on Biological Diversity (CBD) define four broad types of governance for protected areas distinguished by where responsibility and authority for decision-making reside (Borrini-Feyerabend et al. 2013). “Governance by government” situates authority with government ministers, who delegate management responsibilities to less senior government officials and non-governmental actors. “Shared governance” entails some degree of joint decision-making, facilitated through arrangements such as co-management bodies. In the case of “Private governance,” land owners or other private actors are responsible. Finally, “governance by indigenous peoples and local communities” applies to protected areas that are declared and managed locally (Borrini-Feyerabend et al. 2013). Governance and government are not the same thing. Governments play a central role in the governance of most protected areas, but “a growing number of conservation professionals are considering that the good governance of protected areas depends upon the overall power relations between civil society and government, the quality of government, and the quality of engagement of other actors” (Lockwood et al. 2012, pg. 138).

Principles of good governance are dominated by matters of ethics (including legitimacy, fairness, transparency, and accountability), and capacity (including knowledge, financial resources, and human skills). Ultimately, any governance arrangement must be legitimate and effective; legitimate, in particular, in the eyes of those who will be affected, and effective at performing a variety of tasks from coordinating actors and actions across scales and jurisdictions, mediating conflicts, and integrating knowledge (including scientific and traditional knowledge) to produce well-informed decisions. In order to be resilient in the face of changing circumstances, furthermore, many authors emphasize that governance structures and processes need to be flexible and subject to ongoing review and development, whereby gaps are filled, weaknesses revised, and strengths embedded (Agardy et al. 2003; Olson et al. 2004; DFO and WWF 2009; Dickinson et al. 2010; Fox et al. 2013).

Governance directly and indirectly influences the ecological outcomes of MPAs: it affects management effectiveness by determining what inputs and processes are available for making and implementing good quality decisions; and good governance leads to increased support for MPAs, resulting in greater buy-in and compliance with rules and regulations (Pomeroy et al. 2004; Lockwood 2009; Bennett and Dearden 2012). The successful establishment and effective management of MPA networks depends on legitimate and capable governance arrangements that can accommodate ecological criteria while meeting the diverse (and often divergent) expectations of stakeholders.

3.2. LITERATURE REVIEW

3.2.1. *Approach and methods*

To present governance principles pertinent to MPAs and MPA networks, we synthesized literature from natural resource management (NRM) and community-based natural resource management (CBNRM); commons governance; integrated marine planning and MPA management; co-management and adaptive co-management; and social learning. Some of this literature is directly related to MPAs, and some is focused on governance more generally. We combined several different conceptual and organizational approaches while seeking to highlight the close connection between good governance and effective management. While we recognize that governance and management are not the same thing – governance concerns the exercise of power, authority and responsibility, whereas management is more instrumental and concerns resources, plans and actions (Jentoft et al. 2007; Lockwood 2009) – they are highly interdependent and share many of the same principles.

We synthesize guiding principles and examples of good governance practices and strategies from a global literature and grouped them under six thematic headings: Legitimacy; Inclusion and Fairness; Capacity and Performance; Coordination and Collaboration; Knowledge Integration and Adaptability; and Transparency and Accountability (Table 5 and Appendix E). We provide an overview of these guiding principles in the text below, highlighting how governance links to the primary purpose of MPAs, namely conservation. The guiding principles constitute normative statements about how governance should proceed and are focused on inputs and processes rather than generating an evaluative framework for specific outputs and outcomes (see for example Ehler 2003; Pomeroy et al. 2004; Lance et al. 2012). In Appendix E we provide examples of practices or strategies and highlight brief case examples that can contribute to the realization of the guiding governance principles. This list is by no means comprehensive, but provides a selection of commonly cited practices along with examples of their use in cases around the world.

The guiding principles we present are not mutually exclusive. There is overlap between them and different configurations might have worked equally well to organize the key points. No principle, furthermore, is absolute, and context matters when it comes to applying principles of good governance (Jentoft 2000; Graham et al. 2003; Bennett and Dearden 2012). Whereas stakeholder participation, for example, can build a greater sense of ownership and has been shown to lead to long-term conservation success, there are also examples of successful centrally managed MPAs (Pomeroy et al. 2004). Local values and objectives must inform the application of principles that overlap and will even conflict in some cases (Abrams et al. 2003; Graham et al. 2003). Jentoft (2000) cautions against dogmatism when it comes to selecting the best design, “rather, we should stress the need for experimentation of management systems in order to allow the involved partners to learn from experience” (pg. 534).

3.2.2. *Governance principles relevant to MPAs and MPA networks*

Legitimacy

Legitimacy relates to the legal authority of actors (whether public or private) to govern, and to the integrity, commitment and effectiveness with which they do so (Lockwood et al. 2010; Jessen et al. 2011). The legitimacy to exercise authority is typically conferred through democratic institutions, as when MPA managers are delegated responsibilities from more senior levels of government and, ultimately, from elected officials, though alternative or complementary systems (such as hereditary leadership) may also validate authority (Lockwood 2009). The principle of subsidiarity stipulates that as much control over management decisions as possible should be assigned to local governments and communities, or to the lowest level of governance with the capacity to undertake the task at hand (Marshall 2007). Lockwood (2009) suggests that legitimacy is enhanced when governing bodies have “a long-standing cultural or spiritual attachment” to the area within a protected area (pg. 16).

Table 5. Guiding principles synthesized from a global literature on good governance of MPAs and MPA Networks. Principles are organized under six thematic headings. Full details and case examples are provided in Appendix E.

GOVERNANCE THEMES	GUIDING PRINCIPLES
LEGITIMACY:	<i>Rule makers and governance procedures should be legitimate; legitimacy can be earned as well as conferred.</i>
	<ul style="list-style-type: none"> › The authority of actors / organizations to govern should be conferred through valid and credible institutions and clear legal frameworks. › Existing rights and authorities in the area should be affirmed and respected, including those of aboriginal groups. › Public awareness and support should be cultivated.
INCLUSION AND FAIRNESS:	<i>Stakeholders should be meaningfully engaged at all stages of planning and implementation; costs, benefits and regulatory enforcement should be fair.</i>
	<ul style="list-style-type: none"> › Governance processes should be inclusive of all stakeholders. › Costs and benefits of MPA decisions should be fairly distributed. › Enforcement of rules should be fair and impartial. › Governance processes should promote tolerance and respect.
CAPACITY AND PERFORMANCE:	<i>Governance actors should have the strategic direction, leadership, and human / financial resources to effectively and efficiently meet their objectives and responsibilities.</i>
	<ul style="list-style-type: none"> › Governance bodies should have clear objectives (guided by legislation and/or policy), as well as strong political support. › Organizations and individuals should have the capacity and resources to deliver on their responsibilities. › Monitoring and enforcement should be effective and credible. › Mechanisms should be in place to effectively and fairly resolve, manage or minimize conflict.
COORDINATION AND COLLABORATION:	<i>Governance actors should communicate and collaborate effectively; rules and policy initiatives should be coordinated across scales and jurisdictions.</i>
	<ul style="list-style-type: none"> › Effective collaboration should exist between government agencies with overlapping jurisdictions and/or complementary mandates and goals. › Governance rules and arrangements should be integrated and harmonized.
KNOWLEDGE INTEGRATION AND ADAPTABILITY:	<i>Governance processes should enable learning and integration of diverse sources of knowledge, and be responsive to changing circumstances and new information.</i>
	<ul style="list-style-type: none"> › Decision-making should be informed by the best available knowledge. › Constructive stakeholder dialogue should be facilitated in order to build trust and enable learning. › Strategies and arrangements should be adaptable to new information and changing circumstances..
TRANSPARENCY AND ACCOUNTABILITY:	<i>All stakeholders should have access to information about rules / decisions, and about the performance of governance actors and processes; there should be a clear answer to the question "who is accountable to whom for what?"</i>
	<ul style="list-style-type: none"> › Decisions and decision-making processes should be transparent. › Governance performance should be transparent. › Decision makers should be accountable to stakeholders (downward accountability) as well as to higher-level authorities (upward accountability).

A governance body's decisions and actions must accord with its legally-conferred powers (Lockwood et al. 2010). These will be always be circumscribed by the need to respect the jurisdictions and mandates of other governing authorities, as well as the relevant rights of private actors holding, for example, fishery licenses or mineral exploration rights (Lockwood et al. 2012). By the same token, governance legitimacy will be enhanced to the extent that existing rights and authorities are recognized and accommodated, and conflicts between competing claims to legitimacy – notably jurisdictional or ownership disputes – are successfully negotiated (Lockwood et al. 2012).

The inclusion and support of indigenous and others local resource users in conservation planning is viewed globally as a central element of the “new conservation paradigm” (IUCN-WCPA 2012). This is more than a normative principle, however, when aboriginal people have constitutional, treaty or traditional rights respecting the use and management of marine areas, as they do in Canada. Although the authority of Canadian aboriginal groups to manage resources in their traditional territories remains a largely unresolved (and often contentious) issue, particularly in the marine environment, developments in jurisprudence over the past three decades have clearly established that they are most appropriately viewed as an order of government (Hawkes 1996; Jones 2006; Gardner et al. 2008; CPAWS 2009). The Crown (federal and provincial) has a duty to “consult and accommodate” aboriginal peoples that assert ownership to territories where an MPA is being considered (Langdon et al. 2010; Haida Nation v. British Columbia 2004) and MPA regulations that unjustifiably infringe on aboriginal rights (which include the right to food, social and ceremonial (FSC) harvesting) will not be legally valid (Jessen et al. 2011). Approaches to accommodation may include obtaining the consent of aboriginal governments to an MPA designation, arranging for management decisions to be made jointly, and including exceptions in MPA regulations that allow for FSC harvesting (CPAWS 2009; Jessen et al. 2011; Haida Nation v. British Columbia, 2004).

In addition to legally-conferred legitimacy, governance actors and systems earn legitimacy by virtue of their performance (Lockwood et al. 2010). Legitimacy as well as effectiveness demand governance arrangements that are backed up by political commitments, including legislative commitment, commitment to adequate funding, and commitment to meeting timelines and milestones (Jessen et al. 2011). Each of the following guiding principles in this section, furthermore, relate to “earned legitimacy”. In a meta-analysis of protected area cases in developing countries, for example, Andrade and Rhodes (2012) found that among the variables they measured, the level of local participation in decision-making processes had the strongest correlation with acceptance of – and compliance with – protected area policies. Transparency and accountability, similarly, enable stakeholders and others to judge a governing body's legitimacy in terms of the consistency of its decisions and actions with mandates and commitments (Lockwood et al. 2012). In order to consolidate legitimacy, governance bodies should make efforts, such as investing in education and outreach programs, to build public awareness and support for conservation objectives and measures (Jessen et al. 2011).

Inclusion and Fairness

Determining who should be included in making management decisions is always an important question when designing a resource governance system (Lockwood et al. 2010). Charles and Wilson (2009) refer to this as a management right, and it is fundamentally important because without getting this right right, subsequent decisions about the rules of resource access and use (the principle mechanism by which MPAs operate as a conservation tool) are unlikely to be accepted. The inclusion of stakeholders and local resource users – an expression of participatory democracy – increases the likelihood that governance decisions will be supported by those who will be most directly affected, and that broad-based, long-term constituencies in favour of governance objectives will emerge to enhance conservation effectiveness (Borrini-Feyerabend et al. 2004; Charles and Wilson 2009; Ostrom 2009). “Enhancing local autonomy in defining landscapes, managing natural resources and planning and implementing development and conservation initiatives is a powerful means to awaken and utilise the capacities of civil society” (Borrini-Feyerabend et al. 2004, pg. 91). “If stakeholders are involved in the MPA, feel that their views and concerns

are being heard and considered, and feel ownership of it, they are more likely to support [it]" (Pomeroy et al. 2004, pg. 193), whereas the establishment of MPAs without broad consensus from user groups and other stakeholders will make it difficult to obtain their compliance (Pomeroy et al. 2004; Thompson et al. 2005; Pomeroy et al. 2006; TNC et al. 2008; Charles and Wilson 2009; Lockwood 2009). This was the experience of the Marine Life Protection Act (MLPA) in California, which could not be successfully implemented due to public opposition until an extensive participatory process was established (Saarman and Carr 2011).

Evidence shows that MPAs that effectively protect ecosystems and the services they provide can produce valuable benefits, including improvements to commercial fisheries through 'spillover' effects, economic diversification, and the provision of non-consumptive or existence values associated with healthy natural areas (Gell and Roberts 2003; Charles and Wilson 2009; Angulo-Valdes and Hatcher 2010; Bennett and Dearden 2012; Blue Earth Consultants 2012). However, MPAs also impose costs, and actual or perceived inequalities in how these are distributed "are at or near the heart of many, if not most, conflicts over MPAs" (Singleton 2009, pg. 433). Often cited are the costs incurred by fishermen and their households as a consequence of reduced catches or increased operating expenses. In contrast to these direct and immediate costs, at least some of the benefits of fishing restrictions (such as biodiversity conservation, increases in fish biomass, increases in fish age structure, increased ecosystem resilience) are longer term and widely – even globally – dispersed (Jentoft et al. 2007; Charles and Wilson 2009). Ensuring that costs do not fall disproportionately on one group, and that those who bear the costs are also recipients of the benefits flowing from an MPA, is complicated by these spatial and temporal factors (Lockwood et al. 2010). In some areas it may be possible to mitigate these costs by, for example, allowing local harvesting activities to continue within the boundaries of an MPA; but in other cases resource users will have to be displaced if MPAs are to achieve desired outcomes (Charles and Wilson 2009). Experience has shown that the long-term success of MPAs depends on stakeholders agreeing that the long-term benefits of an MPA outweigh the immediate costs, including the direct costs of complying with new rules (Pomeroy et al. 2006; Christie and White 2007; Cox et al. 2010).

Two further aspects of fairness in governance are impartiality and respect. Impartiality is about treating everyone equally when taking decisions such as how (or whether) rules are enforced and infractions sanctioned. It means ensuring that authority is not exercised arbitrarily or in a discriminatory fashion, and that individuals have access to legal recourse if they believe their rights have been violated (Abrams et al. 2003; Graham et al. 2003). Respect is perhaps a more subtle (and hard to measure) quality of governance, but it also bears directly on whether or not MPAs will be thought worth supporting. Are all stakeholders, from government representatives to local resources users, heard and treated respectfully? Is the knowledge they possess recognized and valued? Is the intrinsic worth of nature itself respected? (Graham et al. 2003). "Good governance is not only effective, but also sensitive, caring (and) just" (Jentoft 2000).

Capacity and Performance

Governance bodies must be able to "anticipate, manage, and respond to threats, opportunities, and risks in order to operate effectively" (Lockwood et al. 2010, pg. 998). They need operational capacity, underpinned by clear legislative mandates and strong leadership, to implement management plans, engage stakeholders, manage conflicts, monitor ecological conditions, and enforce rules (Blue Earth Consultants 2012). In a comparative analysis of eight leading international marine planning initiatives, the authors found that having high level government leadership, a legal and policy framework to provide clear direction, comprehensive goals with measurable targets, and regular progress monitoring and evaluation to be key components contributing to successful marine planning efforts (Dickinson et al. 2010). Having good quality information, the ability to adapt plans, as well as effective dispute resolution mechanisms are also noted as critical capacity issues (Ehler 2003; Dickinson et al. 2010; Blue Earth Consultants 2012; Saarman et al. 2013). With respect to these aspects of governance capacity, adequate funding is of course a critical element – a lack of which has been identified as a cause of the slow implementation of an

MPA network in Canada (Jessen et al. 2011; OAG 2012). Attention to capacity must apply to any delegation or decentralization of governance responsibilities. “In a devolved system of environmental governance, there is the risk that responsibilities will be allocated to lower tiers without commensurate resources, so that the capacity of governance bodies to deliver effective outcomes is compromised by insufficient financial autonomy and flexibility” (Lockwood et al. 2010, pg. 996).

The capacity to monitor user behaviour and enforce rules is what distinguishes effective MPAs from “paper parks” (Robb et al. 2011; Blue Earth Consultants 2012). “Very often,” however, “protected area institutions are among the weakest areas of government in terms of enforcement of national laws and policies” (IUCN-WCPA 2012, pg. 9). In developing countries, according to Christie and White (2007), it is common for influential stakeholders to flout regulations with impunity. If governing authorities are viewed as unable – or unwilling – to enforce the rules, then compliance will quickly deteriorate. Just as resource users don’t want to be “suckers” by following rules when no one else is, they are much more likely to obey rules when they perceive the overall rate of compliance to be high (Ostrom 2000; Pomeroy et al. 2006; Andrade and Rhodes 2012). While the more resources (human, financial, and physical) that are put towards enforcement the greater the level of compliance is likely to be, costs can also be lowered by involving stakeholders themselves in designing and implementing monitoring and enforcement activities (Pomeroy et al. 2004; Heck et al. 2012). Participation gives stakeholders ownership over regulations, and actively involving resource users in monitoring creates social pressure to comply with the rules (Pomeroy et al. 2004). The links here to legitimacy and effectiveness are clear.

Another measure of governance capacity and performance relates to the management of stakeholder conflict. “Conflicts involving MPAs are inevitable as, for example, an area is taken out of production, new rights and rules for use of marine resources are implemented, and individual and group interests in the marine resources are affected” (Pomeroy et al. 2004, pg. 176). “Empirical research demonstrates that when collective action and conflict resolution mechanisms break down, MPA effectiveness rapidly deteriorates” (Christie and White 2007, pg. 1048). Conflicts can be managed (if never fully resolved), if governance leaders are provided with the skills and resources to do so (Daniels and Walker 1996; Yaffee and Wondolleck 2003). When governance processes are well designed and resourced – involving a diversity of participants; ground rules for open and unrestrained thinking; and third-party facilitation – they can contribute to trust-building among stakeholders with competing objectives (Schusler et al. 2003). A sign of good governance is that conflicts are not avoided, but rather treated as catalysts for dialogue, relationship-building and problem-solving (Ostrom 2000; Abrams et al. 2003; Lockwood et al. 2010). In addition to forums for deliberation, though, fair, timely and low-cost mechanisms also need to be available for stakeholders to air grievances, resolve misunderstandings and, if necessary, receive arbitration (Ostrom 2000).

Coordination and Collaboration

Due to the social and ecological complexities and interdependencies that characterize marine resource management, and to the fact that management responsibilities are typically assigned to numerous government agencies, coordinating plans and actions across scales and levels of government is essential (Dickinson et al. 2010, Jessen et al. 2011, Lockwood et al. 2010). Achieving MPA objectives such as protecting migratory species, increasing the abundance of valued fish species, mitigating the impacts of pollution, and enhancing ecosystem resilience in the face of human impacts is dependant on events outside MPA boundaries, in the ocean and on land (Cicin-Sain and Belfiore 2005; Christie and White 2007). It is desirable, therefore, that MPAs are connected to larger planning arrangements in which externalities can be monitored, activities coordinated and harmonized, and conflicts managed (Cicin-Sain and Belfiore 2005). MPA networks are preferable to a “patchwork” of individual MPAs, but these require coordination and interaction among agencies working towards common ecological goals (DFO and WWF 2009, Horigue et al. 2012). In Canada, cooperation between the three federal agencies with responsibility for developing an MPA network (DFO, Parks Canada, and Environment Canada) is paramount (Jessen et al. 2011).

Intergovernmental collaboration, including information sharing, integration of policy initiatives, and joint management activities will deliver greater efficiency and less duplication or incoherence in terms of policy making and resource use (Lockwood et al. 2010). It will also address gaps in management responsibilities and ensure effective enforcement of rules (Jessen et al. 2011). Issues such as jurisdictional fragmentation, legislative inconsistency, and “silo behaviour” make coordination and collaboration difficult (Cicin-Sain and Belfiore 2005, Dickinson et al. 2010, Bennett and Dearden 2012, Gardner et al. 2008) and are identified as problems for establishing MPAs and an MPA network in Canada (Canessa and Dearden 2008; Jessen et al. 2011; Heck et al. 2012; OAG 2012). The limited capacity of aboriginal governments to fully engage in MPA processes, and difficult relationships with federal and provincial governments due to historical grievances and unresolved claims of rights and title, are additional complications (CPAWS 2009). Whereas the MLPA initiative in California was able to sidestep the challenge of federal-state coordination by limiting the planning process to state-controlled (coastal) waters, “despite federal agency interest in a combined state-federal effort” (Kirlin et al. 2012), the overlapping jurisdictions of federal, provincial / territorial, and local governments (including First Nations governments) in coastal waters makes this option less feasible in Canada. Effective collaboration starts at the top with political leadership, but it also requires connected mechanisms (e.g. planning committees, working groups, joint management boards, advisory bodies) for vertical and horizontal interaction between government agencies (and also within them), from MPA managers and technical staff to senior decision makers (Jessen et al. 2011; Lockwood et al. 2012).

Coordination and collaboration need not be restricted to government actors, and much of the capacity for solving resource challenges exists outside government in civil society, industry, and academia (Huppé et al. 2012). In the Philippines, for example, scaling up individual MPAs into an interconnected MPA network was achieved by forging inter-institutional collaboration among local governments with assistance from other institutions including non-governmental organizations, development partners, funding agencies, government agencies and academia (Horigue et al. 2012).

Coordination and collaboration can also entail harmonizing MPAs with existing local and/or traditional systems that – by design or not – contribute to conservation objectives. “Using existing governmental and resource user governance systems as the foundation for MPA rules can enhance understanding, support, and compliance among resource users and government officials” (Pomeroy et al. 2006 pg. 16), whereas rules that contradict traditional rules or existing regulations are likely to produce uncertainty, conflict, and very low compliance (Abrams et al. 2003; Pomeroy et al. 2006 pg. 16; Cox et al. 2010). As noted above, aligning MPAs with traditional practices will also have a legal dimension when the latter are legitimized by the authority of an aboriginal government.

Knowledge Integration and Adaptability

Ecologically effective MPAs depend on decision-makers having access to the best available information about natural systems and their human uses (Pomeroy et al. 2004). Scientific research and monitoring are “essential tools in MPA management” (Cicin-Sain and Belfiore 2005, pg. 852), and both social and natural science are needed “in order to understand the complexities of interlinked ecological, socioeconomic and cultural systems” (Dickinson et al. 2010; Pollnac et al. 2010). No single actor has access to all of the knowledge needed to address complex problems, and governance arrangements must provide for the acquisition and integration of information from many sources (Huppé et al. 2012). “An essential ingredient of good governance is a process for citizens, experts and managers to co-produce and use knowledge to address complex problems” (Jessen et al. 2011, pg. 40). Local and traditional (or indigenous) ecological knowledge, which can be provided through public participation in management processes, or joint research initiatives, can be extremely valuable when designing effective MPAs to inform strategies and rules that are reflective of and appropriate to local conditions (Charles and Wilson 2009; Lockwood et al. 2010). Integrating local and indigenous or traditional ecological knowledge with information obtained through scientific research is addressed more fully in Section 5 (Knowledge Integration: Incorporating Traditional Ecological Knowl-

edge into MPA Planning).

Governance actors and systems must also be adaptable to new information and changing circumstances (Dickinson et al. 2010). “It is implausible that the first rules chosen to govern an MPA will be perfect. Even if rules are appropriate when first established, shifting social and biological conditions will likely reduce their efficacy over time” (Mascia 2001, pg. 7). Adaptive management calls for decisions to be treated as hypotheses and adjusted according to their performance, and for cultures of experimentation, self-reflection, and continuous learning to be fostered (Lockwood et al. 2010; Crona and Parker 2012). Collaborative processes for knowledge sharing and learning can strengthen the adaptability of governance systems by fostering innovation and identifying new opportunities for solving problems, but they require trust and respect between actors that can be undermined by competing interests (actual or perceived) and historical animosities (Schusler et al. 2003; Folke and Gunderson 2006; Hahn et al. 2006; Galaz et al. 2008; Crona and Parker 2012; Dedual et al. 2013). Trust and relationship-building is thus an important element of adaptability, and one that non-governmental or “bridging” organizations can be instrumental in facilitating (Hahn et al. 2006; Galaz et al. 2008).

Transparency and Accountability

Ensuring that decisions are fair and equitable, and enjoy the trust and confidence of all stakeholders, requires governance arrangements that are transparent and accountable (Jessen et al. 2011). Accountability needs to be downward from managers to resource users and other stakeholder groups, as well as upward to higher level authorities and outwards or horizontally to management partners in other government agencies (Lockwood et al. 2010; Jessen et al. 2011). Transparency can be delivered through open decision-making processes that provide for meaningful public participation, and through the timely exchange of information at all stages of a governance process. It is important that responsibilities for implementing governance tasks are clearly delineated so that one can see who made a decision, under what authority, and by what reasoning or justification (Dickinson et al. 2010; Jessen et al. 2011). Governance performance should be easy to evaluate by setting clear objectives and timelines, and then reporting regularly on how these have been met (Jessen et al. 2011; Lockwood et al. 2012). Reporting requirements and the timely exchange of information are basic principles of good governance, and targeted efforts may be needed to ensure information is accessible to all stakeholders regardless of where they are located, the language they speak, or their level of education (Lockwood et al. 2010).

Transparency strengthens governance legitimacy and confidence, but it serves important functional purposes as well. Rules and management plans need to be clear so that they are understood and are thus more likely to be complied with; regularly measuring and reporting on performance is necessary in order for governance systems to be adaptive to new information and changing circumstances (Pomeroy et al. 2004; Lockwood et al. 2010).

3.2.3. Discussion

All principles of good governance, from stakeholder inclusion to capacity, adaptability and transparency are related to legitimacy and effectiveness, which are themselves interdependent. MPA governance arrangements must be legitimate in order to enjoy the broad support necessary for these protected areas to be established and managed effectively; MPAs that successfully meet expectations for ecologically effective and socially just conservation will, in turn, earn legitimacy. Across the resource governance literature are calls for more inclusive, participatory, and collaborative decision-making, and indeed the global trend in protected area governance is in this direction (Borini-Feyerabend et al. 2004; Dearden et al. 2005; Andrade and Rhodes 2012). A 2005 survey assessing governance changes over a ten year period (1992-2002) found substantial increases in the perceived influence of local communities, non-governmental organizations, and the private sector in protected area decision-making (Dearden et al. 2005). The principles of stakeholder participation are clearly articulated in legislation and policy documents guiding Canada’s establishment of MPAs, including the Oceans Act (Government of Canada 1997) and Canada’s

Oceans Strategy (DFO 2002), the National Framework for Canada's Network of Marine Protected Areas (DFO 2011), and the Canada – British Columbia MPA Network Strategy (Canada and British Columbia 2014). According to Jones et al. (2011, viii), “it is widely accepted that co-managing MPAs is the way forward,” though its application – which implies some sharing of authority and responsibility for decision-making – will vary widely from case to case.

Stakeholder inclusion is a fundamental requirement in democratic societies, as it gives voice to those who will be affected most by management decisions. Engaging stakeholders in meaningful processes also gives MPA proponents access to diverse knowledge and distributed capacities, and is a means of strengthening relationships, addressing conflict, and building adaptive capacity. However, it is important to recognize that more open and inclusive decision-making processes are not silver bullets for improved governance. Stakeholder engagement is complicated and time-consuming, and participatory or decentralized processes will undermine the legitimacy of MPA governance arrangements if they are perceived to exclude non-local (e.g. national) interests; avoid controversial issues; preference consensual over optimal solutions; marginalize “troublesome” stakeholders; or exacerbate inequalities and power imbalances (Borrini-Feyerabend et al. 2004; Berkes 2009; Flannery and Ó Cinnéide 2012 pg. 98). Conflicting stakeholder interests and competing values are inevitable, and governance legitimacy and effectiveness depend on decisions being made in the face of these complexities (Jentoft 2000). In Canada as elsewhere it is government ministers who have final decision-making authority (Pomeroy and Berkes 1997), and according to Jessen et al. (2011, pg. 40), “political leadership is required to move the process forward despite some opposition, understanding that in the long term, everyone stands to gain from an effective network of MPAs”.

Rusnak (1997) argues that, due to the limits on power sharing imposed by governmental authority, ‘true’ co-management is “an ideal management system which does not actually exist in practice but is aspired to and incrementally approached.” These limits are being tested in Canada, however, by the unique place of aboriginal groups as government actors with substantial rights and authorities in marine areas. Notable examples are agreements between the Government of Canada and the Council of the Haida Nation (CHN) to jointly manage the Sgaan Kinghlas MPA and Gwaii Haanas National Marine Conservation Area Reserve (NMCAR). These agreements (see Canada and CHN 1993, 2007) acknowledge and, through consensus-based decision-making, accommodate the fact that both parties claim decision-making authority. Similar arrangements are likely to feature prominently in the ongoing experience with governance design in Canada. Co-management is just one possible dimension to intergovernmental collaboration, however, and will not be appropriate in all cases or for all actors. Other mechanisms will also be necessary to effectively coordinate the policies and activities of the many government actors with authorities and mandates in marine areas.

3.3. APPLYING GOVERNANCE PRINCIPLES TO REVIEW MPA POLICY DOCUMENTS

Using our framework of governance principles, we assessed four different MPA-related policy documents in British Columbia for their articulation of principles as well as identification of strategies for putting these into practice (described below). A detailed review of the text in each document, organized according to the six thematic headings developed above, is provided in Appendix F. Table 6 displays the review in summary form.

1. Canada – British Columbia Marine Protected Area Network Strategy (Canada and British Columbia 2014)

This document “outlines a vision and goals to help guide MPA establishment and regional planning initiatives” in Pacific Canada. The Strategy is “a high level policy framework for guiding the process of establishing networks of MPAs”. This document addresses both ecological and governance principles, and hence it is assessed here for articulation of governance principles, and in Section 2.3 for articulation of ecological design principles.

2. Letter of Intent (LOI) to Collaborate on Coastal and Marine Planning in the Pacific North Coast (FLNRO, CFN, Nanwakolas, NCSFNSS 2011)

The LOI outlines the context and intended nature of collaborative coastal and marine planning by the Coastal First Nations – Great Bear Initiative, the North Coast Skeena First Nations Stewardship Society, the Nanwakolas Council, and the Province of British Columbia as part of what is now called the Marine Planning Partnership (MaPP - more details and ongoing developments available at www.mappocean.org).

3. West Coast Aquatic Management Board – Governance document (WCA 2012)

West Coast Aquatic (WCA) is a long-standing governance body dedicated to integrated marine planning under the Oceans Act. This document outlines this organization's governance arrangement, including roles, responsibilities and appointments, board decision-making, and board member responsibilities. The Management Board is an advisory body for shared decision-making, and includes representation from three levels of government (federal, provincial and First Nations) and non-government members from a number of marine sectors.

4. Memorandum of Understanding (MOU) on Pacific North Coast Integrated Management Area (PNCIMA) Collaborative Oceans Governance (DFO, CFN, and NCSFNSS 2008)

The MOU outlines a collaborative governance model between the Fisheries and Oceans Canada (DFO), on behalf of the Government of Canada, the Coastal First Nations (CFN), and the North Coast-Skeena First Nations Stewardship Society (NCSFNSS), to implement integrated management within the PNCIMA Large Ocean Management Area. Although this governance model substantially changed in 2011 when DFO decided to streamline the integrated planning process for PNCIMA (see details documented in the Draft PNCIMA Integrated Management Area Plan - DFO 2013), we chose to assess this document as it represents an important initial outline for collaborative marine governance.

Carrying out the assessments involved a detailed review of each of these documents, matching the text therein to the relevant governance principles from our framework. Our assessment is only of the written documents, and does not consider whether the documents are effectively being implemented. Here we assess only the articulation of governance principles, rather than the quality of governance itself. Thus, if a principle or good practice is not mentioned, it does not necessarily mean that it is not being addressed. Similarly, if a principle or good practice is mentioned, it does not mean that it is necessarily being followed in practice. The assessments can usefully serve to show where the documents place their attention, and where they do not, and to direct readers to examples of how governance principles are being articulated and implemented.

For the assessments we chose to distinguish principles that were simply mentioned in the documents from more detailed considerations and/or strategies for how they were (or could be) put into practice. In Table 6 this distinction is shown by light and dark checkmarks, respectively. However the difference between a "mention" and a "strategy" is not always clear-cut. The view we took was that some action should be proposed, or actionable details given, to qualify as a strategy (or practice); but subjective judgements had to be made in many instances. For example, in the Canada-BC MPA Network Strategy (Canada and British Columbia 2014), the following two statements were considered intermediate between mentions and strategies.

"mention"

"A multi-agency, systematic approach will provide regional consistency for planning and establishing new MPAs."

"strategy"

"Implementation plans may be developed at the bioregional scale in collaboration with First Nations, and with input from local governments and stakeholders..."

In these examples, “implementation plans” were viewed as actionable and assigned a dark checkmark in the summary table, whereas “a multi-agency, systematic approach” was considered less precise and given a light checkmark. In general, examples of how principles could be achieved, in addition to actual plans for doing so, were considered adequate to be considered a strategy / practice (dark checkmark).

The principles associated with governance authority (under Legitimacy) and legal powers (under Capacity and Performance) were treated as special cases because they were not typically articulated explicitly as other principles were. In most cases the legitimacy of governance actors (their authority to make decisions regarding MPA planning and management) can be inferred from authorship (e.g. representatives of Provincial or Federal government). In some documents references are also made to enabling legislation (e.g. Oceans Act). For the purpose of this assessment, reference to “legitimacy” was not considered obligatory to merit inclusion in the tables, but some reference to authority, mandate or responsibility was necessary for a mention (light checkmark), and explicit assertions of, justifications for, or measures to strengthen legitimacy were assigned a dark checkmark.

Table 6. Assessment of key policy documents against governance principles. The dark green checkmark (✓) indicates that the principle is explicitly or implicitly referred to, and/or an action or practice is proposed to demonstrate how it might be achieved. The light green checkmark (✓) indicates that the principle is referred to but no action/practice is proposed. No checkmark means that the principle is not mentioned in the document. See Appendix F for assessment details.

GOVERNANCE THEMES & GUIDING PRINCIPLES	POLICY DOCUMENTS			
	Canada-BC MPA strategy	MaPP LoI	WCA	PNCIMA Mo
LEGITIMACY: <i>Rule makers and governance procedures should be legitimate; legitimacy can be earned as well as conferred.</i>				
The authority of actors / organizations to govern should be conferred through valid and credible institutions and clear legal frameworks.	✓	✓	✓	✓
Existing rights and authorities in the area should be affirmed and respected, including those of aboriginal groups.	✓	✓	✓	✓
Public awareness and support should be cultivated.	✓	✓	✓	
INCLUSION AND FAIRNESS: <i>Stakeholders should be meaningfully engaged at all stages of planning and implementation; costs, benefits and regulatory enforcement should be fair.</i>				
Governance processes should be inclusive of all stakeholders.	✓	✓	✓	✓
Costs and benefits of MPA decisions should be fairly distributed.	✓			✓
Enforcement of rules should be fair and impartial.				
Governance processes should promote tolerance and respect.			✓	

(Table continued on following page)

(Table continued from previous page)

GOVERNANCE THEMES & GUIDING PRINCIPLES	POLICY DOCUMENTS			
	Canada-BC MPA strategy	MaPP LoI	WCA	PNCIMA Mo
CAPACITY AND PERFORMANCE: <i>Governance actors should have the strategic direction, leadership, and human / financial resources to effectively and efficiently meet their objectives and responsibilities.</i>				
Governance bodies should have clear objectives (guided by legislation and/or policy), as well as strong political support.	✓	✓	✓	✓
Organizations and individuals should have the capacity and resources to deliver on their responsibilities.	✓	✓	✓	✓
Monitoring and enforcement should be effective and credible.	✓			
Mechanisms should be in place to effectively and fairly resolve, manage or minimize conflict.	✓	✓	✓	✓
COORDINATION AND COLLABORATION: <i>Government actors should communicate and collaborate effectively; rules and policy initiatives should be coordinated across scales and jurisdictions.</i>				
Effective collaboration should exist between government agencies with overlapping jurisdictions and/or complementary mandates and goals.	✓	✓	✓	✓
Governance rules and arrangements should be integrated and harmonized.	✓	✓		✓
KNOWLEDGE INTEGRATION AND ADAPTABILITY <i>Governance processes should enable learning and integration of diverse sources of knowledge, and be responsive to changing circumstances and new information.</i>				
Decision-making should be informed by the best available knowledge.	✓	✓		✓
Constructive stakeholder dialogue should be facilitated in order to build trust and enable learning.	✓	✓	✓	✓
Strategies and arrangements should be adaptable to new information and changing circumstances.	✓			✓
TRANSPARENCY AND ACCOUNTABILITY <i>All stakeholders should have access to information about rules / decisions, and about the performance of governance actors and processes; there should be a clear answer to the question "who is accountable to whom for what?"</i>				
Decisions and decision-making processes should be transparent.	✓			✓
Governance performance should be transparent.	✓			
Decision makers should be accountable to stakeholders (downward accountability) as well as to higher-level authorities (upward accountability).		✓	✓	✓

The governance assessments are not an apples-to-apples evaluation of equivalent governance documents. The documents were written for different purposes and therefore the relevance of various governance principles to each of them is not the same. The West Coast Aquatic document and PNCIMA LOI, for example, provide extensive details on the principle and practice of collaboration, but have little to say about knowledge integration and adaptation, or monitoring and enforcement. The Canada-BC MPA Network Strategy (2014) mentions most of the principles considered in the assessment, but provides little detail on how to put them into practice. For comparative purposes the key strengths and gaps within each individual policy document are summarized below:

Canada – British Columbia Marine Protected Area Network Strategy (2014)

- › The strategy is comprehensive in its incorporation of key governance principles. As a “high level policy framework” it contains very few details or suggested actions.
- › The principle of inclusion is articulated prominently, as is collaboration, and commitments are made for multi-agency collaborative decision making. Further details on how this will be achieved are not given.
- › Special rights of First Nations are affirmed and collaborative decision-making by government agencies and First Nations is a central element of the Strategy.
- › Opportunities to “capitalize” on existing plans, processes and arrangements are recognized.
- › Conflict is noted as a potential issue, but strategies are not given for managing it.
- › The principle of transparency is acknowledged but not developed.

Letter of Intent to Collaborate on Coastal and Marine Planning in the Pacific North Coast (2011)

- › The LOI is focused primarily on collaboration (e.g. knowledge sharing, administrative / technical cooperation); other governance principles such as adaptation, transparency and accountability are not addressed.
- › Respect for the authorities / jurisdictions / rights of the signatories is emphasized.
- › Specific suggestions for facilitating stakeholder / public engagement are given.
- › Some clear planning objectives and an organizational (collaborative) arrangement are outlined.
- › Questions of implementation and performance are not addressed.

West Coast Aquatic (WCA) Management Board – Governance document (2012)

- › Governance arrangement (Management Board) and objectives are described in detail.
- › Strong emphasis is placed on the responsibilities of governance actors, including commitment, respect and integrity.
- › Clear guidelines are given for (consensus-based) decision-making.
- › The Nuu-cha-nulth Tribal Council is recognized alongside the Government of Canada, the Province of B.C., and regional districts as a government actor.

MoU on Pacific North Coast Integrated Management Area (PNCIMA) Collaborative Oceans Governance (between the Department of Fisheries and Oceans and First Nations of the Pacific North Coast) (2008)

- › Respect for the authorities and mandates of the parties are emphasized; a government-to-government relationship with First Nations is affirmed.
- › Inclusion, cooperation and dialogue are highlighted; strategies / tools for facilitating these are described.
- › The absence of the Province as a partner is noted, with a view to inclusion in the future.
- › Governance structures, but not processes, are described.

The ultimate test of good governance, of course, is how stated principles and intentions are implemented in decisions and decision-making processes. It will be important to critically re-examine these planning initiatives as they proceed in order to know whether these government agencies or governance bodies in fact commit to the contents of the documents they released. Ultimately, governance agencies and bodies should ensure measures to provide transparency and accountability for governance performance as a means to communicate progress on stated commitments to stakeholders and the broader public.

4. SOCIAL GOALS FOR MPAS: SYNERGIES AND TRADE-OFFS IN DESIGN AND ESTABLISHMENT

4.1. INTRODUCTION

In the context of marine spatial planning and MPA network design, social goals can broadly be described as goals that address desired human-related outcomes linked to marine resources and ecosystems processes (Charles and Wilson 2009). In many instances, designing marine spatial plans or MPAs to achieve social goals can complement or supplement ecological aspirations by supporting perceptions of fairness and creating opportunities to share culture and knowledge as well as fostering employment and networks linked to ecological stewardship or nature appreciation, among other benefits. In other cases, social goals aim to minimize costs of MPA establishment, or involve negotiating trade-offs between conflicting needs and values. Indeed, mounting evidence suggests that incorporating socio-economic objectives in MPA planning is instrumental for creating incentive structures that support MPA compliance and achieve greater social outcomes (Ban and Klein 2009; Cinner et al. 2009; McClanahan 2010; McClanahan 2012). In order to achieve more desirable social outcomes along with conservation objectives, MPA network designs that consider both socioeconomic and ecological objectives are becoming more common in systematic conservation planning (Sala et al. 2002; Richardson et al. 2006; Ban and Klein 2009; Ban et al. 2013c).

Social and conservation goals are often compatible. A growing number of MPAs and MPA networks have contributed in meaningful ways to community development (Goodwin 2002; Alcala and Russ 2006; Lucas and Kirit 2009), poverty reduction (Leisher et al. 2007), cultural preservation (Salm et al. 2000), and more secure marine resources (Pomeroy et al. 2004; Torell et al. 2010). In some cases, the link between protecting ecosystems and cultural values is explicit: protecting cultural heritage within MPAs that also have ecological value addresses both social and conservation goals. In other cases the link is less obvious, for example, when regulating or supporting ecosystem services are protected, which provide indirect support for social values.

Social goals will not always complement conservation efforts, and will instead involve trade-offs. MPAs influence the benefits that flow from marine ecosystems to people, as well as the distribution of these benefits (Mascia and Claus 2008). Some people may benefit from such a re-distribution, whereas others will be negatively affected. One approach to addressing multiple and potentially conflicting objectives is through zoning marine areas (i.e. creating geographically defined areas where different types of activities are allowed). For example, Marxan with Zones is a decision-support tool that can find options for assigning multiple zones with different objectives in a planning region such that multiple objectives are met (Klein et al. 2008b; Watts et al. 2009; Weeks et al. 2010a). Another recommendation is to be explicit about stating social goals so that trade-offs are transparent (Ban et al. 2013a).

4.2. LITERATURE REVIEW

4.2.1. *Approach and methods*

We synthesized information on social goals and impacts of MPAs by reviewing academic articles and grey literature from diverse social domains (e.g. conservation planning, economics, marine policy, natural resource management, social-welfare, human well-being, governance, co-management, tourism, social-ecological systems, etc.). Based on this literature, we highlight some social goals that can complement or supplement conservation aspirations of MPAs. We organized these social goals under four thematic headings: Marine livelihoods and food security; non-monetary and intangible benefits; culture and history; and education and knowledge sharing (summarized in Table 7, details in Appendix G). Along with each social goal, we list general strategies and practices that have been acknowledged in the literature as contributing to achieving the broader social goal (Table 7, Appendix G). We also highlight brief examples that illustrate where these strategies have been implemented (Appendix G).

Because social goals linked to MPAs are context specific, our examples are not intended to be comprehensive or prescriptive. Unlike ecological MPA network design guidelines, which are widely acknowledged and often broadly applicable to achieving conservation outcomes in different ecosystems, there are no equivalent 'social MPA design guidelines' given the different social contexts of existing and prospective MPA sites. For example, if a planning region encompasses communities of varying socio-economic status, social goals may address poverty alleviation, education and alternative livelihoods while reconciling priorities of recreational opportunities and infrastructure. We provide some examples of common social goals in MPA planning efforts, but emphasize that these examples may not be appropriate in all circumstances, that they are not mutually exclusive, and that many additional potential social goals exist.

Table 7. Examples of social goals for MPAs and MPA network design synthesized from a global literature (literature citations as well as brief case examples in Appendix G). The social goals as well as strategies and practices provide examples of MPA design considerations that complement, supplement or present trade-offs with desired ecological outcomes of MPAs.

SOCIAL THEMES	EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES
MARINE LIVELIHOODS AND FOOD SECURITY: Enhance capabilities and assets for income and subsistence activities.		
Enhance or maintain contributions of sustainable fisheries to employment, income, and food security.		Consider the economic importance of fishing in MPA design and placement – costs of reduced access as well as benefits from spillover.
		Consider aspects of marine area access and adjacency by local marine users.
Support or enhance existing local ‘non fisheries-based’ livelihoods and possible alternative livelihood strategies.		Identify areas that are key sites/routes for current and prospective marine tourism and include them in the MPA network.
		Support local initiatives to grow the tourism industry.
		Identify and develop alternate economic opportunities linked to marine resources within and outside of the MPA network.
		Provide entrepreneurship and marketing training for new local marine-based enterprises.
Support local employment in the implementation and management of the MPA network.		Support employment opportunities related to cultural information and sharing.
		Support local organizations and/or employment of local people in monitoring ecological conditions.
NON-MONETARY AND INTANGIBLE BENEFITS: Understand and incorporate non-monetary benefits of MPAs		
Support local goals of poverty reduction, health and well-being as indirect benefits of protected areas.		Consider poverty reduction strategies as a potential indirect benefit or long-term goal of MPAs.
		Consider how MPAs can support goals to improve local health and well-being.
Enhance opportunities for recreational activities.		Collect information to identify areas that are key sites/routes for current recreational use, and areas of future prospective marine recreation.
		Create “buffer zones” within which recreational activities can be pursued with reduced impacts on sensitive ecological areas.
		Situate MPAs close to population centers in order to facilitate access for recreational users.
Maintain / enhance the services provided by healthy ecosystems.		Protect natural areas that provide important supporting services.
Conserve natural areas for their non-use (e.g. existence; option) values.		Conduct research (e.g. surveys) and/or learn from experience elsewhere to understand how marine areas are valued and incorporate findings into MPA decision-making.

(Table continued on following page)

SOCIAL GOALS FOR MPAS: SYNERGIES AND TRADE-OFFS

(Table continued from previous page)

SOCIAL THEMES	EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES
CULTURE AND HISTORY: <i>Protect cultural and historic features and support traditional practices and connections to natural / sacred areas.</i>		
Protect cultural heritage and traditional practices.		Identify areas of cultural or historical importance and accommodate them within the boundaries of the protected areas.
		Support local efforts to protect and present local culture and history.
		Use indigenous names for fauna, flora, and landscape features.
		Accommodate traditional practices that are compatible with conservation objectives.
Protect spiritual sites and values in the marine environment.		Identify and encompass spiritually significant areas or sacred natural sites within marine protected areas or networks.
		Where necessary, protect the confidentiality of site location and/or associated cultural/spiritual information by, for example, locating sacred natural sites within larger strictly protected zone so exact locations remain confidential.
EDUCATION AND KNOWLEDGE SHARING <i>Foster education, research, and knowledge sharing opportunities within the MPA Network</i>		
Foster knowledge sharing between interest groups.		Make use of local ecological knowledge (LEK) and/or fishers’ ecological knowledge (FEK) in identifying critical habitat for protection within the MPA network.*
		Facilitate dialogue and empower stakeholders to participate in decision-making. **
Foster public understanding and appreciation of marine systems and marine heritage.		Establish services, facilities that provide local residents and visitors with the opportunity to better understand, appreciate and protect the marine system and cultural heritage.
		Provide information and education to visitors on low-impact recreational practices.
		Support the development of educational content linked to the awareness of the marine system and local protected areas that can be used by schools and educational institutions.
		Develop supportive communication, education and public awareness programs that integrate different ways of knowing, expression, and appreciation regarding the protection of sacred natural sites.
		Provide resources to promote accurate and thorough media and multimedia coverage of the MPA Network.
Enhance marine research capacity.		Establish community-based participatory research programs.
		Consider designating or including sites specifically for monitoring and research.

* See Section 5.0 Knowledge Integration for more details.

** See Section 3.0 Governance Design Principles for more details.

4.2.2. Key themes underlying the social goals of MPAs and MPA network design

Marine livelihoods and food security

Given the social and economic implications of placing spatial and management constraints on marine resource use, mounting evidence suggests that consideration of the impact of MPAs (both positive and negative) on local livelihoods and food security needs to be incorporated into MPA network design and marine planning initiatives (Cinner and Aswani 2007; Klein et al. 2008a; Klein et al. 2008b; Klein et al. 2009; Mascia et al. 2010; White et al. 2013). One way of doing this is to ensure the MPA design process considers trying to minimize the costs to fishermen (Smith and Wilen 2003; Stewart and Possingham 2005; Richardson et al. 2006; Klein et al. 2008a; Mascia et al. 2010; Weeks et al. 2010a; White et al. 2013). For example, White et al. (2013) incorporated two methods to assess potential configurations of MPA networks in California by using static assessments of short-term impacts to important fisheries (via fishermen surveys), and complex bio-economic models (include fish population dynamics, spillover, fisher movement, fisheries management outside of MPAs, etc.). Spatial planning software (Marxan and Marxan with Zones) has also been used to incorporate socio-economic information (e.g. commercial fishing, recreational fishing, and other non-consumptive user interests) to optimize MPA configurations that minimize economic losses incurred by fishermen (Stewart and Possingham 2005; Klein et al. 2008a; Watts et al. 2009). For example, in South Australia it was found that by incorporating socio-economic and spatial catch data, small changes in the area and boundary length of proposed MPAs reduced the impact on the rock lobster fishery by up to one-third (Stewart and Possingham 2005). In the Raja Ampat MPA network in Indonesia, Grantham et al. (2013) used Marxan with Zones software to generate zoning configurations such that no-take zones had an equitable impact across fishing communities whilst ensuring each community still had access to a 'sustainable fishing zone.' Along with impacts, MPA design should model and communicate potential fishery benefits. Sala et al. (2013) argue, for example, that combined with other benefits (e.g. tourism and ecosystem services), the value of fisheries benefits from MPA reserves can outweigh the initial costs of creating and maintaining them.

An alternative approach to identifying places that are most optimal to restrict fishing, is for conservation planners to consider designated areas where people can fish. For example, Ban and Vincent (2009) used Marxan software and spatial data on catch statistics for commercial fishing areas in Canada's Pacific region to determine where small reductions in fisheries yields, if strategically allocated, could result in large unfished areas of conservation value that were representative of biophysical regions and habitat types. In another example, on the island Province of Siquijor, Philippines, Marxan with Zones software was used to design an MPA network configuration that considered local marine tenures (Weeks et al. 2010a). By setting the minimum area of fishing grounds to be retained by each community, the MPA network design was more equitable in terms of impacts on resource users (Weeks et al. 2010a). Similarly, Territorial Use Rights for Fishing (TURFs) are spatially-explicit designated access rights systems which are increasingly being heralded as an effective marine conservation tool for supporting social outcomes more broadly, and local, small-scale, community-managed fisheries more specifically (Johannes 2002; Gelcich et al. 2010). Ideally, MPA and TURF systems would be designed jointly to maximize social, ecological and economic outcomes (Costello and Kaffine 2010).

Consideration of non-fisheries-based livelihood opportunities is also important to MPA network design and implementation. For example, tourism has shown to be a viable industry that can support marine conservation efforts, and may be encouraged through entrepreneurship and market training (Leisher et al. 2007; Torell et al. 2010). In the Great Barrier Reef Marine Park, income from tourism is estimated to be about 36 times greater than commercial fishing (McCook et al. 2010). Tourism opportunities were explicitly considered in the zoning plan for Olango Island in the Philippines, where marine sanctuaries are nested among zones for diving and ecotourism opportunities, seaweed farming, and marine collection, crafts and marketing (White et al. 2006). Sala et al. (2013) demonstrate through the use of a bio-economic model that the increase in tourism revenue from establishing MPAs actually

surpasses the projected revenue increase from fishing activity, and that together these economic benefits can offset the initial costs in less than five years. Direct benefits can also flow from MPAs to communities through local employment in MPA management, and can be enhanced further by providing opportunities for cultural information sharing (Salm et al. 2000; Cicin-Sain and Belfiore 2005). Indeed, local community members who are employed to monitor and act as stewards of MPAs are better able to communicate their histories and knowledge of an area, and better communication facilitates more effective MPA management (Salm et al. 2000; Uychiaoco et al. 2005).

Non-monetary and intangible benefits

Marine protected areas provide non-monetary and intangible benefits. For example, they inspire humans, and the existence of MPAs can matter even to people who will never visit them (Harmon 2004). Economic concepts such as “existence value,” which comes simply from knowing that protected areas exist, “option value,” representing the value of healthy ecosystems for possible use in the future, and “bequest value,” the value of securing a site for future generations, try to capture some of the benefits that come from not using natural areas (Harmon 2004; Pomeroy et al. 2004; Charles and Wilson 2009). For example, an economic study examining the value of potential MPA sites throughout the UK to divers and sea-anglers found the non-use values (existence, option and bequest value) of protection to be substantial: the non-use value was estimated between 102-199 million £ for divers and 628 million - 1.34 billion £ for anglers based on sites that were recommended to be designated as English marine conservation zones (Kenter et al. 2013). In discussing the intangible values of protected areas, Harmon (2004) states “existence values - the satisfaction derived from knowing that protected areas exist, and that they safeguard outstanding natural and cultural landscapes...are part of the moral foundation underlying all the other intangible values of protected areas” (pg. 15).

The non-monetary benefits of MPAs are important contributors to human well-being (Mulongoy and Gidda 2008; Angulo-Valdes and Hatcher 2010). For example, a review of MPA literature identified that food security and resource control, as two indicators of social well-being, increased as a result of MPAs while trends were not significant for employment, community organization and income (Mascia et al. 2010). Specific to health benefits, research in the Solomon Islands showed that villages with MPAs are characterized by higher energy and protein intake than those with no MPAs or ineffective MPAs (Aswani and Furusawa 2007). MPAs also have recreational value, which is linked to generating tourism benefits, in addition to contributing to well-being (Harmon 2004). Finally, the benefits to people and communities of protecting marine areas that provide ecosystem services such as flood protection, the provision of medicinal components, global climate regulation, pollution sequestration, and disease prevention are considerable (e.g. Mascia 2003; Mulongoy and Gidda 2008; Charles and Wilson 2009; Angulo-Valdes and Hatcher 2010). One estimate, for example, puts the value of mangroves for their role in coastal protection at 300,000 US\$ per kilometre (Mulongoy and Gidda 2008). Whether through monetization or more qualitative means, it is important that the intangible and/or non-monetary benefits of MPAs are defined in some way so that they are appropriately valued and can be integrated into management practices (English and Lee 2003; Kenter et al. 2013).

Culture and history

Like biodiversity, cultures and traditional values are also threatened globally by external pressures, and in some cases protected areas may be able to both protect nature and support communities in defending their traditions and sacred places (Beltran 2000; Mulongoy and Gidda 2008). A good example of this are Indigenous and Community Conserved Areas⁵ (ICCAs), which are being recognized globally as an essential component of protected area systems (Kothari et al. 2012). Another salient form of culture-based conservation has been the identification

⁵ ICCAs are defined as “natural and/or modified ecosystems, containing significant biodiversity values, ecological services, and cultural values, voluntarily conserved by indigenous and local communities, through customary laws or other effective means” (Kothari et al. 2012).

and protection of “sacred natural sites”⁶ by faith groups and indigenous peoples, which often include areas that harbour valuable biodiversity and key ecosystems (Wild and Mcleod 2008). Recognizing the importance of these areas, a special task group of the IUCN World Commission on Protected Areas (the Specialist Group in Cultural and Spiritual Values of Protected Areas) produced guidelines document synthesizing best practices for supporting the efforts of local stewards in the long-term conservation of their sacred natural sites (Wild and Mcleod 2008). While many of the sites referenced in this report are protected terrestrial systems, most of the guidelines are equally applicable to coastal marine systems and should be considered as key design considerations in reference to cultural and spiritual sites that fall within existing or proposed MPAs (Wild and Mcleod 2008).

Several other examples worldwide demonstrate that protecting cultural and historical heritage is an important component of MPAs or MPA network design. An executive agency of the Scottish Government - Historic Scotland - developed guidelines for identifying and designating “Historic MPAs” (i.e. containing ancient fish traps or ship wrecks, etc.) within its national MPA network (Historic Scotland 2014). In the U.S., a Cultural Heritage Resources Working Group consisting of government and non-government archaeologists and historians, as well as tribal, Pacific Islanders, Alaska Natives, and other representatives was established under the MPA Federal Advisory Committee to provide expertise and recommendations on the development of the cultural heritage component of the National System of MPAs (Grussing 2013). In Canada, the Gwaii Haanas National Marine Conservation Area Reserve is managed to protect and preserve several important Haida cultural sites (Parks Canada 2012). Within Gwaii Haanas, locally trained stewards - the Haida Gwaii Watchmen - watch over the culturally significant sites and educate visitors on the natural and cultural heritage of Gwaii Haanas (Parks Canada 2012).

Education and knowledge sharing

Knowledge sharing recognizes the legitimacy of local rights and stakeholders, and provides opportunities for feedback between resource users, managers, educators, researchers and the public. Knowledge sharing helps to balance power and responsibility in support of building mutual trust and encouraging learning and stewardship (Berkes 2004). For example, fishermen can contribute to fisheries management and determining suitable areas for MPAs by providing and exchanging information on the behaviour and abundance of target species, and on how these influence fishing strategies (Johannes et al. 2000; Johannes 2002), and in return, managers and scientists can contribute their expertise and resources to the benefit of communities (see Section 5.0 Knowledge Integration). Local knowledge can also be integrated into geospatial analyses to help inform MPA network design (e.g. California - Scholz et al. 2004; Oceania - Aswani and Lauer 2006; British Columbia - Ban et al. 2009). There are many more examples of how knowledge sharing and integration (i.e. local knowledge, Indigenous traditional ecological knowledge, and Western science knowledge) can support MPA design and management, and we address this issue separately in Section 5.0 Knowledge Integration.

Increasing public understanding and appreciation of marine systems and marine heritage is often a desired outcome of creating of MPAs. As such, supporting the development of educational content that fosters public recognition of the benefits derived from well-managed ocean resources (Walker et al. 2005) and encourages stewardship activities (Salm et al. 2000), is a worthwhile endeavour. Considerable educational content (e.g. curriculum, learning materials, grants, workshops) was developed in association with the National Marine Sanctuaries in the U.S. to provide resources and training to teachers and educators to support ocean literacy (NOAA 2013). These MPA-associated education materials provide an applied context for increasing people’s awareness of local species, ecosystem processes, ocean resource management and cultural history. Visitor centres are another way to provide critical educational opportunities (Pearce 2004). These centres also have the added benefit of directing tourist

⁶ Sacred natural sites can be defined as “areas of land or water having special spiritual significance to peoples and communities” (Wild and Mcleod 2008).

traffic to a central point, thereby reducing impact on local resources (Pearce 2004). Finally, MPAs can support education, knowledge sharing and knowledge integration through supporting marine research activities. This can include designating specific sites within the network for research and monitoring (e.g. “Scientific Research Zones” exist in the Great Barrier Reef Marine Park, GBRMPA 2011), and fostering collaborative and community-based research programs. These efforts not only result in the generation of information that can be used to improve MPA network management, but can strengthen relationships with local resource users, provide content for educational materials, and foster public awareness of the benefits of marine conservation.

5. KNOWLEDGE INTEGRATION: INCORPORATING TRADITIONAL ECOLOGICAL KNOWLEDGE INTO MPA PLANNING

5.1. INTRODUCTION

Conservation planning literature increasingly recognizes linkages between ecological design principles, local governance and social values. Indeed, increasing evidence suggests that achieving conservation goals to sustain ecological integrity need to consider local interests (Cinner 2007; Cinner et al. 2009; Davies et al. 2012; Murray and King 2012; Ban et al. 2013a). This has been dubbed by the IUCN-WCPA (2012) as the ‘new conservation paradigm.’

Meaningful engagement of local people and their knowledge, (i.e. local knowledge and/or Indigenous traditional knowledge) helps to bridge multiple goals and objectives that link broader ecological, governance and social considerations in the planning of protected areas. As such, the purpose of this section is to review the literature on integrating local knowledge systems into marine planning, and to summarize the opportunities and challenges.

5.2. LITERATURE REVIEW

5.2.1. Approach, methods, and terminology

We reviewed marine conservation initiatives where Indigenous peoples played a key role in designing and planning protected areas, and examined how traditional knowledge systems were incorporated into MPA planning processes. In our review, we include examples from the global literature that refer to Indigenous knowledge systems. We focus primarily on traditional ecological knowledge (TEK) because in Canada, First Nations have constitutional rights⁷, and in some cases there is a legal obligation to include TEK in planning. While our focus is on TEK, much of the text also applies to local ecological knowledge (LEK). This is consistent with previous sections (3.0 MPA Governance and 4.0 Social goals for MPA networks), which affirm the critical role of engaging local communities (non-Aboriginals and Aboriginals) in marine planning processes.

We use the definition of TEK provided by the Central Coast First Nations in their Central Coast Marine Use Plan (Central Coast Marine Use Plan 2011). This definition is similar to many in the academic literature (Berkes 1993; Agrawai 1995; Turner et al. 2000; Drew 2005), and situates TEK as inseparable from its social context:

“A body of knowledge built up by a group of people through generations of living in close contact with nature. It includes a system of classification, a set of empirical observations and concepts or understandings about the local environment, and a system of rules or ethics that govern human behaviour and use of resources. The quantity and quality of this knowledge varies among community members, depending upon gender, age, social status, intellectual capability, and profession (fisherman, spiritual leader, etc.). With its roots firmly in the past, traditional ecological knowledge is both cumulative and dynamic, building upon experience of earlier generations, adapting to socio-economic and environmental changes and adopting useful aspects of technological innovation.”
(Central Coast Marine Use Plan 2011)

TEK typically is based on a long set of observations passed down from previous generations, and is associated with indigenous people (Berkes et al. 2000; Turner et al. 2000, Fig. 3), differentiating it from local ecological knowledge (LEK). TEK encompasses the knowledge-practice-belief complex of indigenous people (Berkes 2012), and thus includes not only information and knowledge specific to the environment and its resources, but also spiritual beliefs, language, mythology, culture, laws, customs, and medicines (Fig. 7). TEK can also be differentiated from traditional knowledge, which does not require specific reference to ecological interactions (Grenier 1998). Scholars

⁷ Aboriginal rights and title are recognized in Canada under Section 35(1) of the Constitution Act, 1982. Subsequently, several acts and policy statements provide directive for the inclusion of TEK in land- and ocean-related management.

emphasize that traditional knowledge and TEK are not static or confined to information gained in the past, but rather should be viewed as process, as a way of knowing, and as form of knowledge that is continually evolving and expanding to incorporate new information (Cruikshank 2004, McGregor 2009, Berkes 2009).

Figure 7. Components of traditional ecological knowledge and wisdom of aboriginal peoples of northwestern North America. Diagram developed by N. Turner, M. Ignace and R. Ignace (see Turner et al. 2000). Reprinted with authors' permission.

It is important to recognize that there are contentions in the literature, and within indigenous communities, around the specific reference to TEK as a descriptor representing Indigenous traditional knowledge. This concern stems from the sentiment that TEK, as written text, often becomes separated “from the land, from the worlds of the spirits, from its source and its meaning, and from the methodologies for transmission that provide the rigor that ensures its proper communications” (Simpson 2004, p.380). Furthermore, several Aboriginal and non-Aboriginal scholars contest the terms “traditional” (Gombay 1995), “ecological”, or “systems of knowledge” (McGregor 2008) as appropriate translations for Indigenous-environment philosophies. Overall this dialogue serves to highlight the significance of TEK being recognized as inextricably linked to the culture and worldview of the people that hold it (The Assembly of First Nations 1995; Berkes et al. 2000; McGregor 2009).

5.2.2. Knowledge integration and TEK in marine planning

Knowledge integration refers to the co-production of knowledge using TEK and Western science (Kofinas et al. 2002; Berkes 2009). The process of knowledge integration is facilitated by the inclusion of TEK holders and scientists, and encompasses considerations of complementary Indigenous and scientific ecological principles, as well as cross-cultural awareness (Lutz and Neis 2008). The goal of knowledge integration is to enable and empower knowledge according to its own assumptions, reference points and worldview (Berkes 2012).

Knowledge integration in marine planning is implicitly affirmed when the rights of Indigenous peoples are recognized. For example, both the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the International Convention on Biological Diversity address Indigenous priorities concerning resource and conservation planning. Knowledge integration may also inform the substance of marine conservation directives, as well as planning and management procedures (Dickinson et al. 2010). In the context of MPA network planning, TEK can provide unique information to support the achievement of ecological objectives as it draws upon a knowledge system that spans generations, is rooted in experience and social interactions, and includes culture and spirituality. Here, we review three methods of knowledge integration in marine planning: (1) Incorporating TEK to better understand the marine system, (2) Incorporating TEK into marine monitoring, and (3) Incorporating TEK to guide management strategies and options.

5.2.3. Incorporating TEK to better understand the marine system

Incomplete information and data gaps are common in marine conservation planning and resource management. TEK can provide independent insight, or enrich other sources of data that can inform our understanding of species distributions, ecological dynamics, the effectiveness of management, as well as baseline conditions. Indigenous peoples have historical continuity in the use and stewardship of resources in their local regions and often possess a broad knowledge of the behaviour of complex ecological systems: species characteristics, seasonal dynamics, and a perspective of changes over time (Gadgil et al. 1993). Although the tendency has been to extract this information and integrate it with scientific understandings, contemporary applications involving TEK increasingly encourage its use as stand-alone insights inseparable from its knowledge holders (McGregor 2009). Much of this knowledge may directly apply to MPA planning by providing ecological information that may be otherwise missing or of low spatial or temporal resolution (Table 8).

Species distributions

Spatial and temporal data on species distributions, life histories, population numbers and rates of change are essential to identify areas that require protection or enhanced management (refer to Section 2.0 Ecological Design Guidelines), yet scientific sampling is often limited, with little or no data available for many species (e.g. many data gaps were evident in species movements and early life history in Section 2.0) and local areas. TEK can fill gaps by supplementing scientific sampling or acting as a standalone data source for species information that may not have been sampled scientifically (Johannes et al. 2000; Aswani and Hamilton 2004; Haggen et al. 2007; Murray et al. 2008). Scientific surveys may focus on certain commercially important species, whereas TEK can provide additional information on culturally valued species (although many cultural species have commercial value). TEK can also provide a more complex picture of species movements and population structure at the local scale, providing information that may not have been captured in scientific surveys (Murray et al. 2008).

Many examples exist of TEK providing species information. For instance, in the Solomon Islands, TEK from fishers provided parrotfish population size structure, habitat usage over specific life history stages, and identified behavioural trends that followed a lunar cycle. This information was critical to identifying priority conservation areas as part of a long-term management strategy (Aswani and Hamilton 2004). In this case, observations from local fishers first identified declining catch rates and abundance of large individuals. In Prince William Sound in Alaska, the spatial and temporal distributions of juvenile and adult Pacific herring populations as well as other forage fish species were recorded using the contributions of LEK and TEK (Brown et al. 2002). In Newfoundland, knowledge from local fishers on local cod stocks provided detailed information on presence/absence, species movements at the microscale (at the level of individual bays), and influential variables (tide, wind, currents, ice conditions), which were deemed critical to managing the recovery of depleted populations (Murray et al. 2008). Finally, in an ecotoxicology study in the Canadian north, Inuit observations of the environment were similar in scale to scientific studies, but provided more qualitative details (Berkes et al. 2007).

Table 8. Potential contribution of Traditional Ecological Knowledge to the MPA ecological design principles outlined in Section 2.0.

MPA ECOLOGICAL DESIGN PRINCIPLES AND ASSOCIATED GUIDELINES	POTENTIAL CONTRIBUTION OF TEK AND LEK
REPRESENTATION: <i>Include adequate representation of each habitat type found within each bioregion.</i>	Local knowledge holders can identify the location of different habitat types, depths, and transition zones.
UNIQUE, IMPORTANT AND VULNERABLE AREAS: <i>Protect areas and features that are biologically/ecologically unique, vulnerable, of high functional importance, or important in species life history stages.</i>	TEK and LEK holders can identify locations of areas that are unique, seasonal or rare, where threatened species, habitats, important life history events, and high biological productivity and diversity occur.
REPLICATION: <i>Include spatially-separated replicates of representative habitat types or features.</i>	TEK and LEK holders can identify candidate locations and ecological features of these areas (see above).
SIZE, SHAPE AND CONNECTIVITY: <i>Ensure MPA sites are adequate in size/shape and are ecologically connected within the network.</i>	TEK and LEK holders can help to identify movement patterns of species, location and dynamics of ecological processes. They can also identify coastal landmarks and shapes of areas they think would best protect features, enhance connectivity and facilitate compliance.
MITIGATING HUMAN IMPACTS: <i>Increase ecological resilience of desirable ecosystem states in the face of human-induced change and stressors. Include marine reserves, protect areas with resistance/resilience to climate change, ensure sustainable use of resources outside of MPA network, ensure long-term protection.</i>	TEK and LEK holders can identify areas that have demonstrated ecological resistance/resilience to external stresses.
	TEK and LEK holders' ongoing involvement in marine planning provides capacity for them to be advocates in long-term protection.
	TEK and LEK holders can provide insights towards a holistic ecosystem approach. Indigenous peoples have many examples of positive influences that humans can have in the marine environment. Other activities around MPAs can include ecocultural restoration or ethnoecological management and restoration.
	TEK and LEK holders identify important linkages between terrestrial and aquatic environments (e.g. nutrient cycling, migratory species). This may be important for identifying cross-system linkages, or impacts, between MPAs and terrestrial or freshwater ecosystems.

Ecological relationships

TEK can include information on ecological relationships (Turner et al. 2000; Salomon et al. 2007), which can be important in marine conservation planning by describing interspecific interactions, food web dynamics, and species abundance, migration or reproductive patterns (Nabhan 2000; Drew 2005; Salomon et al. 2007; Silvano and Valbo-Jorgensen 2008). For example, Silvano and Begossi (2008) reviewed a number of ethnoichthyological studies and found that the food webs and species interactions described by local indigenous peoples closely matched the understandings formalized by university researchers, but described several additional migratory movements of fishes that were previously unknown to Western science. In the Pacific Islands, local knowledge of coral reef fish and observations of fish physiology and aggregation behaviour helped to inform fisheries management by identifying critical links between the lunar cycle and fish reproductive cycles (Foale 1998, 2006; Hamilton and Potuku 2007). Finally, TEK can provide a broader spatial and temporal perspective on ecological interactions (Salomon et al. 2007), noted as a weakness in many assessments or scientific experiments that generalize ecological dynamics and may miss critical patterns relating to species' life histories (Raffaelli and Moller 2000). For example, an ecologist listening to beluga hunters describe their TEK was surprised when discussion turned to trends in regional beaver populations (Huntington 2000). An elder then explained through a complex ecosystem dynamic how the damming of rivers by beavers reduced salmon habitat and salmon, which were a key food resource for belugas, thereby affecting beluga abundance and distribution in coastal areas.

5.2.4. Incorporating TEK into marine monitoring

Monitoring presents a valuable opportunity for TEK to help inform our understanding of ecosystem change resulting from changes in harvest pressure, from climate forcing, and from the implementation of MPA policies. In addition, monitoring creates an active role for TEK holders to participate and empower their knowledge system as they help to establish current priorities and objectives. Several examples demonstrate that TEK in monitoring has helped identify important trends in species populations. For example, in New Zealand, the Rakiura Maori engage in a traditional harvesting of sooty shearwater chicks (*Puffinus griseus*), or titi. During the autumn harvest, they use chick body condition as an indicator of annual chick abundance to make decisions about harvest rates and understand the long-term well-being of the birds (Lyver 2002). Based on the long-term records of several "muttonbirders", the Maori detected a population decline that suggested a population-level pressure originating during the bird's migration (Lyver 2002; Moller et al. 2004). Researchers who have examined how TEK is employed in population monitoring have also documented its application in estimating catch per unit effort, breeding and nest success, and population density (reviewed in Moller et al. 2004). This suggests that TEK can help predict the key parameters of harvest determined through scientific studies, and that the parallel use of the two knowledge systems can improve decision-making for the resource use (Moller et al. 2004).

TEK is also a valuable source of baseline information, especially because scientific studies often commence just prior to anticipated impacts or management interventions. The concept of shifting baselines has been described in detail by Pauly (1995) in reference to fisheries management, where scientists often incorrectly assign "baseline" population size only after human exploitation has occurred. TEK often contains historical information through oral histories (Thornton and Scheer 2012), thereby filling a critical knowledge gap and potentially extending further back in time than many scientific observations. Traditional monitoring not only offers local historical depth that science often lacks, but it often provides observations of abnormal or irregular patterns (Moller et al. 2004; Berkes et al. 2007; Turner and Clifton 2009). For example, community-based observations from multiple regions across the Arctic have noted increased frequency of extreme weather events and variability of weather patterns (Krupnik and Jolly 2002), thereby contributing to our understanding of climate change through describing long-term trends. Several other studies demonstrate the utility of incorporating local and traditional ecological knowledge into climate change monitoring (Kofinas et al. 2002; Krupnik et al. 2010; Gearheard et al. 2011; Nakashima et al. 2012) and

resource monitoring (Berkes et al. 2007; Heaslip 2008), with some making specific reference to how this plays an important role in the implementation of marine protected areas and integrated marine planning (Cobb et al. 2005; Berkes et al. 2007).

TEK can also be used to identify changes in harvesting patterns and human uses of resources, which in turn may identify whether non-compliance with regulations is an issue. This aspect of monitoring is critical to assess whether marine management decisions confer desired ecosystem change and/or change in human behaviour. Furthermore, Drew (2005) identifies that monitoring may provide opportunities to build local capacity through training, and additionally help to mitigate the balance of power in the contribution of Indigenous knowledge to marine conservation. A great example of this takes place on the coast of British Columbia, Canada, where the Guardian Watchmen Program employs local Aboriginal community members to monitor environmental compliance as well as the health and condition of important food, social and ceremonial species throughout their territory (Coastal First Nations n.d.). This program has expanded greatly from its origins in 1981 as the “Haida Watchmen Program,” and continues to be integrated as a key monitoring component in marine planning and resource management along the entire northern and central coasts (Coastal First Nations n.d.).

5.2.5. Incorporating TEK to guide management strategies and options

TEK can provide options for ecosystem management strategies and adaptive approaches (Turner et al. 2000; Mulrennan 2014). Traditional management systems are widespread and common, including systems of customary tenure, species-specific or site-specific cultural taboos, rotational harvests, gear closures, genetic selection, vegetation transplanting, habitat creation, ceremonial practices, among others (Colding and Folke 1997, 2001; Johannes 2002; Brown and Brown 2009). Many traditional fisheries management approaches have parallels in western management techniques. Modern equivalents may include MPAs and closures, gear prohibitions, permitting, species-specific bans, total allowable catch (TACs), and quotas, among others (Johannes 2002; Cinner and Aswani 2007). This suggests it may be practical and feasible to consider how contemporary management can build on traditional management approaches (Johannes 2002; Cinner and Aswani 2007; Mulrennan 2014).

An explicit way of integrating traditional approaches is to directly incorporate Indigenous concepts and language into management plans. Integration of, or a return to, traditional and customary management systems may be desirable as an adaptive management tool (Hviding 1998), especially when other legal mechanisms of conservation fail (Sims 1989). In New Zealand, the Maori adopted this approach, thereby providing a strong knowledge integration component and improving Indigenous buy-in of management (Gibbs 2003). Similarly, in the Maluku Islands of Indonesia, the practice of *sasi*, the traditional social institution for restricting access to certain resources, revived community-based management of local resources (Zerner 1994). In the South Pacific, locally managed marine protected areas are a common management tool, and frequently integrate traditional management with western management tools (Govan et al. 2009). In B.C., examples such as the Gwaii Haanas National Park Reserve on Haida Gwaii and the Tla-o-qui-aht Tribal Parks on the West Coast of Vancouver Island provide examples of protected area governance models developed and co-managed by First Nations and federal government agencies (Murray and King 2012; Thomlinson and Crouch 2012). In these protected areas, the traditions, teachings and concepts of the individual First Nations contribute to governance systems that reflect their cultural values. For example, the zoning scheme of the Haa'uukimun Tribal Park consists of *qwa siin hap'* and *'uuya thluk nish'*; the former roughly translates to “leave as it was” and denotes areas that are sacred or of special significance, and the latter roughly means “we take care” comprising of more impacted areas (Murray and King 2012).

Another way of achieving knowledge integration is through direct involvement of Indigenous leaders and knowledge holders in the planning and management processes. The IUCN-/WCPA (2012) Whakatane initiative identifies a critical role for Indigenous communities in planning marine protected areas, and emphasizes that Indigenous

knowledge should be used for resource assessments, devising options for actions, developing management plans, and assisting with implementation and adaptation of plans. Ideally, Indigenous peoples should be included in advisory, implementation and decision-making roles throughout the conservation planning process (see Kofinas et al. 2002; Dickinson et al. 2010; Lertzman 2010). In B.C., the success of several land-use and marine planning initiatives has been attributed in large part to First Nations playing a central role in plan development, management and implementation (Frame et al. 2004; Price et al. 2009; Jones et al. 2010). On Haida Gwaii for example, the Council of the Haida Nation is engaged in the co-management of the Gwaii Haanas National Marine Conservation Area Reserve and the Sgaan Kinghlas/Bowie Seamount marine protected area, along with local foreshore planning linked to the implementation of land-use plans and regional scale marine planning (Jones et al. 2010). The Marine Planning Partnership (MaPP) initiative provides another good example where a collaborative partnership between the Province of British Columbia and 18 member First Nations has provided a platform for working together on the development of sub-regional and regional marine-use plans (Marine Planning Partnership n.d.).

Indigenous involvement in marine planning and management can also be empowering for Indigenous people, enhancing cross-cultural awareness, and potentially reinforcing Indigenous rights and title (Alcala and Russ 2006; Dickinson et al. 2010). Knowledge integration itself may be an empowering process, leading to capacity building within Indigenous communities. For example, in eastern Canada a long-term collaboration between academics and the Cree First Nation of the Wemindji community helped to designate a biodiversity reserve under the Quebec government (Mulrennan et al. 2009). This process enabled a further partnership with neighbouring First Nations, which led to a proposed National Marine Conservation Area (NMCA) with Parks Canada. Such a partnership has shown that knowledge integration was only a part of a larger goal focused on supporting First Nations in using protected areas as a political strategy to affirm their stake in resources after a history of marginalization in resource development decision making (Mulrennan et al. 2009). In Fiji, community members integrated scientific methods of monitoring abundance and recruitment of their local shellfish in an area closed to harvest, and the community, with support of fisheries managers, pursued further protection of nearby reefs as part of a new community-based management program (Tawake et al. 2001). Overall, Indigenous involvement in planning can lead to improved cross-cultural understandings, the development of common goals and areas of agreement in planning process, as well as conflict reduction strategies during implementation stages.

There are several methods for working toward cross-cultural awareness and ensuring the integrity of TEK, many of which have been mentioned above. Broadly, these include recognizing Indigenous expertise and knowledge holders, following local customs and protocols, recognizing traditional and ceremonial management, and drawing on local languages, stories, vocabularies and modes of knowledge transmission (Huntington 2000; Drew 2005). Cultural empowerment is critical for balancing the power relationship in knowledge transfer (Drew 2005) and also supports a social system that encourages intergenerational transmission of knowledge through teaching and time spent on the land (Berkes et al. 2000; Turner and Spalding 2013). Marine conservation and knowledge integration provide an opportunity for Indigenous peoples to exercise their right to self-determination and autonomy by striving to ensure space remains for them to practice their culture and traditions without constraints.

5.2.6. Challenges in knowledge integration

While there are many examples of fruitful knowledge integration, local customs or management may not always align with Western or scientific approaches. For example, the Cree of northern Quebec maintain that catch-and-release fishing is disrespectful to the fish, and should not be practiced (Berkes 2012). This is in contrast to many other communities and jurisdictions where catch-and-release fishing is a common management practice and an important driver of aquatic recreation and tourism. Similarly, in certain regions of Alaska, Native Americans disagree with scientific field methods such as satellite-collaring and radio-tagging animals, which they consider cruel and disrespectful (Huntington 2000). However, these methods are widely used in scientific monitoring programs

and research projects that result in information on species movements and behaviours that can inform conservation and management policies. Indigenous/local customs and Western/Scientific approaches may also diverge regarding the purpose of management. For instance, in Melanesia resources are protected over time (e.g. in taboo areas) to build an abundant harvest (e.g. the area can be opened for fishing, for example for a feast for a bride ceremony) (Cinner and Aswani 2007). In contrast, most national and international fisheries aim to maintain stocks as productive as possible (often at a targeted reference point) so that they can be continuously exploited to achieve sustainable social and economic benefits. Furthermore, Indigenous understandings of an integrated and connected land-sea interface often contrast the distinctly land-based or water-based jurisdictional boundaries established in Western societies (Scott and Mulrennan 2010; Mulrennan 2014). Lastly, many National Parks have mandates to maintain ecosystem integrity without the inclusion of humans in that objective.

Marine conservation actions often involve a reduction or elimination in human activities (e.g. reduced or no fishing within MPAs or certain zones of MPAs), which may compromise traditional livelihood needs and rights (Mascia and Claus 2008). In some cases, no-take zones or reserves are not supported by Indigenous peoples because they may infringe on their traditional customs and rights to harvest (Ayers 2005; Faasen and Watts 2007; CPAWS 2009). Often this disagreement with no-take zones stems from a worldview that differs greatly from a Western emphasis on preservation to achieve conservation; Indigenous cultures tend to have a 'conservation for future use' ethos, in which humans are viewed as a fully interacting and embedded component of ecosystems (CPAWS 2009; Ayers et al. 2012). For example, interviews conducted with members of the Hul'qumi'num First Nation of Southwest Vancouver Island revealed strong opposition towards "closing some areas permanently to protect resources" because excluding community members from harvesting in a no-take zone would be inconsistent with their worldviews and a violation of Canadian Aboriginal rights (Ayers 2012). This same study however showed that some aspects of no-take zones would have considerable support, such as no-take zones established with Hul'qumi'num agreement or temporary and seasonal no-take areas (Ayers 2012). A report by the Canadian Parks and Wilderness Society (2009) outlines a similar scenario regarding First Nations concerns and interests related to MPAs in B.C., and offers six approaches⁸ for First Nations collaboration, relationship building, and knowledge sharing in MPA establishment. While compromises between dissimilar goals in marine planning may be necessary, conservation goals are becoming increasingly integrated as part of the 'new conservation paradigm', which incorporates TEK and Indigenous traditions (IUCN-WCPA 2012). Ongoing monitoring programs with clear indicators may address substantive concerns about depleted resources and community priorities, and research partnerships may provide assistance towards understanding cross-scale linkages.

One way to potentially reduce negative implications from conservation actions on locally affected peoples is to focus on alternative and diversified livelihoods, which are generally associated with more resilient communities (reviewed in Bennett and Dearden 2012). Accommodation measures to offset negative implications from reduced fisheries access may include alternate fishing grounds, diverting fishing pressure to other areas, exploring other fisheries or gear alternatives, investigating alternate income sources, as well as developing aquaculture and tourism opportunities that are appropriate to the local environment (Johannes 2002; Bennett and Dearden 2012; Turner et al. 2012). However, the development of livelihood alternatives and diversification is not a panacea. For example, in many cases the generation of tourism or ecotourism livelihoods has been successful in connection with MPA development (Hargreaves-Allen et al. 2011), whereas the same efforts in other areas face local challenges (Brondo and Woods 2007; Fabinyi 2008; Torell et al. 2010). Overall, scholars emphasize the need to consider micro and macro level contextual factors that influence marine use and the ability to develop alternative livelihood op-

⁸ Six approaches for First Nations collaboration: (1) Respect Aboriginal rights and title. (2) Build relationships. (3) Connect MPAs to First Nations interests and improve awareness of concerns. (4) Tailor MPAs to address First Nation interests. (5) Encourage shared authority for MPAs. (6) Situate MPAs in a regional and coast-wide context.

tions: market access, local capacity, policy contexts, local leadership, cultural norms, and social cohesion (Pomeroy et al. 2004; O'Garra 2007; Bennett and Dearden 2012). As another important step in marine conservation planning, it is important to include TEK holders in assessing appropriate accommodation measures.

Knowledge integration is often politicized and involves issues surrounding ethics, power, and situated knowledge. To understand some of these issues, one must look to history to recognize the patterns of perpetuated marginalization of displaced and oppressed Indigenous peoples around the world. Not surprisingly, the challenges of knowledge integration often are cross-cultural and may confront legal and institutional legacies. In searching the literature for success in long-term commitments to knowledge integration, we found that "success" can be challenging to evaluate definitively. For example, Nadasdy (2003) describes an initiative in the Yukon where government officials gathered three years of information from the Kluane First Nation and local stakeholders with the aim to integrate this knowledge in a wildlife co-management strategy. Government officials saw the initiative as ultimately successful, whereas Nadasdy's (2003) observations showed that the process repeatedly undermined the contributions of TEK and the Kluane members involved. This does not imply that successful outcomes of knowledge integration are few, but that knowledge integration as a part of conservation planning is an ongoing process rather than an end-point, and therefore difficult to evaluate definitively.

There are no easy solutions to barriers of politics and power. Knowledge integration means meeting multiple goals and objectives, and remains part of an ongoing process in marine conservation. We summarize some of the specific challenges of knowledge integration in Table 9, and note some strategies for their prevention and mitigation. While particular issues may not be directly relevant to marine conservation, awareness may prevent these issues from becoming a burden to the conservation process. For example, one way of mitigating potential issues is to provide opportunity for meaningful knowledge integration at the very beginning of any planning process.

Table 9. Common challenges and sources of conflict between Indigenous knowledge systems and Western scientific knowledge or management.

BROAD CHALLENGE	SPECIFIC CHALLENGE	MITIGATIVE STRATEGIES OR BEST PRACTICES	EXAMPLE
ETHICS	Cultural inclusion and respect	Invite and include ceremony and custom. Engage in active listening and exhibit culturally appropriate courtesies. In some contexts and when appropriate, honoraria may be provided in exchange for expertise and time.	Government and Indigenous representatives engaged in Nu-u-cha-nulth's customary protocols during the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound. (Lertzman 2010) Honoraria can be seen as a demonstration of gratitude and appreciation of traditional knowledge and time. (Tobias 2000)
	Safeguarding knowledge	Cultural advisors and Indigenous knowledge holders should guide the use, sharing and appropriation of Indigenous knowledge.	In northern Canada, the Beaufort Sea Integrated Management Planning Initiative (BSIMPI) organized a Traditional Knowledge Working Group composed of locally respected hunters and elders to map traditional use of the large planning area, and hired an anthropologist through the local cultural center to coordinate review of historical documents. (Berkes et al. 2007)

(Table continued on following page)

(Table continued from previous page)

BROAD CHALLENGE	SPECIFIC CHALLENGE	MITIGATIVE STRATEGIES OR BEST PRACTICES	EXAMPLE
POWER AND POLITICIZATION	Language barrier	Include translators and cultural advisors as well as processes to facilitate two-way cross-cultural awareness.	The Clayoquot Joint Scientific Panel was explicit in its respect and accommodation of traditional knowledge holders as well as their own experts in their institution of knowledge. (Lertzman 2010)
	Resource capacity	Identify common goals and potential friction points so resources may be appropriately allocated; monetary/non-monetary support can come from various sources.	In a long-term effort towards establishing a hunting management plan in the Great Barrier Reef, financial resources provided through private funds matched by the government led to the breakthrough in the plan's implementation. (Marsh 2007) Bridging organizations such as Ecotrust Canada, Conservation International, etc., may provide resources for additional capacity building and skills training. (Berkes 2009, Whakatane 2012)
	Distrust of top-down management processes	Ensure transparent processes and direct involvement/responsibility of knowledge holders in planning. Engage in joint setting of "Guiding Principles" that everyone participates in and agrees to. Past grievances may need to be addressed through dispute resolution processes through recourses internal/external to conservation planning. Provide cross-cultural awareness/training facilitated through workshops.	The Whakatane Mechanism recognizes the tensions of national policy and multiple stakeholders in marine conservation, and couples the conflict resolution process with a dialogue for policy reform between all stakeholders, while providing recourses for Indigenous peoples to engage effectively in such processes. (IUCN-WCPA 2012)
	Misinterpretation and misappropriation of traditional knowledge	Entrust TEK holders to oversee and guide the use TEK. Employ cultural safeguards in knowledge sharing practice. Use proper cultural protocols for integrating knowledge. Strive to maximize cross-cultural awareness. Funding should be allocated to include cultural advisors, mediators and/or social scientists during the process.	Cultural safeguards regarding the interpretation of Indigenous knowledge include cultural mediators. For example, the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound included Dr. Richard Atleo, an elected Nuu-cha-nulth representative to co-chair the Panel, and Dr. Nancy Turner, a published academic ethnobotanist who has developed close working relationships with indigenous botanical and environmental experts in many parts of B.C., who together helped to facilitate cross-cultural understanding. (Lertzman 2010) In northern Canada, a Traditional Knowledge Working Group composed of hunters and elders was responsible for collecting and guiding their own traditional knowledge of land-use for management planning of the Beaufort Sea. (Berkes et al. 2007)

(Table continued on following page)

(Table continued from previous page)

BROAD CHALLENGE	SPECIFIC CHALLENGE	MITIGATIVE STRATEGIES OR BEST PRACTICES	EXAMPLE
POWER AND POLITICIZATION	Benefits are one-way in knowledge exchange	End goals should reflect and benefit those of indigenous communities. Support for local capacity, training, and cultural empowerment should be written into protocols and processes of knowledge integration and marine planning.	The Indigenous-led transnational Arctic monitoring program resulted in key roles for communities and government through their lead involvement in designing monitoring priorities and indicators. (Kofinas et al. 2002)
	Unrelated community concerns are raised	Contentious political issues may be deliberately avoided, addressed in a different forum, or included as minor part of conservation planning. Past and current issues may need to be addressed and/or respectfully set aside with consensus.	In Alaska space was created for including additional concerns of the community, such as indicators for community well-being. (Kofinas et al. 2002)
BALANCING PERSPECTIVES	Multiple stakeholder interests result in irreconcilable differences.	For issues involving a conflict between governments, courts of law offer potential recourse. In cases of general conflict, mediators and facilitators may help divergent parties move toward common goals.	Interest-based negotiations with a cross-cultural component emphasized relationship and trust building through effective communication in the Tsawwassen Treaty process, and helped to move past a troubled history and overcome divergent worldviews. (Rhodes 2009) The Whakatane Mechanism identifies a relatively new paradigm shift in conservation towards the inclusion of local Indigenous peoples with the potential for more dispute resolution mechanisms. (IUCN-WCPA 2012)

5.2.7. Concluding remarks

In this section we explored knowledge integration and knowledge co-production in marine planning. Our examples suggest that incorporating TEK and LEK into planning processes and protected area management is an integral component to pursuing a social-ecological approach to marine planning. Making efforts to better incorporate traditional knowledge as both information and a way of knowing, is important. At the same time, it is critical to recognize that Indigenous communities are both dynamic and unique, therefore conservation planners should avoid generalizations or extrapolations that overlook local contexts and regional differences. Many scholars follow the principles of community-based research and advocate for the inclusion of indigenous peoples to ensure that communities are themselves supported by remaining active and participatory throughout the process. Indigenous scholars are cautious in supporting knowledge integration efforts because of a long history of the misappropriation of traditional knowledge; however many emphasize the positive impacts of participatory and Indigenous-led research efforts that in turn have direct bearing on institutions outside academia, helping to guide governance, policy and adaptive-based management (Chilisa 2012; Smith 2012). Overall, the key challenge will be to move from simply accepting the importance of traditional knowledge in policy-making, to ensuring Indigenous knowledge systems are systematically incorporated into the planning, decision making and implementation of future MPAs and MPA networks. By drawing on global examples, we are better able to find solutions to the challenges faced when integrating knowledge systems, thereby supporting Indigenous peoples and their rights to self-determination.

6. SUMMARY AND RECOMMENDATIONS

In this report, we reviewed and summarized overarching principles and general guidelines that inform MPA design. We synthesized the peer-reviewed literature for ecological and governance good practices, providing summary tables and discussion that can serve as guidance for spatially-explicit marine conservation planning in B.C. and elsewhere. We summarized species-specific adult movement estimates and larval durations for key fish and invertebrate species in B.C. We also assessed some relevant B.C. marine planning policy documents against the ecological principles and governance good practices. We then provided some examples of social goals that can augment or supplement ecological goals in marine planning. Furthermore, we discussed the importance of integrating traditional ecological knowledge into marine planning, and identified how TEK can contribute to achieving ecological and social principles. Indeed, knowledge integration is one important and practical means for pursuing a social-ecological approach to marine planning.

Five broad principles remain consistent directives in designing MPA networks to achieve ecological objectives: 1) represent all habitats, 2) protect unique, important, and vulnerable sites and species, 3) replicate the protection of habitats and features within spatially-separated MPAs, 4) facilitate the connectivity of populations between MPA sites through appropriate size and spacing and 5) mitigate human disturbances and impacts. Using our framework for comparison, we found that the general MPA guidelines designed to meet these broad principles were consistent in the literature and synthetic reports we reviewed. However, specific recommended guidelines for how to achieve these principles varied. We also found that the Canada-BC Marine Protected Area Strategy (2014) addressed 13 out of 15 of the general design guidelines, with the largest gap being a lack in addressing climate change in the MPA network design for B.C.'s Pacific region.

The information we compiled on adult movement and pelagic larval durations (PLD) for ecologically, culturally and economically important marine species in B.C. can be used in future planning and modelling studies to inform whether existing and/or proposed MPA networks are protecting key species or critical life stages. With the peer-reviewed information we summarized on guidelines and good practices in MPA design, along with the information we compiled on adult movement and PLDs, the following general recommendations can be made in reference to MPA network design in B.C.:

1. Combined with the recommended target for Canada to represent 30% of all broad-scale habitat types within each marine bioregion (Jessen et al. 2011), information and representation targets from the BCMCA (2012) could be used as a starting point for planning and evaluating proposed MPA network configurations and regional spatial plans in B.C.
2. Information on unique, important and vulnerable areas in the B.C. marine environment can be drawn from Important Areas and Ecologically and Biologically Significant Areas (Clarke and Jamieson 2006a; 2006b), along with special features identified by the BCMCA (2012) and local/regional mapping efforts led by First Nations, the province and local communities.
3. Replication of representative habitats as well as special or vulnerable features should be ensured at the bioregional scale (at least 3 replicate MPAs per habitat type or feature recommended). Similarly, ensuring replication of habitats is achieved across MPAs within smaller ecologically-defined classifications or coastal planning regions will allow representation objectives to be met at the smaller spatial scales at which marine planning in B.C. is typically conducted.
4. Our review of species movement information suggests that the adult stage of many nearshore coastal species of economic and cultural importance, particularly reef-associated species with limited mobility, could be protected within an MPA area as small as 10 km². However, MPAs of this size would have to be placed directly in the appropriate species habitat, and would not necessarily ensure population level protection.

Guidelines supported by academic literature and implemented in California recommend a minimum size range of 23-80 km². Ultimately, the appropriate size for individual MPAs should be determined by the MPA management objectives.

5. Large MPAs (100 to 1000s of km²) will be required to protect intermediate and more mobile species, encompass representative habitats or unique features, protect large-scale ecological processes, and serve many of the species that were not reviewed here (e.g. other fish and invertebrate species, marine birds, marine mammals). Highly mobile species will also benefit from MPAs that are strategically placed in critical life history areas (e.g. migration bottlenecks and areas for breeding, feeding, or nursing). Because many of these species migrate and shift between habitats and depth classes during their life history, some MPAs should be large enough to encompass both nearshore and offshore regions.
6. Conservation of highly mobile exploitable species will require sustainable management strategies to be implemented outside of reserve boundaries.
7. The lack of movement information and/or spatial distribution data for most B.C. fish and invertebrate species (i.e. species not reviewed here) emphasizes the importance of having a variety of MPA sizes that capture representative habitats within the network as proxies for different fish and invertebrate assemblages.
8. The B.C. species we reviewed show a wide range in pelagic larval duration times (30 days to >1 year), but overall information on larval transport and estimated dispersal distances for B.C. species is limited. Based on the network recommendations for Canada (Jessen et al. 2011), one study that evaluates Rockfish Conservation Area connectivity in B.C. (Lotterhos et al. 2013), and the California MPA network spacing recommendations, we suggest that having MPAs spaced within 20 - 100 km (or closer) of each other provides a good initial guideline for network design and evaluation within B.C.
9. In order to maximize ecological resilience of desirable ecosystem states in the face of human-induced stressors, sufficient area in the network should be in no-take reserves (science-based guidelines suggest ~30%, including recommendations for Canada), MPA network designations should be designed for long-term protection, and sustainable use of marine resources should be promoted beyond the boundaries of the network.
10. The Pacific region is vulnerable to ongoing and future impacts linked to climate change. MPA network planning in B.C. should consider these impacts by ensuring representation and replication of habitats and special features, including large MPAs, and protecting sites that are more resistant to, more able to recover from, or help mitigate climate change effects (e.g. protecting coastal carbon sinks, cold water upwellings, areas of high tidal exchange, etc.)

Governance, which relates to the exercise of power and responsibility, bears directly and indirectly on the ecological outcomes of MPAs due to its influence on management capacity and stakeholder compliance. We synthesized the literature on good governance practices under six thematic headings: (1) Legitimacy; (2) Inclusion and Fairness; (3) Capacity and Performance; (4) Coordination and Collaboration; (5) Knowledge Integration and Adaptability; and (6) Transparency and Accountability. We also drew on international experiences to provide specific examples of how these principles can be achieved. The literature indicates that good governance is tied to management effectiveness through the inputs and processes necessary for making and implementing good quality decisions. Good governance will also strengthen the support for MPAs, which in turn results in greater buy-in to, and compliance with, rules and regulations.

The successful establishment and effective management of MPA networks depends on governance arrangements that can accommodate ecological criteria while also meeting the diverse (and often divergent) expectations of stakeholders. The considerable challenge for governance actors – interdependent individuals and groups/organizations who interact to define and solve problems, make decisions, and initiate actions – is to evaluate problems

at multiple interconnected scales (physical and political) and to respond to these in the face of changing social and ecological complexities. Many of the authors contributing to the literature on resource management and governance argue that centralized governments cannot singlehandedly accomplish this. With respect to MPAs, it is thus essential to involve and empower citizens to share responsibility for the management process, rather than exclusively relying on governmental structures (Vasconcelos et al. 2011). The capacities for addressing today's governance challenges are widely distributed within and beyond governments, and there is a need to develop ways of governing MPAs that combine government responsibilities with those of people and markets (Huppé et al. 2012; Jones et al. 2013). Furthermore, in democratic societies, citizens expect to have input into decisions that will affect them, and this is certainly true of MPAs, which involve costs as well as benefits for users in those areas.

Whereas MPAs are most often thought of as tools for conservation and ecological objectives, the planning, establishment and management of MPAs can also create opportunities to meet other social needs and values (e.g. food security, marine livelihoods, health and well-being, culture and history, knowledge integration and education). Acknowledging the social landscape within which an MPA exists is not simply about trying to minimize the negative impacts that come from constraining resource access and uses. Appreciating the needs, values, and histories of resource users and other stakeholders can also inform the design of MPAs so they have broader and more lasting positive impacts both socially and ecologically. Although win-wins will not always be possible, incorporating and accommodating social priorities will often complement and strengthen ecological outcomes, such as when cultural values and practices that communities wish to protect are oriented, by design or by effect, towards conservation. In other cases, satisfying conservation mandates while also delivering targeted benefits to local stakeholders will involve trade-offs. Social goals are context specific and need to be derived from the input of local resource users and interest groups, and hence there are no universal "social guidelines". We provided examples of the types of synergies that are commonly cited in the literature, many of which have broad applicability. Sustaining and strengthening livelihoods that are dependent on healthy marine ecosystems, such as fishing and tourism, is perhaps the most obvious example of a social goal that MPAs can address. We also outlined strategies and practices to support the non-monetary and intangible benefits of MPAs; to conserve cultural and historical values; and to promote education and knowledge sharing as a valuable output of MPA establishment and implementation. Although the social-related goals are less prescriptive than ecological goals, we emphasize that social considerations are necessary to align MPA design and management with local resource needs and values, which in turn should contribute more effective and socially desirable MPA networks.

A key way of linking ecological, governance and social considerations in planning is through the inclusion of indigenous and local knowledge and practices. Knowledge integration – linking traditional and or local ecological knowledge (TEK / LEK) and knowledge generated from western science – draws heavily on governance principles through the recognition that indigenous knowledge holders have vested interests and knowledge in marine conservation. Based on our synthesis of the literature on how TEK and knowledge integration can contribute to marine planning processes, we suggested that TEK serves as an important source of information on species distributions, ecological relationships, and monitoring. Second, TEK can also provide options for ecosystem management strategies and adaptive approaches. We demonstrated that there are challenges and sources of conflict between Indigenous knowledge systems and Western scientific knowledge or management, and we provided examples of strategies and best practices for to mitigate these issues. Overall, we suggested that incorporating TEK and LEK into planning processes and protected area management is an integral component to pursuing a social-ecological approach to marine planning. The key challenge will be to move from simply accepting the importance of traditional knowledge in policy-making, to ensuring Indigenous knowledge systems are systematically incorporated into the planning, decision making and implementation of future MPAs and MPA networks.

REFERENCES

REFERENCES

- Abrams, P., G. Borrini-Feyerabend, J. Gardner, and P. Heylings. 2003. Evaluating governance: A handbook to accompany a participatory process for a protected area. Draft for field testing. Available online http://cmsdata.iucn.org/downloads/evaluating_governance_handbook.doc (Accessed Aug. 2014).
- Agardy, T., P. Bridgewater, M. Crosby, J. Day, P. Dayton, R. Kenchington, and L. Peau. 2003. Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems* 13:353-367.
- Agrawai, A. 1995. Dismantling the divide between indigenous and scientific knowledge. *Development and Change* 26:413-439.
- Airame, S., J. Dugan, K. Lafferty, H. Leslie, D. McArdle, and R. Warner. 2003. Applying ecological criteria to marine reserve design: A case study from the California Channel Islands. *Ecological Applications* 13:170-184.
- Airame, S., and J. Ugoretz. 2008. Channel Islands marine protected areas: First 5 years of monitoring 2003-2008. California Department of Fish and Game. Monterey, CA.
- Alcala, A., and G. Russ. 2006. No-take marine reserves and reef fisheries management in the Philippines: A new people power revolution. *AMBIO: A Journal of the Human Environment* 35:245-254.
- Allison, G. J. Lubchenco, and M. Carr. 1998. Marine reserves are necessary but not sufficient for marine conservation. *Ecological Applications* 8:579-592.
- Allison, G. W., S. D. Gaines, J. Lubchenco, and H. P. Possingham. 2003. Ensuring persistence of marine reserves: catastrophes require adopting an insurance factor. *Ecological Applications* 13:S8-S24.
- Andrade, G. and J. Rhodes. 2012. Protected areas and local communities: An inevitable partnership toward successful conservation strategies. *Ecology and Society* 17:14.
- Andrello, M., D. Mouillot, J. Beuvier, C. Albouy, W. Thuiller, and S. Manel. 2013. Low connectivity between Mediterranean marine protected areas: A biophysical modeling approach for the dusky grouper *Epinephelus marginatus*. *PloS one* 8:e68564.
- Angulo-Valdes, J., and B. Hatcher. 2010. A new typology of benefits derived from marine protected areas. *Marine Policy* 34:635-644.
- Aswani, S., and T. Furusawa. 2007. Do marine protected areas affect human nutrition and health? A comparison between villages in Roviana, Solomon Islands. *Coastal Management* 35:545-565.
- Aswani, S., and R. Hamilton. 2004. Integrating indigenous ecological knowledge and customary sea tenure with marine and social science for conservation of bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands. *Environmental Conservation* 31:69-83.
- Aswani, S., and M. Lauer. 2006. Incorporating fishermen's local knowledge and behavior into geographical information systems (GIS) for designing marine protected areas in Oceania. *Human Organization* 65:81-102.
- Ayers, C. A. 2005. Marine conservation from a First Nations' perspective: a case study of the principles of the Hul'qumi'num of Vancouver Island, British Columbia. Masters Thesis. University of Victoria, Victoria. 199pp.
- Ayers, C. A., P. Dearden, and R. Rollins. 2012. An exploration of Hul'qumi'num Coast Salish peoples' attitudes towards the establishment of no-take zones within marine protected areas in the Salish Sea, Canada. *The Canadian Geographer* 56:260-274.
- Ballantine, W. 1991. Marine reserves for New Zealand. Leigh Laboratory Bulletin. University of Auckland. 196pp.
- Ballantine, W. 1997. Design principles for systems of 'no-take' marine reserves. In *The Design and Monitoring of Marine Reserves*. University of British Columbia. February, Vancouver, B.C. 20pp.
- Ban, N., M. Mills, J. Tam, C. Hicks, S. Klain, N. Stoeckl, M. Bottrill, J. Levine, R. Pressey, T. Satterfield, and K. Chan. 2013a. A social-ecological approach to conservation planning: embedding social considerations. *Frontiers in Ecology and the Environment* 11:194-202.
- Ban, N., R. Pressey, and S. Weeks. 2012. Conservation objectives and sea surface temperature anomalies in the Great Barrier Reef. *Conservation Biology* 26:799-809.
- Ban, N. C., K. M. Bodtke, D. Nicolson, C. K. Robb, K. Royle, and C. Short. 2013b. Setting the stage for marine spatial planning: Ecological and social data collation and analyses in Canada's Pacific waters. *Marine Policy* 39:11-20.

- Ban, N. C., and C. J. Klein. 2009. Spatial socioeconomic data as a cost in systematic marine conservation planning. *Conservation Letters* 2:206-215.
- Ban, N. C., M. Mills, J. Tam, C. C. Hicks, S. Klain, N. Stoeckl, M. C. Bottrill, J. Levine, R. L. Pressey, T. Satterfield, and K. M. Chan. 2013c. A social-ecological approach to conservation planning: embedding social considerations. *Frontiers in Ecology and the Environment* 11:194-202.
- Ban, N. C., C. R. Picard, and A. C. J. Vincent. 2009. Comparing and integrating community-based and science-based approaches to prioritizing marine areas for protection. *Conservation Biology* 23:899-910.
- Ban, N. C., and A. C. J. Vincent. 2009. Beyond marine reserves: Exploring the approach of selecting areas where fishing is permitted, rather than prohibited. *PloS one* 4:e6258.
- Baskett, M. L., F. Micheli, and S. A. Levin. 2007. Designing marine reserves for interacting species: Insights from theory. *Biological Conservation* 137:163-179.
- BCMCA - British Columbia Marine Conservation Atlas. 2011. Marine atlas of Pacific Canada: a product of the British Columbia Marine Conservation Analysis (BCMCA). Available online <http://bcmca.ca/> (Accessed Aug. 2014).
- BCMCA - British Columbia Marine Conservation Atlas. 2012. A series of marxan scenarios for Pacific Canada: a report from the British Columbia Marine Conservation Analysis (BCMCA) Vancouver, B.C. 61pp.
- BCMEC - British Columbia Marine Ecological Classification. 2002. Marine ecosections and ecounits. The Province of British Columbia. Resources Information Standards Committee. 49pp. Available online http://www.for.gov.bc.ca/hts/risc/pubs/coastal/marine/version_2/bcmec_version_2.pdf (Accessed Sept. 2014).
- Beltran, J. 2000. Indigenous and traditional peoples and protected areas: Principles, guidelines and case studies. IUCN, Gland, Switzerland and Cambridge, UK and WWF International, Gland, Switzerland. 133pp. Available online <https://portals.iucn.org/library/efiles/documents/PAG-004.pdf> (Accessed Sept. 2014).
- Bennett, N., and P. Dearden. 2012. From outcomes to inputs: What is required to achieve the ecological and socio-economic potential of marine protected areas? (Working Paper). Marine Protected Areas Research Group, University of Victoria. Victoria, Canada. 38pp.
- Berkes, F. 1993. Traditional ecological knowledge in perspective. In J. Inglis (Editor), *Traditional ecological knowledge: concepts and cases*. International Program on Traditional Ecological Knowledge, International Development Research Centre (Int. Devel. Res. Cent), Ottawa, ON. 1-10.
- Berkes, F. 2004. Rethinking community-based conservation. *Conservation Biology* 18:621-630.
- Berkes, F. 2009. Evolution of co-management: role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management* 90:1692-1702.
- Berkes, F. 2012. *Sacred Ecology*. Third edition, Routledge, NY.
- Berkes, F., M. Berkes, and H. Fast. 2007. Collaborative integrated management in Canada's North: the role of local and traditional knowledge and community-based monitoring. *Coastal Management* 35:143-162.
- Berkes, F., J. Colding, and C. Folke. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Coastal Management* 10:1251-1262.
- Blue Earth Consultants. 2012. From design to action – Key elements and innovations for effective MPA network implementation: Lessons from successful case studies. Blue Earth Consultants. Oakland, CA.
- Borrini-Feyerabend, G. N. Dudley, T. Jaeger, B. Lassen, N. Pathak Broome, A. Phillips, and T. Sandwith. 2013. *Governance of Protected Areas: From understanding to action*. Gland, Switzerland: IUCN. Available online <https://portals.iucn.org/library/node/29138> (Accessed Aug. 2014).
- Borrini-Feyerabend, G. A. Kothari, and G. Oviedo. 2004. Indigenous and local communities and protected areas: Towards equity and enhanced conservation: Guidance on policy and practice for co-managed protected areas and community conserved areas. (No. 11) World Conservation Union (IUCN). Available online <http://areasprotegidas.info/upload/document/guidelinesindigenouspeople.pdf> (Accessed Aug. 2014).
- Botsford, L., D. Brumbaugh, C. Grimes, J. Kellner, and J. Largier. 2009. Connectivity, sustainability, and yield: bridging the gap between conventional fisheries management and marine protected areas. *Reviews in Fish Biology and Fisheries* 19:69-95.

REFERENCES

- Botsford, L., A. Hastings, and S. Gaines. 2001. Dependence of sustainability on the configuration of marine reserves and larval dispersal distance. *Ecology Letters* 4:144-150.
- Botsford, L., F. Micheli, and A. Hastings. 2003. Principles for the design of marine reserves. *Ecological Applications* 13:25-31.
- Brock, R., E. Kenchington, and A. Martinez-Arroyo. 2012. Scientific guidelines for designing resilient marine protected area networks in a changing climate. Commission for Environmental Cooperation. Montreal, Canada. 95pp.
- Brondo, K., and L. Woods. 2007. Garifuna land rights and ecotourism as economic development in Honduras' Cayos Cochinos Marine Protected Area. *Ecological and Environmental Anthropology* 3:2-18.
- Brown, E. D., J. Seitz, B. L. Norcross, and H. P. Huntington. 2002. Ecology of herring and other forage fish as recorded by resource users of Prince William Sound and the outer Kenai Peninsula, Alaska. *Alaska Fishery Research Bulletin* 9:75-101.
- Brown, F., and Y. K. Brown. 2009. Staying the course, staying alive - Coastal First Nations fundamental truths: biodiversity, stewardship and sustainability. Victoria, BC. 82pp.
- California MLPA Initiative. 2008. Application of science size guidelines and implications for MPA proposals - North Central Coast. California Marine Life Protection Act Initiative. Available online http://www.dfg.ca.gov/mlpa/pdfs/agenda_030408a.pdf (Accessed Sept 2014).
- California MLPA Initiative. 2009. Methods used to evaluate marine protected area proposals in the MLPA South Coast study region. California Marine Life Protection Act Initiative. Available online http://www.dfg.ca.gov/marine/pdfs/agenda_012709h1.pdf (Accessed Sept. 2014).
- Canada and British Columbia. 2014. Canada-British Columbia Marine Protected Area Network Strategy. No. Fs23-585/2012E. Available on-line http://www.for.gov.bc.ca/tasb/SLRP/pdf/ENG_BC_MPA_LOWRES.pdf (Accessed Aug. 2014).
- Canada and CHN. 1993. Gwaii Haanas / South Moresby Agreement. The Government of Canada and the Council of the Haida Nation. Available online <http://www.pc.gc.ca/eng/pn-np/bc/gwaiihaanas/plan/plan1.aspx> (Accessed Aug. 2014).
- Canada and CHN. 2007. Sgaan Kinghlas – Bowie Seamount memorandum of understanding between Her Majesty the Queen in right of Canada and The Haida Nation. Available online [http://www.pac.dfo-mpo.gc.ca/oceans/protection/mpa-zpm/bowie/docs/Bowie MOU_Apr18_07_signed_version.pdf](http://www.pac.dfo-mpo.gc.ca/oceans/protection/mpa-zpm/bowie/docs/Bowie%20MOU_Apr18_07_signed_version.pdf) (Accessed Aug. 2014).
- Canessa, R., and P. Dearden. 2008. Marine Protected Areas. In P. Dearden and R. Rollins (Editors), *Parks and protected areas in Canada: Planning and management* (3rd ed.). Oxford University Press, Toronto, ON.
- Carr, M., and D. Reed. 1993. Conceptual issues relevant to marine harvest refuges: examples from temperate marine fishes. *Canadian Journal of Fisheries and Aquatic Science* 50:2019-2028.
- CDFG - California Department of Fish and Game. 2008. California Marine Life Protection Act: master plan for marine protected areas (revised draft). California Department of Fish and Game. Sacramento, CA. 99pp.
- Central Coast Marine Use Plan. 2011. Central Coast First Nations Integrated Marine Use Plan – Draft. Central Coast Indigenous Resources Alliance. 96pp.
- Charles, A., and L. Wilson. 2009. Human dimensions of marine protected areas. *ICES Journal of Marine Science* 66:6-15.
- Chilisa, B. 2012. *Indigenous Research Methodologies*. Sage Publications, Incorporated, Los Angeles.
- Christie, P., and A. T. White. 2007. Best practices for improved governance of coral reef marine protected areas. *Coral Reefs* 26:1047-1056.
- Cicin-Sain, B., and S. Belfiore. 2005. Linking marine protected areas to integrated coastal and ocean management: A review of theory and practice. *Ocean and Coastal Management* 48:847-868.
- Cinner, J. 2007. Designing marine reserves to reflect local socioeconomic conditions: lessons from long-enduring customary management systems. *Coral Reefs* 26:1035-1045.
- Cinner, J., and S. Aswani. 2007. Integrating customary management into marine conservation. *Biological Conservation* 140:201-216.
- Cinner, J., M. Fuentes, and H. Randriamah. 2009. Exploring social resilience in Madagascar's marine protected areas. *Ecology and Society* 14:41.

- Cinner, J., T. McClanahan, M. MacNeil, N. Graham, T. Daw, A. Mukminin, D. Feary, A. Rabearisoa, A. Wamukota, N. Jiddawi, S. Campbell, A. Baird, F. Januchowski-Hartley, S. Hamed, R. Lahari, T. Morove, and J. Kuange. 2012. Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences* 109:5219-5222.
- Clarke, C., and G. Jamieson. 2006a. Identification of ecologically and biologically significant areas in the Pacific North Coast Integrated Management Area: Phase I – Identification of important areas. Canadian Technical Report of Fisheries and Aquatic Sciences 2678:59.
- Clarke, C., and G. Jamieson. 2006b. Identification of ecologically and biologically significant areas in the Pacific North Coast Integrated Management Area: Phase II – Final Report. Canadian Technical Report of Fisheries and Aquatic Sciences 2686:25.
- Coastal First Nations. n.d. Coastal Guardian Watchmen Programs. Available online <http://coastalguardianwatchmen.ca/guardian-watchmen-programs-overview> (Accessed Aug. 2014).
- Cobb, D., M. K. Berkes, and F. Berkes. 2005. Ecosystem-based management and marine environmental quality in northern Canada. In F. Berkes, R. Huebert, H. Fast, M. Manseau, and A. Diduck (Editors), *Breaking ice: renewable resource and ocean management in the Canadian North*. University of Calgary Press, Calgary. 71-93.
- Colding, J., and C. Folke. 1997. The relations among threatened species, their protection, and taboos. *Conservation Ecology* [online] 1:6.
- Colding, J., and C. Folke. 2001. Social taboos: “Invisible” systems of local resource management and biological conservation. *Ecological Applications* 11.
- Costello, C., and D. T. Kaffine. 2010. Marine protected areas in spatial property-rights fisheries. *Australian Journal of Agricultural and Resource Economics* 54:321-341.
- Council of the Haida Nation. 2011. *Haida Marine Traditional Knowledge Study*. 107pp.
- Cox, M., G. Arnold, and S. V. Tomás. 2010. A review of design principles for community-based natural resource management. *Ecology and Society* 15:38.
- CPAWS. 2009. *First Nations and marine protected areas: An introduction to First Nations rights, concerns and interests related to MPAs on Canada’s Pacific Coast (Discussion Paper)*. Prepared for the Canadian Parks and Wilderness Society by Julie Gardner, Dovetail Consulting. Vancouver, BC. 90pp.
- Crona, B. I., and J. N. Parker. 2012. Learning in support of governance: Theories, methods, and a framework to assess how bridging organizations contribute to adaptive resource governance. *Ecology and Society* 17:32.
- Daniels, S. E. and G. B. Walker. 1996. Collaborative learning: Improving public deliberation in ecosystem-based management. *Environmental impact assessment review* 16:71-102.
- Davies, J., R. Hill, F. Walsh, M. Sandford, D. Smyth, and M. Holmes. 2012. Innovation in management plans for community conserved areas: experiences from Australian indigenous protected areas. *Ecology and Society* 18:14.
- Dearden, P., M. Bennett, and J. Johnston. 2005. Trends in global protected area governance, 1992–2002. *Environmental Management* 36:89-100.
- Dedual, M., O. Sague Pla, R. Arlinghaus, A. Clark, K. Ferter, P. Geertz Hansen, D. Gerdeaux, F. Hames, and S. J. Kennelly. 2013. Communication between scientists, fishery managers and recreational fishers: Lessons learned from a comparative analysis of international case studies. *Fisheries Management and Ecology* 20:234-246.
- DFO. 2002. *Canada’s Oceans Strategy*. Fisheries and Oceans Canada. Ottawa, Ont. Available online <http://www.dfo-mpo.gc.ca/oceans/publications/cos-soc/index-eng.asp> (Accessed Aug. 2014).
- DFO. 2011. *National Framework for Canada’s Network of Marine Protected Areas*. Fisheries and Oceans Canada. Ottawa, Ont. Available online <http://www.dfo-mpo.gc.ca/oceans/publications/dmpaf-eczpm/framework-cadre2011-eng.asp> (Accessed Aug. 2014).
- DFO. 2013. *Draft Pacific North Coast Integrated Management Area Plan, May 27, 2013*. PNCIMA Initiative, Fisheries and Oceans Canada. Vancouver, B.C. Available online <http://www.pncima.org/media/documents/pdf/draft-pncima-plan-may-27--2013.pdf> (Accessed Aug. 2014).

- DFO, CFN, and NCSFNSS. 2008. Memorandum of Understanding on Pacific North Coast Integrated Management Area Collaborative Oceans Governance. Department of Fisheries and Oceans, Coastal First Nations, and North Coast-Skeena First Nations Stewardship Society. Available online http://www.pncima.org/media/documents/pdf/mou_-pncima_-collaborative_-oceans_-governance_-11dec08.pdf (Accessed Aug. 2014).
- DFO, and WWF. 2009. Guidance and lessons learned for Canada's marine protected areas networks: Proceedings of a national workshop held in Ottawa in January 2008. Fisheries and Oceans Canada and the World Wildlife Fund. Available online http://www.dfo-mpo.gc.ca/oceans/publications/ws-at/2008/pdf/mpa_workshop-eng.pdf (Accessed Aug. 2014).
- Dickinson, M., M. Rutherford, and T. Gunton. 2010. Principles for integrated marine planning: A review of international experience. *Environments: A Journal of Interdisciplinary Studies* 37:21-46.
- Drew, J. 2005. Use of traditional ecological knowledge in marine conservation. *Conservation Biology* 19:1286-1293.
- Edgar, G. J., R. D. Stuart-Smith, T. J. Willis, S. Kininmonth, S. C. Baker, S. Banks, N. S. Barrett, M. A. Becerro, A. T. F. Bernard, J. Berkhout, C. D. Buxton, S. J. Campbell, A. T. Cooper, M. Davey, S. C. Edgar, G. Försterra, D. E. Galván, A. J. Irigoyen, D. J. Kushner, R. Moura, P. E. Parnell, N. T. Shears, G. Soler, E. M. A. Strain, and R. J. Thomson. 2014. Global conservation outcomes depend on marine protected areas with five key features. *Nature* 506:216-220.
- Ehler, C. 2003. Indicators to measure governance performance in integrated coastal management. *Ocean and Coastal Management* 46:335-345.
- English, J., and E. Lee. 2003. Managing the intangible. In D. Harmon and A. Putney (Editors), *The full value of parks from economics to the intangible*. Rowman and Littlefield.
- Faasen, H., and S. Watts. 2007. Local community reaction to the 'no-take' policy on fishing in the Tsitsikamma National Park, South Africa. *Ecological Economics* 64:36-46.
- Fabinyi, M. 2008. Dive tourism, fishing and marine protected areas in the Calamianes Islands, Philippines. *Marine Policy* 32:898-904.
- Fedje, D., R. Wigen, Q. Mackie, C. Lake, and I. Sumpter. 2001. Preliminary Results from Investigations at Kilgii Gwaay: An Early Holocene Archaeological Site on Ellen Island, Haida Gwaii, British Columbia. *Canadian Journal of Archaeology / Journal Canadien d'Archéologie* 25:98-120.
- Fennell, D., R. Plummer, and M. Marschke. 2008. Is adaptive co-management ethical? *Journal of Environmental Management* 88:62-75.
- Fernandes, L., J. O. N. Day, A. Lewis, S. Slegers, B. Kerrigan, D. A. N. Breen, D. Cameron, B. Jago, J. Hall, D. Lowe, J. Innes, J. Tanzer, V. Chadwick, L. Thompson, K. Gorman, M. Simmons, B. Barnett, K. Sampson, G. De'Ath, B. Mapstone, H. Marsh, H. Possingham, I. A. N. Ball, T. Ward, K. Dobbs, J. Aumend, D. E. B. Slater, and K. Stapleton. 2005. Establishing representative no-take areas in the Great Barrier Reef: Large-scale implementation of theory on marine protected areas. *Conservation Biology* 19:1733-1744.
- Fernandes, L., A. Green, J. Tanzer, A. White, P. Alino, J. Jompa, P. Lokani, A. Soemodinoto, M. Knight, B. Pomeroy, H. P. Possingham, and B. Pressey. 2012. Biophysical principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity and climate change objectives in the Coral Triangle. *The Nature Conservancy*. Jakarta, Indonesia. 152pp.
- Flannery, W., and M. Ó Cinnéide. 2012. Deriving lessons relating to marine spatial planning from Canada's Eastern Scotian Shelf Integrated Management Initiative. *Journal of Environmental Policy & Planning* 14:97-117.
- FLNRO, CFN, Nanwakolas, and NCSFNSS. 2011. Letter of Intent to collaborate on coastal and marine planning in the Pacific North Coast. Ministry of Forests, Lands and Natural Resource Operations, Coastal First Nations, North Coast-Skeena First Nations Stewardship Society, Nanwakolas Council. Available online http://mappocean.org/wp-content/uploads/2013/10/LOI_Completed_Nov_28_2011-signatures-removed.pdf (Accessed Aug. 2014).
- Foale, S. 1998. Assessment and management of the trochus fishery at West Nggela, Solomon Islands: an interdisciplinary approach. *Ocean and Coastal Management* 40:187-205.
- Foale, S. 2006. The intersection of scientific and indigenous ecological knowledge in coastal Melanesia: implications for contemporary marine resource management. *International Social Science Journal* 58:129-137.
- Fogarty, M., and L. Botsford. 2007. Population connectivity and spatial management of marine fisheries. *Oceanography* 20:112-113.

- Foley, M. M., B. S. Halpern, F. Micheli, M. H. Armsby, M. R. Caldwell, C. M. Crain, E. Prahler, N. Rohr, D. Sivas, M. W. Beck, M. H. Carr, L. B. Crowder, J. Emmett Duffy, S. D. Hacker, K. L. McLeod, S. R. Palumbi, C. H. Peterson, H. M. Regan, M. H. Ruckelshaus, P. A. Sandifer, and R. S. Steneck. 2010. Guiding ecological principles for marine spatial planning. *Marine Policy* 34:955-966.
- Folke, C. 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change* 16:253-267.
- Folke, C., and L. Gunderson. 2006. Facing global change through social-ecological research. *Ecology and Society* 11:43.
- Fox, E. E. Poncelet, D. Connor, J. Vasques, J. Ugoretz, S. MacCreary, and M. Gleason. 2013. Adapting stakeholder processes to region-specific challenges in marine protected area network planning. *Ocean and Coastal Management* 74:24-33.
- Frame, T., T. Gunton, and J. Day. 2004. The role of collaboration in environmental management: an evaluation of land and resource planning in British Columbia. *Journal of Environmental Planning and Management* 47:59-82.
- Friedlander, A., N. Sladek, J. Sanchez, and e. al. 2003. Designing effective marine protected areas in Seaflower Biosphere Reserve, Colombia, based on biological and sociological information. *Conservation Biology* 17:1769-1784.
- Gadgil, M., F. Berkes, and C. Folke. 1993. Indigenous knowledge for biodiversity conservation. *AMBIO* 22:151-156.
- Gaines, S. D., C. White, M. H. Carr, and S. Palumbi. 2010. Marine Reserves Special Feature: Designing marine reserve networks for both conservation and fisheries management. *Proceedings of the National Academy of Sciences - PNAS* 107:18286-18293.
- Galaz, V., P. Olsson, T. Hahn, C. Folke, and U. Svedin. 2008. The problem of fit among biophysical systems, environmental and resource regimes, and broader governance systems: Insights and emerging challenges. In O. Young, L. King, and H. Schroeder (Editors), *Institutions and environmental change: Principle findings, applications and research frontiers*. MIT Press, Cambridge, MA. 147-186.
- Gardner, J., S. Bicego, S. Jessen, and M. Baker. 2008. Challenges and opportunities in progress towards Canada's commitment to a national network of MPAs by 2012. *Canadian Parks and Wilderness Society*. Vancouver, B.C. 148pp. Available online http://cpaws.org/uploads/pubs/report_mythandmadness.PDF (Accessed Aug. 2014). 148pp.
- Gearheard, S., C. Aporta, G. Aipellee, and O. Keefe. 2011. The Igliniit project: Inuit hunters document life on the trail to map and monitor Arctic change. *Canadian Geographer* 55:42-55.
- Gelcich, S., T. P. Hughes, P. Olsson, C. Folke, O. Defeo, M. Fernández, S. Foale, L. H. Gunderson, C. Rodríguez-Sickert, and M. Scheffer. 2010. Navigating transformations in governance of Chilean marine coastal resources. *Proceedings of the National Academy of Sciences* 107:16794-16799.
- Gell, F., and C. Roberts. 2003. Benefits beyond boundaries: the fisheries effects of marine reserves. *Trends in Ecology and Evolution* 18:448-455.
- Gibbs, M. 2003. Indigenous rights to natural resources in Australia and New Zealand: kereru, dugong and pounamu. *Australasian Journal of Environmental Management* 10:138-151.
- Gleason, M., S. McCreary, M. Miller-Henson, J. Ugoretz, E. Fox, M. Merrifield, W. McClintock, P. Serpa, and K. Hottman. 2010. Science-based and stakeholder-driven marine protected area network planning: A successful case study from north central California. *Ocean and Coastal Management* 53:52-68.
- Goodwin, H. 2002. Local community involvement in tourism around National Parks: Opportunities and constraints. *Current Issues in Tourism* 5:338-360.
- Govan, H., A. Tawake, K. Tabunakawai, A. Jenkins, A. Lasgorceix, A. Schwarz, B. Aalbersberg, B. Manele, C. Vieux, and D. Notere. 2009. Status and potential of locally-managed marine areas in the South Pacific: meeting nature conservation and sustainable livelihood targets through wide-spread implementation of LMMAs. *SPREP/WWF/WorldFish-Reefbase/CRISP*. 95pp.
- Government of Canada. 1997. Oceans Act. Department of Justice, Legislative Services Branch, Ottawa.Ont. Available online <http://laws-lois.justice.gc.ca/eng/acts/O-2.4/FullText.html> (Accessed Aug. 2014).
- Government of Canada. 2011. National Framework for Canada's Network of Marine Protected Areas. Fisheries and Oceans Canada, Ottawa, ON. 31pp. Available online <http://www.dfo-mpo.gc.ca/oceans/publications/dmpaf-eczpm/docs/framework-cadre2011-eng.pdf> (Accessed Aug. 2014).

- Graham, J., B. Amos, and T. W. Plumptre. 2003. Governance principles for protected areas in the 21st century. Prepared for the Fifth World Parks Congress, Durban, South Africa. Institute on Governance. Available online http://mercury.ethz.ch/serviceengine/Files/ISN/122197/ipublicationdocument_singledocument/638144bd-f4ba-4324-9c83-b63ac434726e/en/pa_governance2.pdf (Accessed Aug. 2014).
- Grantham, H., V. Agostini, J. Wilson, S. Mangubhai, N. Hidayat, A. Muljadi, C. Rotinsulu, M. Mongdong, M. Beck, and H. Possingham. 2013. A comparison of zoning analyses to inform the planning of a marine protected area network in Raja Ampat, Indonesia. *Marine Policy* 38:184-194.
- Green, A., P. Lokani, S. Sheppard, J. Almany, S. Keu, J. Aitsi, J. Warku Karvon, R. Hamilton, and G. Lipsett-Moore. 2007. Scientific design of a resilient network of marine protected areas. Kimbe Bay, West New Britain, Papua New Guinea. TNC Pacific Islands Countries Report No. 2. Available online <http://www.nature.org/ourinitiatives/regions/asiaandthepacific/papuanewguinea/placesweprotect/scientific-design-of-a-resilient-network-of-marine-protected-areas-kim.pdf> (Accessed Aug. 2014).
- Green, S., A. Meneses, P. Christie, A. T. White, and S. Kilarski. 2009. MPA networks in the Coral Triangle: Development and Lessons. The Nature Conservancy, World Wildlife Fund, Conservation International, Wildlife Conservation Society, and the United States Agency for International Development, Cebu City, Philippines.
- Grenier, L. 1998. Working with indigenous knowledge: a guide for researchers. International Development Research Centre, Ottawa.
- Grüss, A., D. M. Kaplan, S. Guénette, C. M. Roberts, and L. W. Botsford. 2011. Consequences of adult and juvenile movement for marine protected areas. *Biological Conservation* 144:692-702.
- Grussing, V. 2013. Cultural heritage resources and marine protected areas. NOAA - Cultural Heritage MPAs National Marine Protected Areas Center. Available online http://marineprotectedareas.noaa.gov/pdf/helpful-resources/factsheets/cultural_heritage_mpas_mar2011x2.pdf (Accessed Sept 2014).
- Haggen, N., B. Neis, and I. Baird. 2007. Fishers' knowledge in fisheries science and management. Coastal Management Sourcebooks 4. United Nations Educational, Scientific and Cultural Organization. Paris. 58pp.
- Hahn, T., P. Olsson, C. Folke, and K. Johansson. 2006. Trust-building, knowledge generation and organizational innovations: The role of a bridging organization for adaptive co-management of a wetland landscape around Kristianstad, Sweden. *Human Ecology* 34:573-592.
- Haida Nation v. British Columbia. 2004. Supreme Court Judgement. Report [2004] 3 S.C.R. 511. Available online <http://scc-csc.lexum.com/scc-csc/scc-csc/en/item/2189/index.do> (Accessed Aug. 2014).
- Halpern, B. S. 2003. The impact of marine reserves: have reserves worked and does reserve size matter? *Ecological Applications* 13:S117-S137.
- Hamilton, R., and T. Potuku. 2007. Local knowledge of white-dotted grouper (*Epinephelus polystigma*) aggregations in Melanesia. SPC Traditional Marine Resource Management and Knowledge Information Bulletin 22:3-14.
- Hamilton, R., T. Potuku, and J. Montambault. 2011. Community-based conservation results in the recovery of reef fish spawning aggregations in the Coral Triangle. *Biological Conservation* 144:1850-1858.
- Hargreaves-Allen, V., S. Mourato, and E. Milner-Gulland. 2011. A global evaluation of coral reef management performance: Are MPAs producing conservation and socio-economic improvements? *Environmental Management* 47:684-700.
- Harley, C. D. G. A. Randall Hughes, K. M. Hultgren, B. G. Miner, C. J. B. Sorte, C. S. Thornber, L. F. Rodriguez, L. Tomanek, and S. L. Williams. 2006. The impacts of climate change in coastal marine systems. *Ecology Letters* 9:228-241.
- Harmon, D. 2004. Intangible values of protected areas: What are they? Why do they matter? *The George Wright Forum* 21:9-22.
- Hastings, A., and L. Botsford. 2006. Persistence of spatial populations depends on returning home. *Proceedings of the National Academy of Sciences* 103:6067-6072.
- Hawkes, S. 1996. The Gwaii Haanas Agreement: From conflict to cooperation. *Environments* 23:87-100.
- Heaslip, R. 2008. Monitoring salmon aquaculture waste: The contribution of First Nations; rights, knowledge, and practices in British Columbia, Canada. *Marine Policy* 32:988-996.
- Heck, N., P. Dearden, and A. McDonald. 2012. Stakeholder evaluation priorities for demonstrating marine protected area effectiveness at the Pacific Rim National Park Reserve, Canada. *Coastal Management* 40:55-72.

- Heiltsuk Nation Traditional Use Study. 2011. Heiltsuk Integrated Resource Management Department (HIRMD). Bella Bella, B.C.
- Heppell, S., J. Barth, and H. Reiff. 2008. Size and spacing of marine reserves workshop. Science and Technical Advisory Committee report. Marine Resource Management Program, Oregon State University. Charleston, OR. 88pp. Available online http://www.oregon.gov/LCD/OPAC/docs/resources/oregon_size_and_spacing_workshop_report.pdf (Accessed Aug. 2014).
- Historic Scotland. 2014. Marine protected areas in the seas around Scotland: Guidelines on the selection, designation and management of historic marine protected areas. Historic Scotland. Available online <http://www.historic-scotland.gov.uk/historic-mpa-guidelines.pdf> (Accessed Sept 2014).
- Huntington, H. 2000. Using traditional ecological knowledge in science: methods and applications. *Ecological Applications* 10:1270-1274.
- Huppé, G. A., H. Creech, and D. Knoblauch. 2012. The frontiers of networked governance. A report by the International Institute for Sustainable Development (IISD). Available online http://www.iisd.org/pdf/2012/frontiers_networked_gov.pdf (Accessed Sept. 2014).
- Hviding, E. 1998. Contextual flexibility: present status and future of customary marine tenure in Solomon Islands. *Ocean and Coastal Management* 40:253-269.
- Hyrenbach, K. D., K. A. Forney, and P. K. Dayton. 2000. Marine protected areas and ocean basin management. *Aquatic Conservation: Marine and Freshwater Ecosystems* 10:437-458.
- IUCN-WCPA. 2008. Establishing marine protected area networks - making it happen. IUCN World Commission on Protected Areas, National Oceanic and Atmospheric Administration and The Nature Conservancy. Washington, DC. 118pp.
- IUCN-WCPA. 2012. The Whakatane Mechanism: An IUCN "One Programme" initiative to support conflict resolution on protected areas and indigenous peoples and local communities. Draft Framework v5.0. Available online <http://whakatane-mechanism.org/> (Accessed Aug. 2014).
- Jentoft, S. 2000. Co-managing the coastal zone: Is the task too complex? *Ocean & Coastal management* 43:527-535.
- Jentoft, S., T. Van Son, and M. Bjørkan. 2007. Marine protected areas: A governance system analysis. *Human Ecology* 35:611-622.
- Jessen, S., K. Chan, I. Côté, P. Dearden, E. De Santo, M. Fortin, F. Guichard, W. Haider, G. Jamieson, D. Kramer, A. McCrea-Strub, M. Mulrennan, W. Montevecchi, J. Roff, A. Salomon, J. Gardner, L. Honka, R. Menafra, and A. Woodley. 2011. Science-based guidelines for MPAs and MPA networks in Canada. Canadian Parks and Wilderness Society. Vancouver, B.C. 58pp.
- Johannes, R. 2002. The renaissance of community-based marine resource management in Oceania. *Annual Reviews of Ecology, Evolution, and Systematics* 33:317-340.
- Johannes, R., M. Freeman, and R. Hamilton. 2000. Ignore fishers knowledge and miss the boat. *Fish and Fisheries* 1:257-271.
- Jones, P., E. De Santo, W. Qiu, and O. Vestergaard. 2013. Introduction: An empirical framework for deconstructing the realities of governing marine protected areas. *Marine Policy* 41:1-4.
- Jones, R. 2006. Canada's seas and her First Nations: A colonial paradigm revisited. In D. R. Rothwell and D. L. VanderZwaag (Editors), *Towards principled oceans governance: Australian and Canadian approaches and challenges*. Routledge, Abingdon, Oxon.
- Jones, R., C. Rigg, and L. Lee. 2010. Haida marine planning: First Nations as a partner in marine conservation. *Ecology and Society* 15:12.
- Kaplan, D., and L. Botsford. 2005. Effects of variability in spacing of coastal marine reserves on fisheries yield and sustainability. *Canadian Journal of Fisheries and Aquatic Science* 62:905-912.
- Kenter, J., R. Bryce, A. Davies, N. Jobstvogt, V. Watson, S. Ranger, J.-L. Solandt, C. Duncan, M. Christie, H. Crump, K. Irvine, M. Pinard, and M. Reed. 2013. The value of potential marine protected areas in the UK to divers and sea anglers. *UNEP-WCMC*:1-125.
- Kinlan, B., and S. Gaines. 2003. Propagule dispersal in marine and terrestrial environments: a community perspective. *Ecology* 84:2007-2020.
- Kirlin, J., M. Caldwell, M. Gleason, M. Weber, J. Ugoretz, E. Fox, and M. Miller-Henson. 2012. California's Marine Life Protection Act Initiative: Supporting implementation of legislation establishing a statewide network of marine protected areas. *Ocean & Coastal Management* 74:3-13.

- Klein, C., A. Chan, and L. Kircher. 2008a. Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. *Conservation Biology* 33:691-700.
- Klein, C., C. Steinback, A. Scholz, and H. Possingham. 2008b. Effectiveness of marine reserve networks in representing biodiversity and minimizing impact to fishermen: a comparison of two approaches used in California. *Conservation Letters* 1:44-51.
- Klein, C., C. Steinback, M. Watts, A. Scholz, and H. Possingham. 2009. Spatial marine zoning for fisheries and conservation. *Frontiers in Ecology and the Environment* 8:349-353.
- Kofinas, G., Aklavik, Arctic Village, Old Crow, and Fort McPherson. 2002. Community contributions to ecological monitoring: knowledge co-production in the US-Canada Arctic borderlands. In I. Krupnik and D. Jolly (Editors), *The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change*. Arctic Research Consortium of the United States, Fairbanks. 54-91.
- Kothari, A., C. Corrigan, H. Jonas, A. Neumann, and H. Shrumm. 2012. Recognizing and supporting territories and areas conserved by Indigenous peoples and local communities: Global overview and national case studies. Secretariat of the Convention of Biological Diversity, ICCA Consortium, Kalpavriksh, and Natural Justice, Montreal, Canada. Technical Series no. 64, 160pp. Available online <http://www.cbd.int/doc/publications/cbd-ts-64-en.pdf> (Accessed Sept 2014).
- Krupnik, I., C. Aporta, S. Gearheard, G. J. Laidler, and L. K. Holm (Editors). 2010. *SIKU: Knowing our ice: documenting Inuit sea-ice knowledge and use*. Springer, London.
- Krupnik, I., and D. Jolly (Editors). 2002. *The earth is faster now: Indigenous observations of Arctic environmental change*. Arctic Research Consortium of the United States, Fairbanks, Alaska.
- Laffoley, D. d'A., and G. Grimsditch. 2009. *The management of natural coastal carbon sinks*. IUCN. Gland, Switzerland. 53pp.
- Lamb, A., and P. Edgell. 2010. *Coastal fishes of the Pacific Northwest*, revised and expanded second edition. Harbour Publishing, Madeira Park, BC.
- Lance, R. W., P. Dearden, and A. Orozco. 2012. Framework for assessing governance for landscape-level ecosystem-based management – Draft 2.1. PAPP Working Paper No.13. Available online at http://www.papr.co.ca/index.php?p=1_25_Papers (Accessed Aug. 2014).
- Langdon, S., R. Prosper, and N. Gagnon. 2010. Two paths one direction: Parks Canada and Aboriginal Peoples working together. *The George Wright Forum* 27:222-233.
- Leisher, C., P. van Beukering, and L. Scherl. 2007. Nature's investment bank: How marine protected areas contribute to poverty reduction. *The Nature Conservancy*. 52pp.
- Lertzman, D. 2010. Best of two worlds: Traditional ecological knowledge and western science in ecosystem-based management. 10:104-126.
- Lester, S., B. Halpern, K. Grorud-Colvert, J. Lubchenco, B. Ruttenberg, S. Gaines, S. Aïramé, and R. Warner. 2009. Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series* 384:33-46.
- Lester, S. E. and B. S. Halpern. 2008. Biological responses in marine no-take reserves versus partially protected areas. *Marine Ecology Progress Series* 367:49-56.
- Lett, C., S.-D. Ayata, M. Huret, and J.-O. Irisson. 2010. Biophysical modelling to investigate the effects of climate change on marine population dispersal and connectivity. *Progress in Oceanography* 87:106-113.
- Lockwood, M. 2009. Governance assessment of terrestrial protected areas: A framework and three case studies. University of Tasmania. Available online [http://www.geog.utas.edu.au/geography/nrmgovernance/Documents/Lockwood 2009.pdf](http://www.geog.utas.edu.au/geography/nrmgovernance/Documents/Lockwood%202009.pdf) (Accessed Aug. 2014).
- Lockwood, M., J. Davidson, A. Curtis, E. Stratford, and R. Griffith. 2010. Governance principles for natural resource management. *Society and Natural Resources* 23:986-1001.
- Lockwood, M., G. Worboys, and A. Kothari (Editors). 2012. *Managing protected areas: A global guide*. Cromwell Press, Trowbridge, UK.
- Lotterhos, K., S. Dick, and D. Haggarty. 2014. Evaluation of rockfish conservation area networks in the United States and Canada relative to the dispersal distance for black rockfish (*Sebastes melanops*). *Evolutionary Applications* 7:238-259.

- Lotterhos, K. E. and R. W. Markel. 2012. Oceanographic drivers of offspring abundance may increase or decrease reproductive variance in a temperate marine fish. *Molecular Ecology* 21:5009-5026.
- Lubchenco, J., S. Palumbi, S. Gaines, and S. Andelman. 2003. Plugging a hole in the ocean: the emerging science of marine reserves. *Ecological Applications* 13:S3-S7.
- Lucas, E. and R. Kirit. 2009. Fisheries–marine protected area–tourism interactions in Moalboal, Cebu, Philippines. *Coastal Management* 37:480-490.
- Lutz, J., and B. Neis. 2008. Making and moving knowledge: Interdisciplinary and community-based research for a world on the edge. McGill-Queen's University Press, Montreal, QC.
- Lyver, P. 2002. Use of traditional knowledge by Rakiura Maori to guide sooty shearwater harvests. *Wildlife Society Bulletin* 30:29-40.
- Mace, G. M., P. H. Harvey, and T. H. Clutton-Brock. 1983. Vertebrate home-range size and energetic requirements. In S. J. Smith, J. J. Hunt, and D. Rivard (Editors), *The ecology of animal movement*. 32-53.
- Magris, R. A., R. L. Pressey, R. Weeks, and N. C. Ban. 2014. Integrating connectivity and climate change into marine conservation planning. *Biological Conservation* 170:207-221.
- Marine Planning Partnership. n.d. About MaPP. Available online <http://mappocean.org/> (Accessed July 2014).
- Marliave, J. 1986. Lack of planktonic dispersal of rocky intertidal fish larvae. *Transactions of the American Fisheries Society* 115:149-154.
- Marsh, H. 2007. Progress towards the cooperative management of marine hunting in the Great Barrier Reef. In T. McClanahan and J. Castilla (Editors), *Fisheries Management: Progress Towards Sustainability*. Blackwell. 186-203.
- Marshall, G. 2007. Nesting, subsidiarity, and community-based environmental governance beyond the local scale. *International Journal of the Commons* 2:75-97.
- Mascia, M. 2001. Designing effective coral reef marine protected areas. A Synthesis Report Based on Presentations at the 9th International Coral Reef Symposium, Bali, Indonesia, October 2000. Available online http://90plan.ovh.net/~uicnftztz/IMG/pdf/Designing_Effective_Coral_Reef_MPAs.pdf (Accessed Aug. 2014).
- Mascia, M. 2003. The human dimension of coral reef marine protected areas: Recent social science research and its policy implications. *Conservation Biology* 17:630-632.
- Mascia, M., and C. Claus. 2008. A property rights approach to understanding human displacement from protected areas: the case of marine protected areas. *Conservation Biology* 23:16-23.
- Mascia, M., C. Claus, and R. Naidoo. 2010. Impacts of marine protected areas on fishing communities. *Conservation Biology* 24:1424-1429.
- Maypa, A., A. Green, G. Almany, R. Abesamis, and A. White. 2012. Movement patterns and life history strategies of key coral reef and coastal pelagic fisheries species for consideration in MPA network design in the Coral Triangle. Report prepared for the Coral Triangle Support Partnership.
- McClanahan, T. 2012. Scaling the management values divide. *Aquatic Conservation: Marine and Freshwater Ecosystems* 22:565-568.
- McClanahan, T. R. 2010. Effects of fisheries closures and gear restrictions on fishing income in a Kenyan coral reef. *Conservation Biology* 24:1519-1528.
- McGregor, D. 2009. Linking traditional knowledge and environmental practice in Ontario. *Journal of Coastal Conservation* 43:69-100.
- McLeod, E. R. Salm, A. Green, and J. Almany. 2009. Designing marine protected area networks to address the impacts of climate change. *Frontiers in Ecology and the Environment* 7:362-370.
- Moffitt, E. A., L. W. Botsford, D. M. Kaplan, and M. R. O'Farrell. 2009. Marine reserve networks for species that move within a home range. *Ecological Applications* 19:1835-1847.
- Moffitt, E. A., J. Wilson White, and L. W. Botsford. 2011. The utility and limitations of size and spacing guidelines for designing marine protected area (MPA) networks. *Biological Conservation* 144:306-318.
- Moller, H., F. Berkes, P. O. a. B. Lyver, and M. Kislalioglu. 2004. Combining science and traditional ecological knowledge: monitoring populations for co-management. *Ecology and Society* 9:2.

- Mora, C., S. Andrefouet, M. J. Costello, C. Kranenburg, A. Rollo, J. Veron, K. J. Gaston, and R. A. Myers. 2006. Coral reefs and the global network of marine protected areas. *Science* 312:1750-1751.
- Mulongoy, K., and S. Gidda. 2008. The value of nature: Ecological, economic, cultural and social benefits of protected areas. Secretariat of the Convention on Biological Diversity. Montreal, CA. 40pp.
- Mulrennan, M. E. 2014. On the edge: a consideration of the adaptive capacity of Indigenous Peoples in coastal zones from the Arctic to the Tropics. In I. P. Martini and H. R. Wanless (Editors), *Sedimentary Coastal Zones from High to Low Latitudes: Similarities and Differences*. Geological Society, London, Special Publications, 388.
- Murray, G. and L. King. 2012. First Nations Values in Protected Area Governance: Tla-o-qui-aht Tribal Parks and Pacific Rim National Park Reserve. *Human Ecology* 40:385-395.
- Murray, G. B. Neis, C. T. Palmer, and D. C. Schneider. 2008. Mapping cod: fisheries science, fish harvesters' ecological knowledge and cod migrations in the Northern Gulf of St. Lawrence. *Human Ecology* 36:581-598.
- Nabhan, G. P. 2000. Interspecific relationships affecting endangered species recognized by O'Odham and Comcaac cultures. *Ecological Applications* 10:1288-1295.
- Nadasdy, P. 2003. Reevaluating the co-management success story. *Arctic* 56:367-380.
- Nakashima, D. J., M. K. Galloway, H. D. Thulstrup, R. Castillo, and J. T. Rubis. 2012. *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*. UNESCO, and Darwin, UNU. Paris. 120pp.
- NOAA. 2013. National Marine Sanctuaries: Education for teachers (Website - updated Mar. 2013). NOAA. Available online <http://sanctuaries.noaa.gov/education/teachers/welcome.html> (Accessed Sept 2014).
- National Research Council. 2001. *Marine Protected Areas: Tools for Sustaining Ocean Ecosystems*. National Academy Press. Washington, DC. 273pp.
- O'Garra, T. 2007. Supplementary livelihood options for Pacific Island communities: a review of experiences. 35pp.
- OAG. 2012. Report of the Commissioner of the Environment and Sustainable Development (Ch.3. Marine Protected Areas). Office of the Auditor General.
- Okey, T. A., H. M. Alidina, V. Lo, A. Montenegro, and S. Jessen. 2012. *Climate Change Impacts and Vulnerabilities in Canada's Pacific Marine Ecosystems*. CPAWS BC and WWF-Canada. Vancouver, BC.
- Olsson, P., C. Folke, and F. Berkes. 2004. Adaptive comanagement for building resilience in social-ecological systems. *Environmental Management* 34:75-90.
- OSPAR. 2007. Background document to support the assessment of whether the OSPAR Network of Marine Protected Areas is ecologically coherent. 978-1-905859-59-7. 54pp.
- Ostrom, E. 2000. Collective action and the evolution of social norms. *Journal of Economic Perspectives* 14:137-158.
- Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325:419-422.
- Palumbi, S. 2001. The ecology of marine protected areas. In M. Bertness, S. Gaines, and M. Hays (Editors), *Marine ecology: the new synthesis*. 509-530.
- Palumbi, S. 2004. Marine reserves and ocean neighborhoods: the spatial scale of marine populations and their management. *Annual Review of Environment and Resources* 29:31-68.
- Parks Canada. 2009. *Public Values: Story of a Mapping Workshop*. Parks Canada. 106pp.
- Parks Canada. 2012. Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site: Cultural Resources (Website - Updated Dec. 2012). Available online <http://www.pc.gc.ca/eng/pn-np/bc/gwaiihaanas/plan/Plan3.aspx> (Accessed Sept 2014).
- Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution* 10:430.
- Pearce, P. L. 2004. The functions and planning of visitor centres in regional tourism. *The Journal of Tourism Studies* 15:8-16.
- Pelc, R. A., R. R. Warner, S. D. Gaines, and C. B. Paris. 2010. Detecting larval export from marine reserves. *Proceedings of the National Academy of Sciences* 107:18266-18271.

- Pollnac, R., P. Christie, J. E. Cinner, T. Dalton, T. M. Daw, G. E. Forrester, N. A. J. Graham, and T. R. McClanahan. 2010. Marine reserves as linked social-ecological systems. *Proceedings of the National Academy of Sciences* 107:18262-18265.
- Pomeroy, R., and F. Berkes. 1997. Two to tango: The role of government in fisheries co-management. *Marine Policy* 21:465-480.
- Pomeroy, R., M. Mascia, and R. Pollnac. 2006. Marine protected areas the social dimension. Expert workshop on marine protected areas and fisheries management: Review of issues and considerations. Food and Agricultural Organization (FAO)
- Pomeroy, R., J. Parks, and L. Watson. 2004. How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness. World Conservation Union (IUCN).
- Price, K., A. Roburn, and A. MacKinnon. 2009. Ecosystem-based management in the Great Bear Rainforest. *Forest Ecology and Management* 258:495-503.
- Raffaelli, D., and H. Moller. 2000. Manipulative field experiments in animal ecology: do they promise more than they can deliver? *American Biological Research* 30:299-388.
- Rhodes, C. 2009. Cross cultural neighbours: exploring settler responses to the Tsawwassen Urban Treaty. Master of Dispute Resolution, University of Victoria, Victoria.
- Richardson, E. M. Kaiser, G. Edwards-Jones, and H. Possingham. 2006. Sensitivity of marine-reserve design to the spatial resolution of socioeconomic data. *Conservation Biology* 20:1191-1202.
- Robb, C. K., K. M. Bodtker, K. Wright, and J. Lash. 2011. Commercial fisheries closures in marine protected areas on Canada's Pacific coast: The exception, not the rule. *Marine Policy* 35:309-316.
- Roberts, C., G. Branch, R. Bustamante, J. Castilla, J. Dugan, B. Halpern, K. Lafferty, H. Leslie, J. Lubchenco, and D. McArdle. 2003. Application of ecological criteria in selecting marine reserves and developing reserve networks. *Ecological Applications* 13:215-228.
- Robinson, C., and L. McBlane. 2013. A summary of major upper ocean sub regions found within Parks Canada's five Natural Marine Regions of the Pacific coast of Canada. A report completed for the BC Marine Conservation Analysis. Available online <http://bcmca.ca/> (Accessed Aug. 2014).
- Robinson, C., J. Morrison, and M. Foreman. 2005. Oceanographic connectivity among marine protected areas on the north coast of British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences* 62:1350-1362.
- Rodwell, L., and C. Roberts. 2004. Fishing and the impact of marine reserves in a variable environment. *Canadian Journal of Fisheries and Aquatic Science* 6:2053-2068.
- Rusnak, G. 1997. Co-management of natural resources in Canada: A review of concepts and case studies. International Development Research Centre. Ottawa, Ont. Available online <https://idl-bnc.idrc.ca/dspace/handle/10625/30126> (Accessed Aug. 2014).
- Saarman, E. and M. Carr. 2011. The California Marine Life Protection Act MPA Network - governance analysis. In P. J. S. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: getting the balance right - Volume 2. Technical Report to Marine & Coastal Ecosystems Branch, UNEP, Nairobi.* 65-75.
- Saarman, E. M. Gleason, J. Ugoretz, S. Airamé, M. Carr, E. Fox, A. Frimodig, T. Mason, and J. Vasques. 2013. The role of science in supporting marine protected area network planning and design in California. *Ocean & Coastal Management* 74:45-56.
- Sala, E. O. Aburto-Oropeza, G. Paredes, I. Parra, J. Barrera, and P. Dayton. 2002. A general model for designing networks of marine reserves. *Conservation Biology* 20:1191-1202.
- Sala, E. C. Costello, D. Dougherty, G. Heal, K. Kelleher, J. H. Murray, A. A. Rosenberg, and R. Sumaila. 2013. A general business model for marine reserves. *PloS one* 8:e58799.
- Salm, R. V., J. Clark, and E. Siirila. 2000. Marine and coastal protected areas: a guide for planners and managers. IUCN, Wasington D.C.
- Salm, R. V., T. Done, and E. Mcleod. 2006. Marine protected area planning in a changing climate. In J. T. Phinney, O. Hoegh-Guldberg, J. Kleypas, W. Skirying, and A. Strong (Editors). *American Geophysical Union, Washington, D.C.* 207-221.
- Salomon, A., J. Ruesink, and et al. 2001. Incorporating human and ecological communities in marine conservation; An alternative to Zacharias and Roff. *Conservation Biology* 15:1452-1455.
- Salomon, A., J. Ruesink, and et al. 2006. Population viability, ecological processes and biodiversity: Valuing sites for reserve selection. *Biological Conservation* 128:79-92.

- Salomon, A., N. Waller, and et al. 2002. Modeling the trophic effects of marine protected area zoning policies: A case study. *Aquatic Ecology* 36:85-95.
- Salomon, A. K., N. M. Tanape, and H. P. Huntington. 2007. Serial depletion of marine invertebrates leads to the decline of a strongly interacting grazer. *Ecological Applications* 17:1752-1770.
- Samoilys, M. A., K. M. Martin-Smith, B. G. Giles, B. Cabrera, J. A. Anticamara, E. O. Brunio, and A. C. J. Vincent. 2007. Effectiveness of five small Philippines' coral reef reserves for fish populations depends on site-specific factors, particularly enforcement history. *Biological Conservation* 136:584-601.
- Scholz, A., K. Bonzon, R. Fujita, N. Benjamin, N. Woodling, P. Black, and C. Steinback. 2004. Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California. *Marine Policy* 28:335-349.
- Schusler, T. M., D. J. Decker, and M. J. Pfeffer. 2003. Social learning for collaborative natural resource management. *Society & Natural Resources* 16:309-326.
- Sciberras, M., S. R. Jenkins, R. Mant, M. J. Kaiser, S. J. Hawkins, and A. S. Pullin. 2013. Evaluating the relative conservation value of fully and partially protected marine areas. *Fish and Fisheries*:published on-line.
- Scott, C. H., and M. E. Mulrennan. 2010. Reconfiguring Mare Nullius: Torres Strait islanders, indigenous sea rights and the divergence of domestic and international norms. In M. Blaster, R. De Costa, D. McGregor, and W. D. Coleman (Editors), *Indigenous Peoples and Autonomy: Insights for a Global Age*. University of British Columbia Press, Vancouver. 148-176.
- Shanks, A. 2009. Pelagic larval duration and dispersal distance revisited. *Biological Bulletin* 216:373-385.
- Shanks, A., G. BA, and M. Carr. 2003. Propagule dispersal distance and the size and spacing of marine reserves. *Ecological Applications* 13:S159-S169.
- Silvano, R. A. M., and J. Valbo-Jorgensen. 2008. Beyond fishermen's tales: contributions of fishers' local ecological knowledge to fish ecology and fisheries management. *Environment Development and Sustainability* 10:657-675.
- Simpson, L. R. 2004. Anticolonial strategies for the recovery and maintenance of Indigenous Knowledge. *The American Indian Quarterly* 28:373-384.
- Sims, N. 1989. Adapting traditional marine tenure and management practices to the modern fisheries framework in the Cook Islands. In K. Ruddle and R. E. Johannes (Editors), *Traditional Marine Resource Management in the Pacific Basin: An Anthology*. UNESCO, Jakarta. 323-358.
- Singleton, S. 2009. Native people and planning for Marine Protected Areas: How stakeholder processes fail to address conflicts in complex, real-world environments. *Coastal Management* 37:421-440.
- Smith, L. 2012. *Decolonizing methodologies: research and indigenous peoples*. Zed Books, New York.
- Smith, M., and J. Wilen. 2003. Economic impacts of marine reserves: the importance of spatial behavior. *Journal of Environmental Economics and Management* 46:183-206.
- Snively, G. 1978. *Exploring the seashore in British Columbia, Washington, and Oregon: a guide to shorebirds and intertidal plants and animals*. Writing Works, Vancouver, B.C.
- Sobel, J. 1996. Marine reserves: necessary tools for biodiversity conservation? *Global Biodiversity* 6:8-18.
- Stewart, G. B., M. J. Kaiser, I. M. Cote, B. S. Halpern, S. E. Lester, H. R. Bayliss, and A. S. Pullin. 2009. Temperate marine reserves: global ecological effects and guidelines for future networks. *Conservation Letters* 2:243-253.
- Stewart, R., and H. Possingham. 2005. Efficiency, costs and trade-offs in marine reserve system design. *Environment Modeling and Assessment* 10:203-213.
- Szpak, P., T. Orchard, I. McKechnie, and D. Grocke. 2012. Historical ecology of late Holocene sea otters (*Enhydra lutris*) from northern British Columbia: isotopic and zooarchaeological perspectives. *Journal of Archaeological Science* 39:1553-1571.
- Tawake, A., J. Parks, P. Radikedike, B. Aalbersberg, V. Vuki, and N. Salafsky. 2001. Harvesting clams and data involving local communities in monitoring can lead to conservation success in all sorts of unanticipated ways: a case in Fiji. *Conservation* 2:32-35.
- The Assembly of First Nations. 1995. *The feasibility of representing Traditional Indigenous knowledge in cartographic, pictorial or textual forms*. National Aboriginal Forestry Association and National Atlas Information Service. Ottawa, ON.

- Thomlinson, E. and G. Crouch. 2012. Aboriginal peoples, Parks Canada, and protected spaces: a case study in co-management at Gwaii Haanas National Park Reserve. *Annals of Leisure Research* 15:69-86.
- Thompson, L., B. Jago, L. Fernandes, and J. Day. 2005. Barriers to communication: How these critical aspects were addressed during the public participation for the rezoning of the Great Barrier Reef Marine Park. Staff Paper. Great Barrier Reef Marine Park Authority, Townsville, Australia. Available online http://www.gbrmpa.gov.au/__data/assets/pdf_file/0019/6175/Breaking_through_the_barriers_15April0420FINAL.pdf (Accessed Aug. 2014).
- Thornton, T. F., and A. M. Scheer. 2012. Collaborative engagement of local and traditional knowledge and science in marine environments: A review. *Ecology and Society* 17:8.
- TNC, WWF, CI, and WCS. 2008. Marine protected areas in the coral triangle: Development and lessons. The Nature Conservancy, World Wildlife Fund, CI, WCS and the United States Agency for International Development., Cebu City, Philippines.
- Tobias, T. 2000. Chief Kerry's Moose: a guidebook to land use and occupancy mapping, research design and data collection. Union of BC Indian Chiefs and Ecotrust Canada. 66pp. Available online http://www.nativemaps.org/files/Tobias_FullCopy.pdf (Accessed July 2014).
- Torell, E. B. Crawford, D. Kotowicz, M. Herrera, and J. Tobey. 2010. Moderating our expectations on livelihoods in ICM: Experiences from Thailand, Nicaragua, and Tanzania. *Coastal Management* 38:216-237.
- Turner, K., F. Berkes, and N. Turner. 2012. Indigenous perspectives on ecotourism development: a British Columbia case study. *Journal of Enterprising Communities: People and Places in the Global Economy* 6:213-229.
- Turner, N., and H. Clifton. 2009. "It's so different today": Climate change and indigenous lifeways in British Columbia, Canada. *Global Environmental Change* 19:180-190.
- Turner, N., M. Ignace, and R. Ignace. 2000. Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications* 10:1275-1287.
- Turner, N., and P. Spalding. 2013. "We might go back to this"; drawing on the past to meet the future in northwestern North American Indigenous communities. *Ecology and Society* 18:29.
- Turner, N., and K. Turner. 2007. Traditional food systems, erosion and renewal in Northwestern North America. *Indian Journal of Traditional Knowledge* 6:57-68.
- Uychiaoco, A., H. Arceo, S. Green, M. De La Cruz, P. Gaite, and P. Alino. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. *Biodiversity and Conservation* 14:2775-2794.
- Vasconcelos, L., M. J. Ramos Pereira, U. Caser, G. Gonçalves, F. Silva, and R. Sá. 2011. MARGov – Setting the ground for the governance of marine protected areas. *Ocean & Coastal Management* 72:46-53.
- Walker, S. H., C. Strang, and S. Cook. 2005. The centers for ocean sciences education excellence (COSEE): a national success story. In *OCEANS. Proceedings of MTS/IEEE* 2399-2406pp.
- Walters, C., R. Hilborn, and R. Parrish. 2007. An equilibrium model for predicting the efficacy of marine protected areas in coastal environments. *Canadian Journal of Fisheries and Aquatic Science* 64:1009-1018.
- Walters, C., D. Pauly, and et al. 1999. ECOSPACE: prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas. *Ecosystems* 2:539-554.
- Watts, M. E. I. R. Ball, R. S. Stewart, C. J. Klein, K. Wilson, C. Steinback, R. Lourival, L. Kircher, and H. P. Possingham. 2009. Marxan with Zones: software for optimal conservation based land-and sea-use zoning. *Environmental Modelling & Software* 24:1513-1521.
- WCA. 2012. West Coast Aquatic Governance. West Coast Aquatic, January 31, 2012. Available on-line <http://westcoastaquatic.ca/wp-content/uploads/2012/03/WCA-Governance-2012.pdf> (Accessed Aug. 2014).
- Weeks, R., G. Russ, A. Bucol, and A. Alcala. 2010a. Incorporating local tenure in the systematic design of marine protected area networks. *Conservation Letters* 3:445-453.
- Weeks, R., G. R. Russ, A. C. Alcala, and A. T. White. 2010b. Effectiveness of marine protected areas in the Philippines for biodiversity conservation. *Conservation Biology* 24:531-540.

REFERENCES

- White, A., P. Aline, and A. Meneses. 2006. Creating and managing marine protected areas in the Philippines. Fisheries Improved for Sustainable Harvest, Coastal Conservation and Education Foundation and the University of the Philippines Marine Science Institute. Cebu City, Philippines. 83pp.
- White, J., A. Scholz, A. Rassweiler, C. Steinback, L. Botsford, S. Kruse, C. Costello, S. Mitarai, D. Siegal, P. Drake, and C. Edwards. 2013. A comparison of approaches used for economic analysis in marine protected area network planning in California. *Ocean & Coastal Management* 74:77-89.
- White, J. W., L. W. Botsford, A. Hastings, and J. L. Largier. 2010a. Population persistence in marine reserve networks: incorporating spatial heterogeneities in larval dispersal. *Marine Ecology Progress Series* 398:49-67.
- White, J. W., L. W. Botsford, E. A. Moffitt, and D. T. Fischer. 2010b. Decision analysis for designing marine protected areas for multiple species with uncertain fishery status. *Ecological Applications* 20:1523-1541.
- Wild, R., and C. Mcleod. 2008. Sacred natural sites: Guidelines for protected area managers. IUCN, Gland, Switzerland.
- Yaffee, S., and J. Wondolleck. 2003. Collaborative ecosystem planning processes in the United States: Evolution and challenges. *Environments: A Journal of Interdisciplinary Studies* 31:55-72.
- Zerner, C. 1994. Transforming customary law and coastal management practices in the Maluku Islands, Indonesia, 1870-1992 In D. Western and R. M. Wright (Editors), *Natural connections: perspectives in community-based conservation*. Island Press, Washington, D.C. 80-112.
- Zetterberg, P., and E. Carter. 2010. Strait of Georgia Sport Fishery Creel Survey Statistics for Salmon and Groundfish, 2008. Fisheries and Oceans Canada, Science Branch, Pacific Region, Stock Assessment Division.

APPENDICES

APPENDIX A

Ecological principles and guidelines for designing MPA networks

APPENDIX B

Assessment of MPA policy document using ecological design guidelines

APPENDIX C

Adult movement and depth information for select B.C. fish and invertebrate species

APPENDIX D

Larval characteristics for select B.C. fish and invertebrate species

APPENDIX E

Guiding principles and practices/strategies for governance of MPAs and MPA networks

APPENDIX F

Assessment of marine planning policy documents using governance principles and guidelines

APPENDIX G

Examples of social goals that complement, supplement or present trade-offs with desired ecological outcomes of MPAs

APPENDIX A: ECOLOGICAL PRINCIPLES AND GUIDELINES FOR DESIGNING MPA NETWORKS

- MPA network guidelines are organized by five overarching conceptual design principles.
- General Guidelines are broadly acknowledged and have sufficient support in both the academic literature and referenced science-based MPA network guideline reports (brief descriptions of each of the five selected reports are provided below the table).
- The Specific Targets and Strategies are drawn from the five science-based synthetic reports to provide examples of ways to achieve the broader general guidelines and illustrate a range of options available for achieving ecological objectives.

GENERAL GUIDELINES	RATIONALE	SPECIFIC TARGET OR STRATEGY
REPRESENTATION		
Protect the full range of biological diversity and the associated oceanographic environment.		
The MPA network includes adequate representation of each habitat type found within each bioregion. (OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)	Different marine habitats contain different marine species and communities. Protecting diverse habitats confers protection of the species within them and also those that move among different habitats over their lifetime.	20-30% of broad-scale habitat types is represented within the network. (IUCN-WCPA 2008)
		At least 30% of the area of each habitat type (within a bioregion) should be placed in no-take reserves. (Jessen et al. 2011)
		If biodiversity conservation is the main objective, a minimum of 35% of each habitat should be within no-take areas. If fisheries benefits are the main objective, 20-35% of each habitat type should be within no-take areas. If building climate change resilience is the primary objective, a minimum of 30% of each habitat type should be within no-take areas. To achieve objectives that integrate fisheries, biodiversity, and climate change, 30% of each habitat type should be protected in no-take areas. (Fernandes et al. 2012)
		A variety of depths within, and transition zones between, broad-scale habitat types are included in the network. (IUCN-WCPA 2008)
UNIQUE, IMPORTANT AND VULNERABLE AREAS		
Protect areas and features that are biologically/ecologically unique, vulnerable or of high functional importance		
Ensure areas or features that are unique (1 per bioregion) or rare (few per bioregion) within the bioregion are captured within the network. (OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Fernandes et al. 2012)	Areas and features that are unique or rare are valuable because they are not replaceable, and their loss would be permanent, leading to a significant reduction in marine biological diversity.	All unique sites and most rare sites must be protected. Unique or rare areas may include habitat types, geological features, oceanographic processes, habitat forming organisms, or populations (genetic pools). (Jessen et al. 2011)

GENERAL GUIDELINES	RATIONALE	SPECIFIC TARGET OR STRATEGY
<p>Protect areas of special importance to certain life history stages.</p> <p>(OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Fernandes et al. 2012)</p>	<p>Many species utilize regular areas for foraging and/or reproduction. Inclusion of these areas offers a degree of protection to sites that species depend on to complete their life cycle.</p>	<p>Most areas of ‘critical habitat’ or ‘special biological function’ including breeding grounds, spawning and nursery areas, juvenile habitat and stopover sites along migratory routes should be protected.</p> <p>(IUCN-WCPA 2008; Jessen et al. 2011; Fernandes et al. 2012)</p>
		<p>Protect “source populations” - important sources of reproduction (nurseries, spawning areas, egg sources, etc.). MPAs located at source populations, when identifiable, can help retain recruits and larvae to sustain local populations, as well as serve to export surplus larvae.</p> <p>(IUCN-WCPA 2008; Fernandes et al. 2012)</p>
		<p>Places where critical life stages are concentrated in smaller areas should receive greater than normal protection.</p> <p>(OSPAR 2007)</p>
<p>Protect areas characterized by high biological diversity.</p> <p>(OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>There is a strong relationship between species richness and ecosystem resilience. Also, sites with high biological diversity allow protection of more features with equivalent effort.</p>	<p>Identify and specifically target areas of high biological diversity (high species richness) for inclusion in the MPA network.</p> <p>(IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>
<p>Protect areas characterized by high productivity.</p> <p>(Jessen et al. 2011)</p>	<p>Areas with comparatively high natural biological productivity are important sources of nutrients and play important roles in maintaining populations and fuelling ecosystems.</p>	<p>Identify and specifically target areas of high biological productivity (high nutrient availability, primary productivity and growth rates) for inclusion in the MPA network.</p> <p>(Jessen et al. 2011)</p>
<p>Protect species or habitats that are threatened, vulnerable, or declining.</p> <p>(OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>Species or habitats that are threatened, vulnerable or declining are important to protect because they are not replaceable, and their loss would be permanent leading to a significant reduction in marine biological diversity.</p>	<p>Protect areas that contain significant populations of species that are threatened, vulnerable or declining to ensure the protection, recovery and restoration of such species.</p> <p>(Jessen et al. 2011)</p>
		<p>Protect species of “Special Conservation Concern” - any species or subspecies that is undergoing a long-term decline in abundance or that is vulnerable to a significant decline due to low numbers, restricted distribution, dependence on limited habitat resources, or sensitivity to environmental disturbance.</p> <p>(Brock et al. 2012)</p>
		<p>Identify species and habitat traits that are vulnerable to projected climate change impacts, and if applicable, use MPAs to help species adapt or mitigate impacts.</p> <p>(Brock et al. 2012)</p>

GENERAL GUIDELINES	RATIONALE	SPECIFIC TARGET OR STRATEGY
REPLICATION		
Provide redundancy to safeguard against unexpected (natural or anthropogenic) habitat loss or population collapse.		
Include spatially-separated replicates of representative habitat types or features. (OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)	Replicate MPA sites provide a safeguard against (a) local environmental disaster that can impact populations and habitats in individual MPAs; (b) uncertainty in the identification of features/habitats. They also enable the dispersal/exchange of marine species between adjacent areas and ensure that natural variation in the feature/habitat is represented.	Network should contain at least two, spatially well-separated examples of each habitat type. (OSPAR 2007; Jessen et al. 2011)
		Network should include at least three widely-separated replicates of every habitat within, ideally, no-take areas. (IUCN-WCPA 2008; Fernandes et al. 2012)
		When their natural abundance allows it, the network should contain at least three to five examples of all rare or important life history areas (refer to section above). (Jessen et al. 2011)
SIZE, SHAPE AND CONNECTIVITY		
Maintain the integrity and viability of protected features and processes by ensuring MPA sites are adequate in size/shape and are ecologically connected within the network.		
Individual MPAs within the network are large enough to provide adequate protection for the feature or ecological process they are meant to protect. (OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)	Individual species have very different movement patterns and spatial distributions over their life cycle. The choice of any MPA size determines the subset of species that will potentially benefit.	To ensure self-seeding of a reserve it should be as large as the mean larval dispersal distance of the target species. An average MPA size of 10-20 km (in the smallest dimension) is recommended to meet biodiversity objectives. (IUCN-WCPA 2008; Jessen et al. 2011; Fernandes et al. 2012)
		If targeting species that are highly mobile, MPAs should be a recommended minimum diameter of 30 km – 60 km. (Jessen et al. 2011)
		A mixture of small (min 0.4 km ²) and large (4 - 20 km across) no-take areas is required to achieve biodiversity, climate change, and fisheries objectives. (Fernandes et al. 2012)
		Consider how species movement patterns may shift as a result of climate change (e.g. changing temperature, shifting distribution, shifting migrations) and adjust MPA boundaries accordingly. (Brock et al. 2012)
		Create marine protected areas that are as large as possible. (IUCN-WCPA 2008; Jessen et al. 2011; Fernandes et al. 2012)

GENERAL GUIDELINES	RATIONALE	SPECIFIC TARGET OR STRATEGY
<p>Individual MPAs within the network have an optimal shape.</p> <p>(OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>The shapes of individual MPAs influence the ratio of edge to volume (affects the degree of species retention vs. spillover) and the ease of compliance (navigation around boundaries).</p>	<p>MPA boundaries are regularly shaped and demarcated with clear landmark or coordinates. (IUCN-WCPA 2008; Fernandes et al. 2012)</p>
		<p>The ratio of edge habitat to core interior habitat should be considered when designing individual MPAs. Rectangular and triangular MPAs will offer a large edge per unit volume, which enhances spillover. Squares and circles have less edge per unit volume and maximize internal integrity. Circles however may be harder to enforce. (IUCN-WCPA 2008; Fernandes et al. 2012)</p>
		<p>The shape of the MPA should capture the gradient from onshore-offshore or habitat-habitat shifts of species of interest. (IUCN-WCPA 2008)</p>
		<p>Individual MPA shapes should minimize the amount of edge. (Jessen et al. 2011)</p>
		<p>If a site is at the small end of the expected viability range for given feature, then compact sites are preferable. If a given site is at the large end of the estimated viability range, then a less compact shape would allow for greater spill-over and benefits outside of the reserve. (OSPAR 2007)</p>
<p>Individual MPAs are adequately spaced to ensure functionally connectivity (have ecological linkages) between individual MPAs within the larger network.</p> <p>(OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>Individual sites will benefit from one another if they are linked by a flow of dispersing or migrating organisms (eggs, larvae, juveniles or adults). Enhanced linkages will contribute to a more functional and resilient MPA network.</p>	<p>All MPAs (including stepping stones) should generally be within 20 to 200 km from the nearest MPA in the network. The appropriate distance between MPAs in a network should depend on the scale of dispersal of the species of concern. (Jessen et al. 2011)</p>
		<p>The spacing between individual MPA sites should range from 10-20 km up to 50-100 km (depending on the habitat type and region). (IUCN-WCPA 2008)</p>
		<p>When specific data is lacking, nearshore MPA sites should be spaced not further than 50 km apart to maintain connectivity of most short to moderate larval dispersing species. (OSPAR 2007)</p>
		<p>Apply a variety of spacing of individual no-take areas (from 1 to 20 km apart) throughout the entire management area. Inshore areas should be located closer together (more towards ≥ 1 km apart) than the more offshore areas (more toward ~ 20 km apart). (Fernandes et al. 2012)</p>
		<p>Consider how larval dispersal may shift as a result of climate change (e.g. changing temperature and current patterns) and adjust MPA boundaries accordingly. (Brock et al. 2012)</p>

GENERAL GUIDELINES	RATIONALE	SPECIFIC TARGET OR STRATEGY
MITIGATING HUMAN IMPACTS <i>Increase ecological resilience of desirable ecosystem states in the face of human-induced change and stressors.</i>		
<p>Sufficient area within the network is encompassed in no-take “marine reserves” - self-sustaining, viable areas that are free from extractive and habitat-altering activities that may be stressful to marine habitats and/or organisms.</p> <p>(OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>Fully protected marine reserves have been shown to provide the greatest level of ecological protection and benefits, especially for overexploited species.</p>	<p>Represent a minimum of 20% (recommended 30%) of each habitat type within no-take areas.</p> <p>(IUCN-WCPA 2008; Fernandes et al. 2012)</p>
		<p>At least 30% of each habitat type should be within no-take reserves. Also, At least 30% of each bioregion should be within no-take reserves.</p> <p>(Jessen et al. 2011)</p>
		<p>The MPA network has been specifically designed so 30% or more of the study area is free from extractive activities or habitat-altering activities, or other significant human-induced stresses.</p> <p>(OSPAR 2007)</p>
		<p>If the only protection offered is no-take areas, then the proportion of no-take areas needs to be higher (40% of each habitat).</p> <p>(Fernandes et al. 2012)</p>
		<p>Include an additional 15% in shorter-term no-take protection within the network. For example, seasonal, rotational or other temporally variable zones.</p> <p>(Fernandes et al. 2012)</p>
<p>Areas with reduced/minimal human impact are targeted for protection.</p> <p>(OSPAR 2007; Jessen et al. 2011; Fernandes et al. 2012)</p>	<p>Areas with a higher degree of “naturalness” can act as reference sites to assess habitat recovery and decline.</p>	<p>No details given</p>
<p>Areas and features that exhibit characteristics associated with ecological resistance/resilience to climate change are targeted for protection.</p> <p>(IUCN-WCPA 2008; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>Habitats that exhibit characteristics of resistance and resilience to climate change may be able to resist or adapt to long-term changes.</p>	<p>Areas to target include: physical features that reduce temperature stress (e.g. cold water upwellings, areas adjacent to deep waters), physical features that enhance water movement and flush toxins (e.g. permanent strong currents, areas of high tidal exchange or wave energy), physical areas that decrease radiation stress, areas with historically variable sea surface temperature and carbonate chemistry, among others.</p> <p>(IUCN-WCPA 2008; Brock et al. 2012; Fernandes et al. 2012)</p>
		<p>The network is designed to protect the best carbon sink sites (e.g. mangroves, salt marshes, seagrasses, kelp) and ensure enough of them are protected.</p> <p>(Jessen et al. 2011; Brock et al. 2012)</p>

GENERAL GUIDELINES	RATIONALE	SPECIFIC TARGET OR STRATEGY
<p>Ensure long-term protection.</p> <p>(IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>Long-term protection allows the entire range of species and habitats to recover and maintain natural ecosystem health. Longer time frames are necessary to observe associated biodiversity and fishery benefits.</p>	<p>No-take areas, prohibitions on destructive fishing gear, other fishing gear and access limits should be in place for the long-term, preferably permanently.</p> <p>(IUCN-WCPA 2008; Fernandes et al. 2012)</p>
		<p>The MPA network has a well-developed and periodically audited program of long-term funding in order to meet core costs, emerging issues and provide adaptive management.</p> <p>(OSPAR 2007; IUCN-WCPA 2008; Jessen et al. 2011)</p>
<p>Sustainable use of marine resources is promoted beyond the boundaries of the MPA network.</p> <p>(IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>Because MPAs are intimately connected to surrounding areas, the ability of MPAs to achieve conservation outcomes and benefits depends upon the management, planning and use in adjacent marine areas.</p>	<p>MPAs are used in conjunction with other management tools, such as integrated coastal management, marine spatial planning and broad area fisheries management.</p> <p>(IUCN-WCPA 2008; Jessen et al. 2011; Fernandes et al. 2012)</p>

SOURCES OF ECOLOGICAL GUIDELINES FOR BUILDING MPA NETWORKS

IUCN-WCPA (2008)

This document represents a synthesis of the expertise, knowledge and views of leading experts in marine protected area (MPA) network design and implementation. It was developed through a series of international meetings and workshops starting in 2003 through to 2005. In 2008, the MPA group of the Global Marine Initiative of The Nature Conservancy took responsibility to merge all of various contributions into this document.

Central Guidelines:

1. Include the full range of biodiversity present in the biogeographic region
2. Ensure ecologically significant areas are incorporated
3. Maintain long-term protection
4. Ensure ecological linkages
5. Ensure maximum contribution of individual MPAs to the network

JESSEN ET AL. (2011)

A group of leading marine and conservation scientists from all over Canada were assembled to discuss and compile best practice guidelines for creating a national network of MPAs. Report includes ecological guidelines, social, cultural and economic considerations for MPA sites, as well as MPA governance.

Central Ecological Guidelines:

1. Characterize all areas of the seascape according to key ecological criteria to allow the identification of ecologically or biologically significant areas
2. Create no take reserves
3. Provide adequate representation of habitat types and sites with unique, rare and species character
4. Ensure connectivity among MPAs
5. Create large MPAs
6. Ensure multiple representation of protected habitat types and features
7. Plan MPAs with consideration of climate change

OSPAR (2007)

This document summarizes the scientific background and literature for assessing the ecological coherence and design criteria for MPA networks in the North East Atlantic. The OSPAR Commission represents 15 Contracting Parties and the European Commission representing the European Union. It also provides criteria guidelines for assessing ecological coherence and an assessment checklist to rate ecological coherence of a network at different scales.

Central Guidelines:

1. Representation
2. Replication
3. Size of site
4. Adequacy
5. Connectivity
6. Management

FERNANDES ET AL. (2012)

The purpose of this report is to deliver useful, clear biophysical design principles that can be used to create MPA networks that achieve fisheries, biodiversity and climate change objectives in tropical ecosystems. The principles developed are designed to contribute to a larger process that includes implementing networks of marine protected areas in tropical ecosystems in ways that complement human uses and values and align with local legal, political and institutional requirement.

1. Prohibit destructive activities throughout the management area
2. Represent 20-40% of each habitat within marine reserves
3. Replicate protection of habitats within marine reserves
4. Ensure marine reserves include critical habitats
5. Ensure MPAs are in place for the long-term (20-40 years), preferably permanently
6. Create a multiple use marine protected area that is as large as possible
7. Apply minimum and variable sizes to MPAs
8. Separate marine reserves by 1 to 20 km
9. Include an additional 15% of key habitats in shorter-term marine reserves
10. Locate MPA boundaries both within habitats and at habitat edges
11. Have MPAs in more square or circular shapes
12. Minimize and avoid local threats
13. Include resilient sites in marine reserves
14. Include special or unique sites in marine reserves
15. Locate more protection upstream

BROCK ET AL. (2012)

This document presents a set of guidelines for designing MPA networks which aim to consider expected climate change impacts on marine ecosystems. It was prepared by a joint study group of the Commission for Environmental Cooperation (CEC), the North American Marine Protected Area Network (NAMPAN) Technical Group, and the International Council for the Exploration of the Sea (ICES).

Central Guidelines:

1. Protect species and habitats with crucial ecosystem roles, or those of species conservation concern
2. Protect potential carbon sinks
3. Protect ecological linkages and connectivity pathways for a wide range of species
4. Protect the full range of biodiversity present in the target biogeographic area

REFERENCES

- Brock, R., E. Kenchington, and A. Martinez-Arroyo. 2012. Scientific guidelines for designing resilient marine protected area networks in a changing climate. Commission for Environmental Cooperation. Montreal, Canada. 95pp.
- Fernandes, L., A. Green, J. Tanzer, A. White, P. Alino, J. Jompa, P. Lokani, A. Soemodinoto, M. Knight, B. Pomeroy, H. P. Possingham, and B. Pressey. 2012. Biophysical principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity and climate change objectives in the Coral Triangle. The Nature Conservancy. Jakarta, Indonesia. 152pp.
- IUCN-WCPA. 2008. Establishing marine protected area networks - making it happen. IUCN World Commission on Protected Areas, National Oceanic and Atmospheric Administration and The Nature Conservancy. Washington, DC. 118pp.
- Jessen, S., K. Chan, I. Côté, P. Dearden, E. De Santo, M. Fortin, F. Guichard, W. Haider, G. Jamieson, D. Kramer, A. McCrea-Strub, M. Mulrennan, W. Montevecchi, J. Roff, A. Saloman, J. Gardner, L. Honka, R. Menafrá, and A. Woodley. 2011. Science-based guidelines for MPAs and MPA networks in Canada. Canadian Parks and Wilderness Society. Vancouver, B.C. 58pp.
- OSPAR. 2007. Background document to support the assessment of whether the OSPAR Network of Marine Protected Areas is ecologically coherent. 978-1-905859-59-7. 54pp.

APPENDIX B: ASSESSMENT OF MPA POLICY DOCUMENT USING ECOLOGICAL DESIGN GUIDELINES

The purpose of Canada-BC Marine Protected Area Network Strategy (Canada and British Columbia 2014) is to outline a vision and goals for the MPA network design, and the design process, in British Columbia. The document is a high-level strategic framework to guide MPA establishment and thus design remains focused on broad visions and general design principles.

This strategy document provides a vision and goals to achieve socio-cultural, governance and ecological outcomes. In the table below, we have reviewed the text from the Canada-BC MPA Network Strategy focusing only on the articulation of ecological “General Guidelines” (Appendix A).

GENERAL GUIDELINES	MENTIONED IN TEXT AND DEFINED	SPECIFIC TARGET OR STRATEGY
REPRESENTATION <i>Protect the full range of biological diversity and the associated oceanographic environment.</i>		
<p>The MPA network includes adequate representation of each habitat type found within each bioregion.</p>	<p>MPA Vision: “An ecologically comprehensive, resilient and representative network of marine protected areas...” (p. 9)</p> <p>MPA Goal #1 “To protect and maintain marine biodiversity, ecological representation, and special natural features.” This goal is noted to be of “primary importance.” (p. 9)</p> <p>Goal #1: “Represent each habitat type in the overall MPA network.” (p. 10)</p> <p>“Ecological representation (or representativity) means protecting relatively intact, naturally functioning examples of the full range of ecosystems and habitat diversity found within a given planning area. Establishing a network of MPAs that captures examples of all habitat types will ensure that the finer-scale elements of biodiversity and physical characteristics are also protected.” (p.10)</p> <p>Ecological Network Design Principles: “Represent each habitat type in the overall MPA network. For example, rocky reef habitat, eelgrass meadow, intertidal mudflat, persistent gyres or eddies, or representation within a hierarchy of ecological scales (e.g., representation of rocky reefs within a broader biogeographic classification).” (p. 14)</p>	<p>“The degree of replication [of representative habitats] should be assessed at a bioregional (or finer) scale(s) in an effort to safeguard against catastrophic events or disturbances and to build resilience in the overall MPA network.” (p. 14)</p> <p>Planning Bioregional MPA Networks: “An inventory of existing marine areas with some level of protection will be taken to determine whether they meet MPA network eligibility criteria, and to assess the extent to which they already cover representative habitats and ecosystems. The different habitat types found in a bioregion can be identified and delineated using existing habitat classification schemes based on best available physical and biological information.” (p. 26)</p> <p>“Those involved in the planning process may also wish to define conservation targets that specify how much of each habitat, feature, function or value requires protection to achieve goals, relevant design principles and bioregional objectives.” (p. 26)</p> <p>“Every new MPA should be designated on the basis that it is representative of one or more habitats or ecosystems, or ecologically and biologically significant areas or features and in a manner consistent with the Canada-BC MPA Network Strategy planning principles.” (p. 27)</p> <p>Reviewer Notes:</p> <ul style="list-style-type: none"> - What is considered “adequate representation” is not stated in the document (e.g. no representativity targets or ranges given), although it is suggested that those involved in planning may wish to do so. - bioregional scale is mentioned - good. - No mention of the importance of transition zones between representative habitats

GENERAL GUIDELINES	MENTIONED IN TEXT AND DEFINED	SPECIFIC TARGET OR STRATEGY
UNIQUE, IMPORTANT AND VULNERABLE AREAS <i>Protect areas and features that are biologically/ecologically unique, vulnerable or of high functional importance</i>		
Ensure areas or features that are unique (1 per bioregion) or rare (few per bioregion) within the bioregion are captured within the network.	<p>MPA Goal #1: "To protect and maintain marine biodiversity, ecological representation, and <u>special natural features</u>." This is noted to be of primary importance. (p. 9)</p> <p>"<u>Special natural features</u> are elements of the environment that are <u>rare, outstanding or unique</u>. These areas may include stopover sites for migrating species, seabird colonies and their surrounding waters, areas with <u>rare and unique</u> capabilities for maintaining early-life stages of important fish and shellfish species, habitats for marine species at risk and habitats of high biodiversity such as estuaries or upwellings." (p. 10)</p>	<p>Ecological Network Design Principle #2: Ensure biologically significant areas are incorporated.</p> <p>a) Protection of Unique or Vulnerable Habitats: Design networks to include biophysically special and unique places. (p. 14)</p> <p>Reviewer Notes:</p> <p>Details on how these areas will be identified or considered for inclusion in the network is not given. E.g. unique or rare by what standards?</p>
Protect areas of special importance to certain life history stages.	<p>MPA network Ecological benefits: "protecting habitats <u>critical to lifecycle stages such as spawning, juvenile rearing and feeding</u>." (p. 3)</p> <p>MPA Goal #1: "To protect and maintain marine biodiversity, ecological representation, and <u>special natural features</u>." This is noted to be of primary importance. (p. 9)</p> <p>"<u>Special natural features</u> ...include areas with <u>rare and unique capabilities for maintaining early-life stages of important fish and shellfish species....</u>" (p. 10)</p>	<p>Ecological Network Design Principle #2: Ensure biologically significant areas are incorporated:</p> <p>a) <u>Protection of Foraging or Breeding Grounds: Design networks to include important areas for breeding, feeding and high aggregation.</u> (p. 14)</p> <p>b) <u>Protection of Source Populations: Design networks to include important sources of reproduction (e.g. nurseries, spawning areas, egg sources, etc.)</u> (p. 14)</p>
Protect species or habitats that are threatened, vulnerable, or declining	<p>"<u>MPAs give refuge to vulnerable species</u>, thus helping to maintain species presence, age, size distribution and abundance." (p.10)</p> <p>"<u>Special natural features</u> ...<u>include habitats for marine species at risk...</u>" (p. 10)</p> <p>Ecological Network Design Principle #2: Ensure biologically significant areas are incorporated.</p> <p>a) Protection of Unique or <u>Vulnerable Habitats</u>: Design networks to include biophysically special and unique places. (p. 14)</p>	<p>Reviewer Notes:</p> <p>- "Vulnerable Habitats" is not well defined (i.e. habitats that contain species that are in decline? Habitats that are sensitive to disturbance? Habitats that are vulnerable to climate change?).</p> <p>- Vulnerable by whose standards?</p>

GENERAL GUIDELINES	MENTIONED IN TEXT AND DEFINED	SPECIFIC TARGET OR STRATEGY
Protect areas characterized by high biological diversity..	<p>MPA Goal #1: "To protect and maintain <u>marine biodiversity</u>, ecological representation, and <u>special natural features</u>." This is noted to be of primary importance. (p. 9)</p> <p>"In addition to other resource management tools, <u>MPAs can contribute to the maintenance of biodiversity</u> and the protection of ecological processes and food web relationships. They can provide additional protection to endangered or threatened species, preventing species loss, and <u>they can contribute to the protection of the diversity of marine habitats</u> (i.e., representative ecosystems) and special natural features." (p. 10)</p> <p>"<u>Special natural features</u> ...include <u>habitats of high biodiversity</u> such as estuaries or upwellings." (p. 10)</p>	<p>MPA Goal #1: "To protect and maintain marine biodiversity, ecological representation, and <u>special natural features</u>." This is noted to be of primary importance. (p. 9)</p> <p>"Special natural features ...include <u>habitats of high biodiversity</u> such as estuaries or upwellings." (p. 10)</p> <p>Reviewer Notes:</p> <p>- areas of high biological diversity are listed as an example of "Special natural features", but are not mentioned otherwise as specific targets for protection such as important life history areas.</p>
Protect areas characterized by high productivity.	<p>"<u>Special natural features</u> ...include habitats of high biodiversity such as estuaries or upwellings." (p. 10)</p>	<p>Reviewer Notes:</p> <p>- no specific mention of interest in areas of high productivity, however, mention of upwelling areas, which is an example of an area characterized by both high productivity, and in many cases high biodiversity.</p>
REPLICATION <i>Provide redundancy to safeguard against unexpected (natural or anthropogenic) habitat loss or population collapse.</i>		
Include spatially-separated replicates of representative habitat types or features.	<p>Ecological Network Design Principle #1: Representation and Replication (p. 14)</p>	<p>"Ecological Network Design Principle #1: The degree of replication should be assessed at a bioregional (or finer) scale(s) in an effort to safeguard against catastrophic events or disturbances and to build resilience in the overall MPA network." (p.14)</p> <p>Ecological Network Design Principle #3: "Ensure ecological linkages: to the extent possible, consider dispersal dynamics, the home range(s) of marine organisms, and distribution of marine habitats, over space and time, <u>especially when assessing replicates</u> and when determining the spacing of individual MPA sites within the network."</p> <p>Reviewer Notes:</p> <p>- scale is mentioned (bioregional or finer), but not a minimum level of replicates mentioned (i.e. 2 or 3 or more?)</p>

GENERAL GUIDELINES	MENTIONED IN TEXT AND DEFINED	SPECIFIC TARGET OR STRATEGY
SIZE, SHAPE AND CONNECTIVITY <i>Maintain the integrity and viability of protected features and processes by ensuring MPA sites are adequate in size/shape and are ecologically connected within the network.</i>		
Individual MPAs within the network are large enough to provide adequate protection for the feature or ecological process they are meant to protect.	<p>"MPAs will serve a range of functions, and will appear in a <u>wide array of sizes</u>, shapes, designs, and protection standards." (p. 7)</p> <p>Ecological Network Design Principle #5: "Ensure maximum contribution of individual MPAs - <u>Size</u>, Spacing, Shape." (p. 15)</p>	<p>Ecological Network Design Principle #5: "Size - Design individual MPAs to include sufficient area to meet the related site objectives and effectively contribute to network goals and bioregional objectives over the long term." (p. 15)</p> <p>Reviewer Notes:</p> <ul style="list-style-type: none"> - recommended size guidelines not provided - no suggestion that some MPAs stretching over a gradient of near-shore to offshore should be included in the network
Individual MPAs within the network have an optimal shape.	<p>"MPAs will serve a range of functions, and will appear in a wide array of sizes, <u>shapes</u>, designs, and protection standards." (p. 7)</p> <p>Ecological Network Design Principle #5: "Ensure maximum contribution of individual MPAs. Size, Spacing, <u>Shape</u>." (p. 15)</p> <p>IUCN definition description: "<i>Clearly Defined</i>: implies a spatially defined area with agreed and demarcated borders. These borders can sometimes be defined by physical features that move over time (e.g. river banks) or by management actions (e.g. agreed no-take zones).</p>	<p>Ecological Network Design Principle #5: "Shape - Design the shape of individual MPAs to the degree possible to follow ecological boundaries, avoid fragmenting cohesive habitats, and facilitate surveillance and enforcement." (p.15)</p> <p>Reviewer Notes:</p> <ul style="list-style-type: none"> - recommended shapes, or mention of whether edge effects should be minimized or maximized not included.
Individual MPAs are adequately spaced to ensure functionally connectivity (have ecological linkages) between individual MPAs within the larger network.	<p>Ecological Network Design Principle #3: "Ensure ecological linkages. Connectivity..." (p. 14)</p> <p>Ecological Network Design Principle #5: "Ensure maximum contribution of individual MPAs. Size, <u>Spacing</u>, Shape." (p. 15)</p>	<p>Ecological Network Design Principle #3: "Ensure ecological linkages – to the extent possible, consider dispersal dynamics, the home range(s) of marine organisms, and distribution of marine habitats, over space and time, especially when assessing replicates and when determining the spacing of individual MPA sites within the network." (p. 14)</p> <p>Ecological Network Design Principle #5: "Spacing - Design MPA networks to reflect the spacing of habitats, cover the geographic range of habitats, and facilitate ecological connectivity between sites. Spacing should be assessed at multiple scales (i.e. bioregionally and coast wide) to best facilitate connectivity." (p. 15)</p> <p>Reviewer Notes:</p> <ul style="list-style-type: none"> - recommendations for minimum spacing distances not included.

GENERAL GUIDELINES	MENTIONED IN TEXT AND DEFINED	SPECIFIC TARGET OR STRATEGY
MITIGATING HUMAN IMPACTS <i>Increase ecological resilience of desirable ecosystem states in the face of human-induced change and stressors.</i>		
<p>Sufficient area within the network is encompassed in no-take “marine reserves” - self-sustaining, viable areas that are free from extractive and habitat-altering activities that may be stressful to marine habitats and/or organisms.</p>	<p>Marine protected area network definition: “A collection of individual marine protected areas that operates cooperatively and synergistically, at various spatial scales, and with a <u>range of protection levels</u>, in order to fulfill ecological aims more effectively and comprehensively than individual sites could alone.” (p. 7)</p> <p>The availability of various designation options provides additional opportunity <u>to customize the level of protection to achieve goals and objectives for an area</u> while minimizing impact on human activities. (p. 17)</p> <p>Social, Economic, and Cultural Network Design Principle #15: “Include a full range of protection levels ...MPA networks <u>will include a full range of protection standards</u> that meet criteria described in the IUCN’s protected area <u>categories I through IV</u>. This may require the introduction of management measures that could range from <u>permanent limitations on specific human activities or restrictions adapted to seasons or species lifecycles</u>, to promoting/ facilitating specific human uses.” (p. 19)</p>	<p>Reviewer Notes:</p> <p>- The terms “marine reserves” or “no-take zones” are not explicitly referred to in the strategy report, but having sites that meet IUCN criteria for category 1 imply these areas would be equivalent.</p>
<p>Areas with reduced/minimal human impact are targeted for protection.</p>	<p>No details given</p>	<p>No details given</p>
<p>Areas and features that exhibit characteristics associated with ecological resistance/ resilience to climate change are targeted for protection.</p>	<p>Appendix 1: Marine Ecosystem Stressors in the North East Pacific: “Marine ecosystems of Pacific Canada face several challenges including habitat alteration, resource use pressure, land and sea-based pollutants, invasive species and <u>larger scale impacts related to global climate change</u>.” (p. 28)</p> <p>Appendix 1: “<u>Climate Change and Ocean Acidification</u>: In the Strait of Georgia, sea surface temperatures have been increasing at a rate of 1°C over 90 years, based on lighthouse records gathered throughout southern British Columbia. Ocean warming in the Pacific Region may be a stressor for aquatic ecosystems through changes including altered oxygen concentrations, oceanographic conditions and primary productivity. Species assemblage changes may occur at multiple trophic levels and cold water species may have reduced survival or overall condition as well as changes to habitat range or depth strata that provide optimal conditions for survival.” (p. 28)</p>	<p>General operating principles #13: “Apply Adaptive Management - Including adaptive strategies (i.e. learning by doing) in MPA network planning processes allows for adjustments in management approach and/or alterations to protected area boundaries <u>as science evolves and the dynamics of the marine environment change</u>. In addition, flexibility and adaptability will be required to effectively and efficiently consider the interests of marine resource users now and into the future. (p. 19)</p> <p>Reviewer Notes:</p> <p>- Climate change mentioned in Appendix 1, but no reference to how MPA networks contribute to mitigating climate change impacts, or considerations of how MPA networks could be designed to mitigate climate change impacts.</p> <p>- Adaptive management is mentioned as a strategy to deal with “environmental change,” which is good, but overall, mention of adaptation to climate change specifically is absent.</p>

GENERAL GUIDELINES	MENTIONED IN TEXT AND DEFINED	SPECIFIC TARGET OR STRATEGY
Ensure long-term protection.	<p>The strategy adopts the IUCN definition of an MPA, which includes “to achieve the <i>long term</i> conservation of nature with associated ecosystem services...” (p. 7)</p> <p>To be considered for inclusion in the network, BC MPAs will have to meet each of the terms described in the IUCN MPA definition, including “long-term.” (p. 7)</p> <p>Appendix - IUCN definition description: “<i>Dedicated</i> – implies specific binding commitment to conservation in the <i>long term</i>...” (p. 32)</p> <p>Ecological Network Design Principle #4: “<i>Maintain long-term protection</i>.” (p. 14)</p> <p>Appendix - IUCN definition description: “<i>Long term</i>: protected areas should be managed in perpetuity and not as short term or a temporary management strategy.” (p. 32)</p>	<p>Ecological Network Design Principle #4: “<u>Maintain long-term protection</u> – The benefits of MPA networks may be realized in a few seasons, or it may take several decades. <u>Therefore, management measures should be implemented on a permanent basis to better realize the benefits of protection.</u>” (p. 14)</p>
<p>Sustainable use of marine resources is promoted beyond the boundaries of the MPA network.</p> <p>(IUCN-WCPA 2008; Jessen et al. 2011; Brock et al. 2012; Fernandes et al. 2012)</p>	<p>General operating principles #12: “<u>Foster ecosystem based management</u>” (p. 19)</p> <p>General operating principles #14: “Build on existing MPAs, <u>other management tools</u>, and marine planning initiatives.” (p. 19)</p>	<p>General operating principles #12: “<u>Foster ecosystem based management - MPA network planning will take into account the broader movement towards EBM of marine areas</u>. EBM is an adaptive approach to managing human activities in a manner that ensures the coexistence of healthy, fully functioning ecosystems and human communities. The intent of EBM has been described as “to maintain those spatial and temporal characteristics of ecosystems such that component species and ecological processes can be sustained and human well-being supported and improved” (p. 19)</p> <p>General operating principles #14: “Build on existing MPAs, other management tools, and marine planning initiatives - Marine protected areas will be established and operated in the context of broader <u>marine management that includes a range of conservation tools / management techniques applied in adjacent marine and terrestrial areas (e.g. fisheries closures, shipping regulations, etc.)</u>” (p. 19)</p>

REFERENCES

Canada and British Columbia. 2014. Canada-British Columbia Marine Protected Area Network Strategy. No. Fs23-585/2012E. Available online http://www.for.gov.bc.ca/tasb/SLRP/pdf/ENG_BC_MPA_LOWRES.pdf (Accessed Aug. 2014)..

APPENDIX C: ADULT MOVEMENT AND DEPTH INFORMATION FOR SELECT B.C. FISH AND INVERTEBRATE SPECIES

Table of fish and invertebrate home range, depth range, general movement and critical habitat. The “Grouping” category aggregates species with similar characteristics. Home range is defined as the typical area (here we use distance travelled) that an individual animal uses on a regular basis for its routine activities (Moffitt et al. 2009). Home range is given as a min-to-max range, a maximum distance (up to –), or a reported average distance (in parentheses). Movement category (0 km, <0.05 km, <1 km, 1-10 km, 10-50 km, 50-1000 km, >1000 km, or unknown) was assigned to each species based on the home range, or was inferred from the notes column. Depth range gives the depths within which the species are reported to be most commonly encountered (species may readily occur at shallower depths). Max depth is the reported maximum depth where a species has been observed. Method refers to the type of study used to report home range, T=tagging study. Geographic area is the region in which the relevant studies were conducted or where the information is cited to come from, (BC) British Columbia, (PNW) Pacific Northwest, (PS) Puget Sound, (SOG) Strait of Georgia. Habitat category shows whether the species generally occurs on sandy (S) or rocky bottom (R) habitat or is predominantly pelagic (P). Critical habitat lists features and habitats reported as important for particular life history stages. “U” in any category indicates data for that value is unknown or was not encountered.

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
FISH SPECIES												
DEMERSAL SPECIES	<i>Hippoglossus stenolepis</i>	Pacific halibut c,r,⌘	Up to 1420 (200)	50-1000	Onshore-offshore spawning migrations, seasonal summer site fidelity (<50m displacement).	50-650	650	T	BC, Gulf of Alaska	S	Slope (spawning).	(IPHC 1987; Loher and Seitz 2006; Loher and Blood 2009)
	<i>Anoplopoma fimbria</i>	sablefish c,r,⌘	Up to 2000 (<200)	50-1000	Resident behaviour common (<50km).	200-700	1500	T	BC	P	Slope (spawning).	(Beamish and McFarlane 1988)
	<i>Ophiodon elongatus</i>	lingcod c,r,⌘	3.3-498 (28.3)	10-50	The majority of individuals have movement less than 50km (typically less than 30km). Several studies document a small percentage (7-9%) of tagged individuals that migrate long distances (50-500km). Individuals move to nearshore rocky reef habitats for spawning.	10-100	400	T	BC	R	Rocky reef, eelgrass and kelp beds.	(Mathews and LaRiviere 1987; Jagielo 1990, 1995; Martell et al. 2000; Starr et al. 2004)
	<i>Scorpaenichthys marmoratus</i>	cabezon r,⌘		<0.05	Residential and non-migratory (small movement category inferred).	0-20	75		PS	R	Rock and cobble, shallow intertidal.	(Love 1996; Lamb and Hanby 2005; McCain et al. 2005)
	<i>Hexagrammos decagrammus</i>	kelp greenling r,⌘	0.1-0.5	<1	Kelp greenlings have small home ranges on scales of several hundred square meters.	<13	45	T	California	R	Kelp beds and rocky reefs.	(Moulton 1977; Lea et al. 1999; Freiwald 2009)
	<i>Oxylebius pictus</i>	painted greenling r	Up to 0.02	<0.05	Movement generally within 2m.	0-20	50	T	PS, California	R	High relief rocks.	(DeMartini and Anderson 1980)
	<i>Hemilepidotus hemilepidotus</i>	red Irish lord r		<0.05	Residential and non-migratory (small movement category inferred).	0-20	50		California	R		(Eschmeyer et al. 1983)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
DEMERSAL SPECIES	<i>Merluccius productus</i>	Pacific hake c,r		1000+	Highly migratory species on outer coast (large movement category inferred). However, genetic studies suggest populations and behaviour are different in the SOG and PS.	50-200	1000		SOG, PS	P	Inland bays, near fresh-water influence.	(Eschmeyer et al. 1983)
	<i>Atheresthes stomias</i>	arrowtooth flounder c,⌘		50-1000	Migrate from shallow water feeding grounds to continental slope for spawning (large movement category inferred).	50-500	500		SOG, PS	S	Euryhaline waters, sand or sand-gravel.	(NOAA 1990; McCain et al. 2005)
	<i>Gadus macrocephalus</i>	Pacific cod c,r,⌘	>1000	1000+	Highly mobile species.	50-300	900	T	SOG, PS	SP	Soft-bottom, continental shelf/slope.	(NOAA 1990; Lamb and Hanby 2005; McCain et al. 2005; Shi et al. 2007)
	<i>Theragra chalcogramma</i>	walleye pollock c,r,⌘	>500	1000+	Highly mobile species.	100-300	970	T and genetics	Gulf of Alaska, Bering Sea (Japan)	SRP	Mud, sand and rock bottoms.	(Walline 1982; Kooka 2012) (Takahashi and Yamaguchi 1972; Mulligan et al. 1992; Lamb and Hanby 2005)
	<i>Microstomus pacificus</i>	dover sole c,r,⌘	37-360 (<93)	50-1000	Inshore (summer) - offshore (winter) movement.	50-1000	1000	T	Oregon	P	Shallow bays (feeding), shelf (larvae settle).	(Barss and Demory 1988; Love 1996; McCain et al. 2005)
	<i>Parophrys vetulus</i>	English sole c,r,⌘	Up to 1126	1000+	Maximum migration rate 4mi/day. Tag recovery distances reported up to 700miles (1126km).	30-120	550	T	PNW	S	Estuaries and eelgrass.	(Toole et al. 1987; Lassuy 1989; Lamb and Hanby 2005; McCain et al. 2005)
	<i>Anarrhichthys ocellatus</i>	wolf eel ⌘		<0.05	When in mating pairs, individuals reside in single den with restricted movement (very limited movement category inferred). However, they will travel long distances in search of mate.	0-20	225		PNW	R	Rocky sub tidal zone.	(Eschmeyer et al. 1983; Love 1996)
ROCKFISH	<i>Sebastes maliger</i>	quillback rockfish c,r,~,⌘	0-2.8 (<0.05)	<1	Home range most commonly reported as 'limited' (<30m2). Larger home ranges observed in low relief habitat (4000m2).	14-143	2000	T	SOG, PS	R	Rocky reefs, high relief, eelgrass and kelp for juvenile rearing (cloud sponges).	(Love et al. 2002; Yamanaka et al. 2006; Tolimieri et al. 2009)
	<i>Sebastes caurinus</i>	copper rockfish c,r,⌘	0-0.3	<1	Home range most commonly reported as 'limited' (<30m2). Larger home ranges observed in low relief habitat (4000m2).	0-20	183	T	BC, PS, California	R	Rocky reefs, high relief, eelgrass and macrophytes for juvenile rearing.	(Matthews 1990; Love et al. 2002; Tolimieri et al. 2009)
	<i>Sebastes nebulosus</i>	china rockfish c,r,⌘	Up to 0.01	<0.05	Tagging studies showed minimal movement and high site fidelity.	18-92	128	T	California	R	Rocky reefs, high relief, kelp beds for juvenile rearing.	(Lea et al. 1999; Love et al. 2002; McCain et al. 2005)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
ROCKFISH	<i>Sebastes nigrocinctus</i>	tiger rockfish c,r,⌘	0.02-0.03	<0.05	High site fidelity.	21-140	298	T	PNW	R	Rocky reefs, high relief.	(Love et al. 2002; Hannah and Rankin 2011)
	<i>Sebastes mystinus</i>	blue rockfish c,⌘	1.3-43 (<0.1)	<1	Tagged individuals most commonly have very restricted movements, however some have been observed to move longer distances.	25-90	550	T	PNW, California	R	Kelp forests and rocky and artificial reefs (adults), nearshore kelp (juveniles).	(Love et al. 2002; McCain et al. 2005; Jorgensen et al. 2006)
	<i>Sebastes melanops</i>	black rockfish c,r,⌘	0-619 (0.5)	<1	Tagged individuals mostly have very restricted movements (<500m) for long periods, but are documented to relocate long distances periodically.	0-55	366	T	Oregon	SR	Continental slope/shelf and kelp forests (adults & juveniles) and seagrass (juvenile rearing).	(Mathews and Barker 1983; Love et al. 2002; Parker et al. 2007; Green and Starr 2011)
	<i>Sebastes flavidus</i>	yellowtail rockfish c,⌘	140-1400	50-1000	Most show considerable movement.	90-180	549	T	PS, Oregon, California	P	Kelp (juvenile rearing).	(Mathews and Barker 1983; Lea et al. 1999; Love et al. 2002; McCain et al. 2005)
	<i>Sebastes ruberrimus</i>	yelloweye rockfish c,r,~,⌘		<0.05	Sedentary and likely to have limited movement. (Small movement category inferred).	50-200	2000		Oregon	R	Rocky reefs and boulder fields.	(Love et al. 2002; Yamanaka et al. 2006; Hannah and Rankin 2011)
	<i>Sebastes paucispinis</i>	bocaccio c,~,⌘	>12	10-50	Most tagged individuals observed to move outside of a 12km2 study area (estimated 10-50km movement category).	50-250	475	T	California	RP	Eelgrass and sand (juvenile rearing).	(Love et al. 2002; Starr et al. 2002; McCain et al. 2005)
	<i>Sebastes elongatus</i>	greenstriped rockfish c		<1	Species reported as sedentary (small movement category inferred).	100-250	828		BC, California	SR	Shallow and soft bottom (juvenile recruitment).	(Richards 1986; Love et al. 2002; McCain et al. 2005)
	<i>Sebastes proriger</i>	redstripe rockfish c,r		<0.05	Reported as 'very sedentary' (minimal movement category inferred).	150-275	425		PNW	SR	Interface between sand and rock, low relief rocky area.	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes entomelas</i>	widow rockfish c,r		<1	High site fidelity reported (small movement category inferred).	100-350	800		California	P	High relief substrata.	(Love et al. 2002; McCain et al. 2005; Hanan and Curry 2012)
	<i>Sebastes brevispinis</i>	silvergray rockfish c,⌘		U	No reported information on movement.	100-300	580		BC, Gulf of Alaska	RP	Rocky bottom and open coastal regions, near bottom.	(Love et al. 2002; Stanley and Kronlund 2005)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
ROCKFISH	<i>Sebastes pinniger</i>	canary rockfish c,r,~,⌘	Up to 700	50-1000	Capable of major movement.	50-250	425	T	BC, Oregon	R	Complex bottoms of rock and boulder.	(Matarese et al. 1989; Lea et al. 1999; Love et al. 2002; McCain et al. 2005; Hannah and Rankin 2011)
	<i>Sebastes alutus</i>	Pacific ocean perch c		U	Very little movement data available. Studies report discrete populations within 30km (suggests movement may be limited).	55-350	825		PNW	R	Gullies, canyons, pinnacles and seamounts of continental shelf.	(Gunderson 1997; Love et al. 2002; McCain et al. 2005)
	<i>Sebastes aleutianus</i>	rougeye rockfish ~		<1	Limited movement data available, studies report little adult movement (small movement category inferred).	150-450	2830		PNW	R	Steep slopes (>20 degrees) (offshore).	(Gunderson 1997; Love et al. 2002; Gharett et al. 2007)
	<i>Sebastes crameri</i>	darkblotched rockfish c,~		<1	Adults highly sedentary (small movement category inferred).	50-200	904		PNW	R	Mud near cobble/boulders on bottom.	(Love et al. 2002; COSEWIC 2009b)
	<i>Sebastes reedi</i>	yellowmouth rockfish c,~		U	No reported information on movement.	130-400	430		BC	RP	Aggregate in mid-water over rocky continental shelf.	(Love et al. 2002; McCain et al. 2005; Haigh and Starr 2008; COSEWIC 2010)
	<i>Sebastolobus alascanus</i>	shortspine thornyhead c		1-10	Species undergo ontogenetic migrations. Information on adult movement is limited. Reported as 'sit and wait' predators that remain motionless for extensive periods (moderate movement category inferred).	100-850	1524		Oregon	S	Mud bottoms near sponges, some rock.	(Jacobson and Vetter 1996) (Love et al. 2002)
	<i>Sebastes babcocki</i>	redbanded rockfish c		U	No encountered information on adult movement.	150-400	625		BC	S	Soft bottoms, demersal.	(Love et al. 2002; McCain et al. 2005)
SHARKS & SKATES	<i>Squalus acanthias</i>	spiny dogfish c,r,~,⌘	250-7,000	1000+	Inshore-offshore movement. Highly mobile.	<350	1244	T	BC	SP	Muddy bottoms or water column.	(McCain et al. 2005; Beamish and Sweeting 2009; McFarlane and King 2009)
	<i>Hydrolagus coliei</i>	spotted ratfish ⌘	>90 (20)	50-1000	Ratfish make significant seasonal and diel migrations. One tagged group remained in one general location with few excursions, whereas a second tag group moved within a 20km radius. Some individuals reported to move >90 km.	50-400	971	T	PS	SR	Mud or rocky bottom, found in bays in north.	(Allen and Smith 1988; McCain et al. 2005; Andrews and Quinn 2012)
	<i>Raja rhina</i>	longnose skate c,r		U	No encountered information on adult movement.	100-350	1069		PNW	S	Soft-bottom habitats, mud/sand and clay, continental shelf.	(Allen and Smith 1988; McCain et al. 2005; DFO 2012)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
SHARKS & SKATES	<i>Raja binoculata</i>	big skate c,r	Up to 2340 (21)	50-1000	75% of tagged individuals recaptured within 21km. Long distance movement mostly mature females.	22-137	800	T	BC	S	Soft-bottom habitats, mud/sand and clay.	(McCain et al. 2005; King and McFarlane 2010; DFO 2012)
	<i>Lamna ditropis</i>	salmon shark r	7-3271 (787)	1000+	Data for female movement only.	2-60	371	T	Prince William Sound Alaska	P	Near shore and oceanic environment.	(Hulbert et al. 2006; Goldman and Musick 2008)
	<i>Hexanchus griseus</i>	bluntnose sixgill shark ~	Up to 1500 (5-10)	1000+	Observed residential behaviour (movement within ~10km) as well as long distance (1000+km) ontogenetic shifts to coastal waters.	>100	1600	T	PS	P	Continental and insular shelves.	(Andrews et al. 2010; DFO 2011a)
	<i>Cetorhinus maximus</i>	basking shark ~	120-6480 (1904)	1000+	Highly mobile species.	200-1000	2000	T	E. coast North America	P	Areas of zooplankton concentrations, continental shelf.	(COSEWIC 2009a; Skomal et al. 2009)
PELAGIC FINFISH	<i>Clupea pallasii</i>	Pacific herring c,¶		50-1000	Adult movement from nearshore spawning sites to offshore feeding grounds (large movements of 100km+, large movement category inferred).	100-150	1000		BC, Gulf of Alaska	P	Spawning on eelgrass and macroalgae in sheltered bays and estuaries.	(Hourston and Haegele 1980; Carlson 1984)
	<i>Sardinops sagax</i>	Pacific sardine c		1000+	Large-scale migrations (large movement category inferred).	<100	500		PNW	P		(Agostini 2005)
	<i>Thunnus alalunga</i>	albacore tuna c,r	>1000	1000+	Highly mobile species.	0-250 (<20)	1125	T	trans-Pacific	P		(Sund et al. 1981; Childers et al. 2011)
	<i>Cymatogaster aggregata</i>	shiner perch c,r		U	Move from shallow habitats in summer to deeper water in winter.	<20	146		BC, California	S/R	Shallow, eelgrass beds and rocky reefs, brackish & freshwater, wharf pilings.	(Lane et al. 2002; Lamb and Edgell 2010)
	<i>Rhacochilus vacca</i>	pile perch c,r		U	Move from shallow habitats in summer to deeper water in winter.	<20	74		BC, California	S/R	Shallow, eelgrass beds and rocky reefs, brackish & freshwater, wharf pilings.	(Lane et al. 2002; Lamb and Edgell 2010)
	<i>Embiotoca lateralis</i>	striped perch c,r		<1	Specific movement information not available. Reported primarily in localized eelgrass beds and wharf pilings (inferred limited movement category).	0-8	24		BC, California	S/R	Shallow, eelgrass beds and rocky reefs, brackish & freshwater, wharf pilings.	(Lane et al. 2002; Lamb and Edgell 2010)
	<i>Brachyistius frenatus</i>	kelp perch c,r		<1	Specific movement information not available, but reported as 'restricted to kelp beds' (inferred limited movement category).	0-7	7		BC, California	S/R	Shallow, eelgrass and kelp beds, brackish & freshwater, wharf pilings.	(Lane et al. 2002; Lamb and Edgell 2010)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (¶) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
PELAGIC FINFISH	<i>Hypomesus pretiosus</i>	surf smelt c, r		U	Adults are suggested to remain within near-shore habitats, but no information on movement patterns is reported.	0-20	U		PNW	S	Brackish, benthopelagic, sandy beaches (spawning).	(Therriault et al. 2002b)
	<i>Ammodytes hexapterus</i>	Pacific sand lance r		U	Schooling behaviour in near-shore pelagic waters. No specific information on movement range.	6-50	100		Gulf of Alaska	S	Near-shore, sandy-gravel substrates.	(Robards et al. 1999)
	<i>Engraulis mordax</i>	Northern anchovy c	595	50-1000	Large-scale movements.	6 to 20	313	T	California	P	Continental shelf.	(Haugen et al. 1969; Laroche and Richardson 1980; Therriault et al. 2002a)
ANADROMOUS FINFISH	<i>Oncorhynchus keta</i>	chum c,r,~,⌘		1000+	Long distance spawning migrations.	20-50	40	T	PNW/ Gulf of Alaska	p	Estuary (juvenile rearing).	(Groot and Margolis 1991)
	<i>Oncorhynchus gorbuscha</i>	pink c,r,⌘		1000+	Long distance spawning migrations.	0-20	37	T	PNW/ Gulf of Alaska	p	Estuary (juvenile rearing).	(Groot and Margolis 1991)
	<i>Oncorhynchus nerka</i>	sockeye c,r,~,⌘		1000+	Long distance spawning migrations.	20-50	60	T	PNW/ Gulf of Alaska	p	Coastal migration routes.	(Groot and Margolis 1991)
	<i>Oncorhynchus tshawytscha</i>	Chinook c,r,~, ⌘		1000+	Long distance spawning migrations.	20-50	110	T	PNW/ Gulf of Alaska	p	Coastal migration routes.	(Groot and Margolis 1991)
	<i>Oncorhynchus kisutch</i>	coho c,r,⌘		1000+	Long distance spawning migrations.	0-50	90	T	PNW/ Gulf of Alaska	p	Coastal migration routes.	(Groot and Margolis 1991)
	<i>Oncorhynchus mykiss</i>	steelhead c,r,⌘		1000+	Long distance spawning migrations.	0-20	23	T	PNW/ Gulf of Alaska	p	Coastal migration routes.	(Light et al. 1989; Melnychuk et al. 2007; Nielsen et al. 2011)
	<i>Thaleichthys pacificus</i>	eulachon c,r,~,⌘		50-1000	Migration between offshore feeding grounds and freshwater spawning areas. (Large movement category inferred).	0-100	420		BC	p	Estuaries and shallow bays (spawning).	(Levesque and Therriault 2011)
	<i>Acipenser medirostris</i>	green sturgeon ~	221-968	50-1000	Migratory species.	40-70	100	T	Oregon/ BC	p	Bays and estuaries (feeding).	(Moyle et al. 1995; Erickson and Hightower 2007)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
INVERTEBRATE SPECIES												
	<i>Strongylocentrotus droebachiensis</i>	green sea urchin c,⌘		<0.05	Urchin barren fronts reported to move up to 6.9cm/day. Little to no movement in winter, greater movement in summer (small movement category inferred).	<10	130	TIME LAPSE VIDEO	PNW, New Brunswick	R	Ledges and crevices.	(Strathmann 1987; Lauzon-Guay and Scheibling 2007)
	<i>Strongylocentrotus franciscanus</i>	red sea urchin c,⌘		<1	Movement rate reported between 7.5 - 50cm/day (limited movement category inferred).	<10	125	T	California	R	Ledges and crevices.	(Mattison et al. 1976; Kato and Schroeter 1985; Strathmann 1987)
	<i>Strongylocentrotus purpuratus</i>	purple sea urchin c,⌘	Up to 0.1	<1	Reported movement from 10 to 100m in lifetime. Sub-tidal populations may undertake modest foraging and spawning migrations.	<10	160		PNW	R	Rounded burrows or depressions with moderate wave action.	(Strathmann 1987; Ebert et al. 1994; Workmann 1999)
	<i>Parastichopus californicus</i>	sea cucumber c,⌘		<1	Movement rate reported as 3.9m/day (limited movement category inferred).	5 to 15	250	T	PNW	R	Exposed coast to sheltered inlets.	(Da Silva et al. 1986; Cameron and Fankboner 1989; DFO 1999)
	<i>Enteroctopus dofleini</i>	giant Pacific octopus c,⌘	Up to 2	1-10	Generally move within a relatively small area (13.2m), with periods of larger-scale movement.	0-100	1500	T	BC	R	Under rocks and in crevices.	(Cosgrove and McDaniel 2009)
	<i>Cancer magister</i>	Dungeness crab c,r,⌘	0.65-10.2	1-10	Female movement reported between 0.6-2 km, male movement between 1-10.2 km.	0-89	230	T	California	S	Mud, eelgrass and sand.	(Collier 1983; Stone and O'Clair 2001)
	<i>Cancer productus</i>	red rock crab c,r,⌘	Up to 3.1	1-10	Mostly localized movements. Movement rarely exceeding a few km of tag release sites.	2 to 15	91	T	PNW	R	Bays, kelp beds and estuaries.	(Robles et al. 1989)
	<i>Lithodes aequispina</i>	golden king crab c,r	Up to 17.5 (11.5)	10-50		200-400	569	T	Alaska	R	Deep fjords.	(Sloan 1985; Hoyt et al. 2002)
	<i>Paralithodes camtschaticus</i>	red king crab c,r	Up to 426	50-1000	Movement over long distances, from 3-13km/day and up to 426km/year.	10-300	366	T	Alaska	R		(Simpson and Shippen 1968; ICES 2005)
	<i>Chionoecetes tanneri</i>	grooved tanner crab c,r		10-50	Movement of deep water Tanner crabs is not well understood. Movement is thought to be random in nature although some documentation of breeding migrations. Based on information from similar species, movement estimated to be <75km over adult lifespan.	458-1784	3000		Alaska, BC	S	Soft bottom of mud or sand	(Colgate 1982; Hart 1982; Phillips and Lauzier 1997; Krause et al. 2001)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
	<i>Chionoecetes bairdi</i>	inshore Tanner crab c,r	4.5 -75km	10-50	Tagging studies in Alaska show range averaging between 24-75km. However, tagging in Rivers Inlet, BC showed movement to be relatively localized (maximum 4.5km).	6-474	474	T	Alaska, BC	S	Soft bottom of mud or sand	(Hart 1982; Krause et al. 2001; Fong and Dunham 2007), Colgate 1982)
	<i>Haliotis kamtschatkana</i>	abalone ~,⌘	Up to 0.125	<1	Often immobile if habitat conditions suitable. Maximal movements from different studies report 20m, 50m, and 125m.	5 to 15	35	T	BC	R	Habitats with crustose algae, exposed rock surfaces, cryptic rock surfaces.	(Sloan and Breen 1988; Grantham et al. 2003)
	<i>Tegula funebris</i>	black turban snail ⌘	Up to 0.003	<0.05	Tagged individuals moved between tide pools 3m apart (small movement category inferred).	(+) 1 to (-) 1		T	Washington	R	Tide pools.	(Byers and Mitton 1981)
	<i>Pandalus platyceros</i>	spot prawns c,r,⌘	Up to 1.7	1-10	Following maturation and migration from shallow nursery habitats, deeper residing adults remain in a restricted area (limited to the size of the habitat patch they inhabit). Diel migrations reported in more protected waters.	100-220	485	T, DIVE	Atlantic Canada, PNW	S/R	Hard bottom, rock crevices, muddy bottoms, intertidal. Nursery stages in kelp beds.	(Marliave and Roth 1995; Boutillier and Bond 1999; Lowry 2007)
	<i>Pandalus spp.</i>	shrimp spp. c,r,⌘		U	Vertical and horizontal migrations observed for multiple species of <i>Pandalus</i> ranging from local (<16km) to greater distances.	>50	2000			S	Hard bottom, rock crevices, muddy bottoms, intertidal. Strong to medium tidal currents.	(Butler and Boutillier 1983)
	<i>Euphausia pacifica</i>	krill c		1000+	Highly mobile species.	>20	2000		PNW	P	Oceanic often near surface.	(Nicol and Endo 1997)
	<i>Cryptochiton stelleri</i>	giant Pacific chiton ⌘	0.002-0.022	<0.05	Highly limited movement.	0-60	60	T	Oregon	R		(Lord 2011)
	<i>Katharina tunicata</i>	black kate chiton ⌘	0.001-0.002	<0.05	Highly limited movement.	(+) 0.5 to (-) 1	40	T AND DIVE	Alaska	R	Associated with alga <i>Hedophyllum sessile</i> .	(Plett and Konar 2001; Burnaford 2004)
	<i>Chlamys rubida</i>	pink scallop c,⌘		<0.05	"Swimming" response to predators.	0-200	200		BC	R	Rocky reefs.	(DFO 2011b)
	<i>Chlamys hastata</i>	spiny scallop c,⌘		<0.05	"Swimming" response to predators.	0-150	150		BC	R	Rocky reefs.	(DFO 2011b)
	<i>Crassadoma gigantea</i>	rock scallop ⌘	n/a	n/a	Highly limited movement.	0-80	80		BC	R		(Jamieson and Francis 1986; Williams 1989)
	<i>Tresus spp.</i>	horse clam c,⌘	n/a	n/a	Highly limited movement.	0-20	20		BC	S		(Williams 1989)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

GROUPING	SPECIES NAME	COMMON NAME	HOME RANGE (MEAN) [km]	MOVEMENT CATEGORY [KM]	NOTES	DEPTH RANGE [m]	MAX DEPTH [m]	METHOD	GEOGRAPHIC AREA	HABITAT CATEGORY	CRITICAL HABITAT	SOURCES
	<i>Panope abrupta</i>	geoduck c,⌘	n/a	n/a	Highly limited movement.	9 to 18	120		BC	S		(Williams 1989)
	<i>Venerupis philippinarum</i>	Japanese littleneck clam c,r,⌘	n/a	n/a	Highly limited movement.	0-1	1		BC	S	Intertidal	(Gillespie et al. 2012)
	<i>Protothaca staminea</i>	Pacific little-neck clams c,r,⌘	n/a	n/a	Highly limited movement.	0-5	5		BC	S	Intertidal	(Lamb and Hanby 2005)
	<i>Saxidomus gigantea</i>	butter clam r,⌘	n/a	n/a	Highly limited movement.	0-15	15		BC	S	Intertidal	(Williams 1989)
	<i>Pollicipes polymerus</i>	gooseneck barnacle ⌘	n/a	n/a	Sessile.	(+) 2 to 5	5		BC	R	Intertidal	(Jamieson et al. 2001)
	<i>Mytilus edulis</i>	blue mussels ⌘	n/a	n/a	Sessile.	1.5 to 3.7	45		BC	R	Intertidal	(Williams 1989)
	<i>Crassostrea gigas</i>	Pacific oyster c,⌘	n/a	n/a	Sessile.	2 to 4	4		BC	S	Intertidal	(Williams 1989)
	<i>Clinocardium nuttallii</i>	Nuttall's cockle ⌘	n/a	n/a	Highly limited movement.	0-30	30		BC	S	Intertidal	(Williams 1989)
	<i>Mytilus californianus</i>	California mussels r,⌘	n/a	n/a	Sessile.	(+) 2 to 5	5		BC	R	Intertidal	(Jamieson et al. 2001)

(c) commercially fished species, (r) recreationally fished species, (~) species at risk, (⌘) harvested (past or present) by First Nations for FSC

REFERENCES

- Agostini, V. 2005. Climate, ecology and productivity of Pacific sardine (*Sardinops sagax*) and hake (*Merluccius productus*). PhD Thesis. University of Washington. Washington, Seattle. 188pp.
- Allen, M., and G. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA. 151pp.
- Andrews, K., and T. Quinn. 2012. Combining fishing and acoustic monitoring data to evaluate the distribution and movements of spotted ratfish *Hydrolagus coliei*. Marine Biology 159:769-782.
- Andrews, K., G. Williams, and P. Levin. 2010. Seasonal and ontogenetic changes in movement patterns of sixgill sharks. PLoS one 5:12549.
- Barss, W., and R. Demory. 1988. Results of dover sole tagging projects conducted by the state of Oregon, 1948-75. Fish Division, Oregon Department of Fish and Wildlife. Oregon. 22pp.
- Beamish, R., and G. McFarlane. 1988. Resident and dispersal behavior of adult sablefish (*Anoplopoma fimbria*) in the slope waters off Canada's west coast. Canadian Journal of Fisheries and Aquatic Sciences 45:152-164.

- Beamish, R., and R. Sweeting. 2009. Spiny dogfish in the pelagic waters of the Strait of Georgia and Puget Sound. In V. Galucci, G. McFarlane, and G. Bargman (Editors), *Biology and Management of Dogfish Sharks*. American Fisheries Society, Bethesda, Maryland. 101-118.
- Boutillier, J., and J. Bond. 1999. A progress report on the control of growth and recruitment overfishing in the shrimp trap fishery in British Columbia. Northwest Atlantic Fisheries Organization. Dartmouth, NS.
- Burnaford, J. 2004. Habitat modification and refuge from sublethal stress drive a marine plant–herbivore association. *Ecology* 85:2837-2849.
- Butler, T., and J. Boutillier. 1983. Selected shrimps of British Columbia. *Underwater World*. Fisheries Oceans Canada. Ottawa, Canada. 6pp.
- Byers, B., and J. Mitton. 1981. Habitat choice in the intertidal snail *Tegula funebris*. *Marine Biology* 65:149-154.
- Cameron, J., and P. Fankboner. 1989. Reproductive biology of the commercial sea cucumber *Parastichopus californicus* (Stimpson) (Echinodermata : Holothuroidea). II. Observations on the ecology of development, recruitment, and the juvenile life stage. *Journal of Experimental Biology and Ecology* 127:43-61.
- Carlson, H. 1984. Seasonal distribution and environment of adult Pacific Herring (*Clupea harengus pallasi*) near Auke Bay, Lynn Canal, Southeastern Alaska. PhD Thesis. Oregon State University, Oregon. . Oregon.
- Childers, J., S. Snyder, and S. Kohn. 2011. Migration and behavior of juvenile North Pacific albacore (*Thunnus alalunga*). *Fisheries Oceanography* 2:157-173.
- Colgate, W. 1982. A review of the Gulf of Alaska tanner crab, *Chionoecetes bairdi*, fishery and management related research In *Proceedings of the International Symposium on the Genus Chionoecetes*. Alaska Seagrant Report. 41-70pp.
- Collier, P. 1983. Chapter 9: Movement and growth of post-larval dungeness crabs, *Cancer Magister*, in the San Francisco area. State of California, Resources Agency, Dept. of Fish and Game. Sacramento, California.
- COSEWIC. 2009a. COSEWIC assessment and status report on the Basking Shark *Cetorhinus maximus*, Atlantic population, in Canada. Ottawa, Canada. 56pp.
- COSEWIC. 2009b. COSEWIC assessment and status report on the Darkblotched Rockfish *Sebastes crameri* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Canada. 48pp.
- COSEWIC. 2010. COSEWIC assessment and status report on the Yellowmouth Rockfish *Sebastes reedi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 57pp.
- Cosgrove, J., and N. McDaniel. 2009. Super suckers: the giant Pacific octopus and other cephalopods of the Pacific Coast. Harbour Publishing, Madeira Park, BC.
- Da Silva, J., J. Cameron, and P. Fankboner. 1986. Movement and orientation patterns in the commercial sea cucumber *Parastichopus californicus* (Stimpson) (Holothuroidea: Aspidochirota). *Marine Behaviour and Physiology* 12:133-147.
- DeMartini, E., and M. Anderson. 1980. Comparative survivorship and life history of painted greenling (*Oxylebius pictus*) in Puget Sound, Washington and Monterey Bay, California. *Environmental Biology of Fishes* 5:33-47.
- DFO. 1999. Giant red sea cucumber. Stock Status Report C6-10. Department of Fisheries and Oceans. Available online <http://www.dfo-mpo.gc.ca/csas/csas/status/1999/c6-10e.pdf> (Accessed Aug. 2014).
- DFO. 2011a. Sharks of British Columbia. Identification guide. Fisheries and Oceans Canada. Ottawa, ON. Available online <http://www.pac.dfo-mpo.gc.ca/publications/pdfs/sharksBC-requinsCB-eng.pdf> (Accessed Sept. 2014).
- DFO. 2011b. Updated framework for the pink and spiny scallop (*Chlamys rubida* and *C. hastata*) dive fishery in British Columbia. Science Advisory Report - 2010/078. Department of Fisheries and Oceans. Available online <http://www.dfo-mpo.gc.ca/Library/343819.pdf> (Accessed Sept 2014).
- DFO. 2012. Skates of British Columbia. Identification guide. Department of Fisheries and Oceans. Ottawa, ON. Available online <http://www.pac.dfo-mpo.gc.ca/publications/pdfs/skates-raies-2012-eng.pdf> (Accessed Sept. 2014).
- Ebert, T., S. Schroeter, J. Dixon, and P. Kalvass. 1994. Settlement patterns of red and purple sea urchins (*Strongylocentrotus franciscanus* and *S. purpuratus*) in California, USA *Marine Ecology Progress Series* 111:41-52.
- Erickson, D., and J. Hightower. 2007. Oceanic distribution and behavior of green sturgeon. *American Fisheries Society Symposium* 56:197-211.
- Eschmeyer, W., E. Herald, and H. Hammon. 1983. A field guide to Pacific Coast fishes of North America. Houghton Mifflin, Boston, Massachusetts.
- Fong, K., and J. Dunham. 2007. Inshore tanner crab (*Chionoecetes bairdi*) biology in a central coast inlet, British Columbia, Canada. *Journal of Shellfish Research* 26:581-595.
- Freiwald, J. 2009. Density-dependent change in home range size of a temperate reef fish, the kelp greenling In *Sanctuary Currents: Back to the Future Preserving the Sanctuary by Exploring its Past*. Monterey Bay National Marine Sanctuary Monterey Bay, California.
- Gharet, A., A. Matala, E. Peterson, A. Gray, Z. Li, and J. Heifetz. 2007. Distribution and population genetic structure of sibling rougheye rockfish species. In J. Heifetz, J. Dilusino, A. Gharet, M. Love, V. O'Connell, and R. Stanley (Editors), *Biology, assessment, and management of North Pacific Rockfishes*. Alaska Sea Grant, University of Alaska, Fairbanks

- Gillespie, G., S. Bower, K. Marcus, and D. Kieser. 2012. Biological synopses for three exotic molluscs, Manila Clam (*Venerupis philippinarum*), Pacific Oyster (*Crassostrea gigas*) and Japanese Scallop (*Mizuhopecten yessoensis*) licensed for aquaculture in British Columbia. Fisheries and Oceans Canada. Nanaimo, BC. 97pp.
- Goldman, K., and J. Musick. 2008. Biology and ecology of the salmon shark, *Lamna ditropis*. In E. Pikitch (Editor), *Sharks of the Open Ocean* Blackwell Scientific, Maldon, MA.
- Grantham, B., G. Eckert, and A. Shan. 2003. Dispersal potential of marine invertebrates in diverse habitats. *Ecological Applications* 13:S108-S116.
- Green, K., and R. Starr. 2011. Movements of small adult black rockfish: implications for the design of MPAs. *Marine Ecology Progress Series* 436:219-230.
- Groot, C., and L. Margolis. 1991. *Pacific Salmon Life Histories*. UBC Press, Vancouver, BC.
- Gunderson, D. 1997. Spatial patterns in the dynamics of slope rockfish stocks and their implications for management. *Fisheries Bulletin* 95:219-230.
- Haigh, R., and P. Starr. 2008. A review of yellowmouth rockfish *Sebastes reedi* along the Pacific coast of Canada: biology, distribution, and abundance trends. Department of Fisheries and Oceans. Ottawa.
- Hanan, D., and B. Curry. 2012. Long-term movement patterns and habitat use of nearshore groundfish: tag-recapture in central and southern California waters. *The Open Fish Science Journal* 5:30-43.
- Hannah, R., and P. Rankin. 2011. Site fidelity and movement of eight species of Pacific rockfish at a high-relief rocky reef on the Oregon Coast. *North American Journal of Fisheries Management* 31:483-494.
- Hart, J. 1982. Crabs and their relatives of British Columbia. British Columbia Provincial Museum, Victoria, BC.
- Haugen, C., J. Messersmith, and R. Wickwire. 1969. Progress report on anchovy tagging off California, March 1966 through May 1966. California Department of Fish and Game. California.
- Hourston, A., and C. Haegele. 1980. Herring on Canada's Pacific coast. Canadian Special Publication of Fisheries and Aquatic Sciences 48:23.
- Hoyt, Z., T. Shirley, J. Warrenchuk, C. O'Clair, and R. Stone. 2002. Observations of movement and habitat utilization by golden king crabs (*Lithodes aequispinus*) in Frederick Sound, Alaska. In A. Paul, E. Dawe, R. Elner, G. Jamieson, G. Kruse, R. Otto, B. Sainte-Marie, T. Shirley, and D. Woodby (Editors), *Crabs in cold water regions: Biology, management, and economics*. Alaska Sea Grant College Program Fairbanks, Alaska. 595-608.
- Hulbert, L., M. Siegler, and C. Lunsford. 2006. Depth and movement behaviour of the Pacific sleeper shark in the north-east Pacific Ocean. *Journal of Fish Biology* 69:406-425.
- ICES. 2005. The intentional introduction of the marine red king crab (*Paralithodes camtschaticus*) into the Southern Barents Sea. 277. 18pp.
- IPHC. 1987. The Pacific halibut: Biology, fishery and management. 22, International Pacific Halibut Commission. Seattle (WA). 59pp.
- Jacobson, L., and R. Vetter. 1996. Bathymetric demography and niche separation of thornyhead rockfish: *Sebastes alascanus* and *Sebastes altivelis*. *Canadian Journal of Fisheries and Aquatic Science* 53:600-609.
- Jagiello, T. 1990. Movement of tagged lingcod *Ophiodon elongatus* at Neah Bay, Washington. *Fisheries Bulletin* 88:815-820.
- Jagiello, T. 1995. Abundance and survival of lingcod at Cape Flattery, Washington. *Transactions of the American Fisheries Society* 124:170-183.
- Jamieson, G., S. Dixon, and R. Lauzier. 2001. Initial evaluation of community structure in goose barnacle (*Pollicipes polymerus*) and sea mussel (*Mytilus californianus*) beds off the west coast of Vancouver Island, British Columbia. Fisheries and Oceans Canada. Nanaimo, BC.
- Jamieson, G., and K. Francis. 1986. Invertebrate and marine plant fishery resources of British Columbia. Canadian Special Publication of Fisheries and Aquatic Sciences 91:89.
- Jorgensen, S., D. Kaplan, A. Klimley, S. Morgan, M. O'Farrell, and L. Botsford. 2006. Limited movement in blue rockfish *Sebastes mystinus*: internal structure of home range. *Marine Ecology Progress Series* 327:157.
- Kato, S., and S. Schroeter. 1985. Biology of the red sea urchin and its fishery in California. NOAA. 20pp.
- King, J., and G. McFarlane. 2010. Movement patterns and growth estimates of big skate (*Raja binoculata*) based on tag-recapture data. *Fisheries Research* 101:50-59.
- Kooka, K. 2012. Life-history traits of walleye pollock, *Theragra chalcogramma*, in the northeastern Japan Sea during early to mid 1990s. *Fisheries Research* 113:35-44.
- Krause, G., G. Workman, and A. Phillips. 2001. A phase "0" review of the biology and fisheries of the Tanner Crab. Fisheries and Oceans Canada. Nanaimo, BC. 79pp.
- Lamb, A., and P. Edgell. 2010. Coastal fishes of the Pacific Northwest, revised and expanded second edition. Harbour Publishing, Madeira Park, BC.
- Lamb, A., and B. Hanby. 2005. Marine life of the Pacific Northwest: a photographic encyclopedia of invertebrates, seaweeds and selected fishes. Harbour Publishing, Madeira Park.
- Lane, E., W. Wuff, A. McDiarmid, D. Hay, and B. Rusch. 2002. A review of the biology and fishery of the Embiotocids of British Columbia. Canadian Science Advisory Secretariat Report., Department of Fisheries and Oceans. Nanaimo, BC.

- Laroche, J., and S. Richardson. 1980. Reproduction of northern anchovy, *Engraulis Mordax*, off Oregon and Washington. Fishery Bulletin 78:603-618.
- Lassuy, D. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): English sole. 82, U.S. Army Corps of Engineers. 17pp.
- Lauzon-Guay, J., and R. Scheibling. 2007. Seasonal variation in movement, aggregation and destructive grazing of the green sea urchin (*Strongylocentrotus droebachiensis*) in relation to wave action and sea temperature. Marine Biology 151:2109-2118.
- Lea, R., R. McAllister, and D. VenTresca. 1999. Biological aspects of nearshore rockfishes of the genus *Sebastes* from central California. California Department of Fish and Game Fish Bulletin.
- Levesque, C., and T. Therriault. 2011. Information in support of a recovery potential assessment of eulachon (*Thaleichthys pacificus*) in Canada. Fisheries and Oceans Canada. Nanaimo, BC. 78pp.
- Light, J., C. Harris, and R. Burgner. 1989. Ocean distribution and migration of steelhead (*Oncorhynchus mykiss*, formerly *Salmo gairdneri*). University of Washington. Seattle, WA. 50pp.
- Loher, T., and C. Blood. 2009. Seasonal dispersion of Pacific halibut (*Hippoglossus stenolepis*) summering off British Columbia and the US Pacific Northwest evaluated via satellite archival tagging. Canadian Journal of Fisheries and Aquatic Sciences. 66:1409-1422.
- Loher, T., and A. Seitz. 2006. Seasonal migration and environmental conditions of Pacific halibut *Hippoglossus stenolepis*, elucidated from pop-up archival transmitting (PAT) tags. Marine Ecology Progress Series 317:259-271.
- Lord, J. 2011. Larval development, metamorphosis and early growth of the gumboot chiton *Cryptochiton stelleri* (middendorff, 1847) (Polyplacophora: Mopaliidae) on the Oregon Coast. Journal of Molluscan Studies 77:182-188.
- Love, M. 1996. Probably more than you want to know about the fishes of the Pacific coast. Really Big Press, Santa Barbara, CA.
- Love, M., M. Yoklavich, and L. Thornsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley, CA.
- Lowry, N. 2007. Biology and fisheries for the spot prawn (*Pandalus platyceros*, Brandt 1851). PhD Thesis. University of Washington, Seattle, WA. Pagespp.
- Marliave, J., and M. Roth. 1995. Agarum kelp beds as nursery habitat of spot prawns, *Pandalus platyceros* Brandt, 1851 (Decapoda: Caridea). Crustaceana 68:27-37.
- Martell, S., C. Walters, and S. Wallace. 2000. The use of marine protected areas for conservation of lingcod (*Ophiodon Elongatus*). Bulletin of Marine Science 66:729-743.
- Matarese, A., A. Kendell, D. J. Blood, and B. Vinter. 1989. Laboratory guide to early life history stages of Northeast Pacific fishes. NOAA.
- Mathews, S., and M. Barker. 1983. Movements of rockfish (*Sebastes*) tagged in northern Puget Sound. Washington. Fisheries Bulletin 81:916-922.
- Mathews, S., and M. LaRiviere. 1987. Movement of tagged lingcod, *Ophiodon elongatus*, in the Pacific Northwest. Fisheries Bulletin 85:153-159.
- Matthews, K. 1990. A telemetric study of the home ranges and homing routes of copper and quillback rockfishes on shallow rocky reefs. Canadian Journal of Zoology 68:2243-2250.
- Mattison, J., J. Trent, A. Shanks, T. Akin, and J. Pearse. 1976. Movement and feeding activity of red sea urchins (*Strongylocentrotus franciscanus*) adjacent to a kelp forest. Marine Biology 39:25-30.
- McCain, B., S. Miller, and W. Wakefield. 2005. Life history, geographical distribution, and habitat associations of 82 West Coast groundfish species: a literature review (Appendix B2). National Marine Fisheries Service. Seattle, WA. 266pp.
- McFarlane, G., and R. Beamish. 1985. Biology and fishery of Pacific whiting, *Merluccius productus*, in the Strait of Georgia. Marine Fisheries Review 47:23-34.
- McFarlane, G., and J. King. 2009. Movement patterns of spiny dogfish within the Strait of Georgia. In V. Galucci, G. McFarlane, and G. Bargman (Editors), Biology and management of dogfish sharks. American Fisheries Society, Bethesda, MD. 77-87.
- Melynychuk, M., D. Welch, C. Walters, and V. Christensen. 2007. Riverine and early ocean migration and mortality patterns of juvenile steelhead trout (*Oncorhynchus mykiss*) from the Cheakamus River, British Columbia. Hydrobiologia 582:55-65.
- Moffitt, E. A., L. W. Botsford, D. M. Kaplan, and M. R. O'Farrell. 2009. Marine reserve networks for species that move within a home range. Ecological Applications 19:1835-1847.
- Moulton, L. 1977. Ecological analysis of fishes inhabiting the rocky nearshore regions of northern Puget Sound. PhD Thesis. University of Washington, Washington. 181pp.
- Moyle, P., R. Yoshiyama, J. Williams, and E. Wikramanayake. 1995. Fish species of special concern of California. second edition. California Department of Fish and Game Sacramento, CA.
- Mulligan, P., W. Chapman, and B. Brown. 1992. Mitochondria1 DNA analysis of walleye pollock, *Theragra chalcogramma*, from the eastern Bering Sea and Shelikof Strait, Gulf of Alaska. Canadian Journal of Fisheries and Aquatic Science 49:319-326.
- Nicol, S., and Y. Endo. 1997. Krill fisheries of the World. FAO Technical Paper 100pp.

- Nielsen, J., S. Turner, and S. Zimmerman. 2011. Electronic tags and genetics explore variation in migrating steelhead kelts (*Oncorhynchus mykiss*), Ninilchik River, Alaska. *Canadian Journal of Fisheries and Aquatic Science* 68:1-16.
- NOAA. 1990. West coast of North America coastal and ocean zones strategic assessment: Data atlas. U.S. Dept. Commer., NOAA. OMA/NOS.
- Parker, S., P. Rankin, J. Olson, and R. Hannah. 2007. Movement patterns of black rockfish (*Sebastes melanops*) in Oregon coastal waters. In J. Heifetz, J. Dilusino, A. Gharett, M. Love, V. O'Connell, and R. Stanley (Editors), *Biology, assessment, and management of North Pacific Rockfishes*. Alaska Sea Grant, University of Alaska, Fairbanks. 39-57.
- Phillips, A., and R. Lauzier. 1997. Biological background for the development of a new fishery for the grooved tanner crab (*Chionoecetes tanneri*) off British Columbia. *Canadian Stock Assessment Secretariat Research Document* 97/148. 79pp.
- Plett, J., and B. Konar. 2001. Movement patterns of the chiton *Katharina tunicata* in Kachemak Bay, Alaska. University of Alaska. Fairbanks.
- Richards, L. 1986. Depth and habitat distributions of three species of rockfish (Sebastes) in British Columbia: observations from the submersible PISCES 1V. *Environmental Biology of Fishes* 17:13-21.
- Robards, M., M. Willson, R. Armstrong, and J. Piatt. 1999. Sand lance: a review of biology and predator relations and annotated bibliography. U.S. Department of Agriculture, Forest Service. Portland Oregon. 327pp.
- Robles, C., D. Sweetnam, and D. Dittman. 1989. Diel variation of intertidal foraging by *Cancer productus* L. in British Columbia. *Journal of Natural History* 23:1041-1049.
- Shi, Y., D. Gunderson, P. Munro, and J. Urban. 2007. Estimating movement rates of Pacific cod (*Gadus macrocephalus*) in the Bering Sea and the Gulf of Alaska using mark-recapture methods. Final report for the North Pacific Research Board #620.
- Simpson, R., and H. Shippen. 1968. Movement and recovery of tagged king crabs in the eastern Bering Sea 1955-63. *Bulletin of the International North Pacific Fisheries Commission* 24:111-123.
- Skomal, G., S. Zeeman, J. Chisholm, E. Summers, H. Walsh, K. McMahon, and S. Thorrold. 2009. Transequatorial migrations by basking sharks in the western Atlantic Ocean. *Current Biology* 19:1019-1022.
- Sloan, N. 1985. Life history characteristics of fjord-dwelling golden king crabs *Lithodes aequispina*. *Marine Ecology Progress Series* 22:219-228.
- Sloan, N., and P. Breen. 1988. Northern abalone, *Haliotis kamtschatkana*, in British Columbia: fisheries and synopsis of life history information. *Canadian Special Publication of Fisheries and Aquatic Sciences* 103:46.
- Stanley, R., and A. Kronlund. 2005. Life history characteristics for silvergray rockfish (*Sebastes brevispinis*) in British Columbia waters and the implications for stock assessment and management. *Fish. Fisheries Bulletin* 103:670-684.
- Starr, R., J. Heine, J. Felton, and G. Cailliet. 2002. Movement of bocaccio (*Sebastes paucispinis*) and greenspotted (*Sebastes chlorostictus*) rockfishes in a Monterey submarine canyon: implications for the design of marine reserves. *Fisheries Bulletin* 100:324-337.
- Starr, R., V. O'Connell, and S. Ralston. 2004. Movements of lingcod (*Ophiodon elongatus*) in southeast Alaska: potential for increased conservation and yield from marine reserves. *Journal of Canadian Fisheries and Aquatic Sciences* 61:1083-1094.
- Stone, R., and C. O'Clair. 2001. Seasonal movements and distribution of Dungeness crabs *Cancer magister* in a glacial southeastern Alaska estuary. *Marine Ecology Progress Series* 214:167-176.
- Strathmann, M. 1987. Reproduction and development of marine invertebrates of the northern Pacific coast. University of Washington Press, Seattle.
- Sund, P., M. Blackburn, and F. Williams. 1981. Tunas and their environment in the Pacific Ocean: a review. *Oceanography and Marine Biology Annual Review* 19:443-512.
- Takahashi, Y., and H. Yamaguchi. 1972. Stock of the Alaska Pollack in the Eastern Bering Sea. *Bulletin of the Japanese Society for the Science of Fish* 38:389-399.
- Therriault, T., A. McDiarmid, W. Wulff, and D. Hay. 2002a. Review of Northern Anchovy (*Engraulis mordax*) biology and fisheries, with suggested management options for British Columbia. Department of Fisheries and Oceans. Nanaimo, BC.
- Therriault, T., A. McDiarmid, W. Wulff, and D. Hay. 2002b. Review of surf smelt *Hypomesus pretiosus* biology and fisheries with suggested management options for BC. Department of Fisheries and Oceans. Nanaimo, BC. 37pp.
- Tolimieri, N., K. Andrews, G. Williams, S. Katz, and P. Levin. 2009. Home range size and patterns of space use by lingcod, copper rockfish and quillback rockfish in relation to diel and tidal cycles. *Marine Ecology Progress Series* 380:229-243.
- Toole, C., R. Barnhard, and C. Onuf. 1987. Habitat suitability index models; juvenile English sole. Biological report 82 (10.133). Fish and Wildlife Service U.S Department of the Interior. Washington, DC.
- Walline, P. 1982. Early life history of walleye pollock in the eastern Bering Sea. Northwest Alaska Fisheries Center (NOAA) 33pp.
- Williams, G. 1989. Coastal/estuarine fish habitat description and assessment manual part 1. Fisheries and Oceans Canada.

- Workmann, G. 1999. A review of the biology and fisheries for purple sea urchin (*Strongylocentrotus purpuratus*, Stimpson, 1857) and discussion of the assessment needs for a proposed fishery. Canadian Stock Assessment Secretariat Research Document 99/163., Fisheries and Oceans Canada. Nanaimo, BC. 58pp.
- Yamanaka, K., L. Lacko, K. Miller-Saunders, C. Grandin, J. Lohead, J. Martin, N. Olsen, and S. Wallace. 2006. A review of quillback rockfish *Sebastes maliger* along the Pacific coast of Canada: biology, distribution and abundance trends Department of Fisheries and Oceans Canada.

APPENDIX D: LARVAL CHARACTERISTICS FOR SELECT B.C. FISH AND INVERTEBRATE SPECIES

Table of larval duration and reproductive characteristics for select fish, invertebrate and algal species in B.C. Larval duration for the three algal species refer to spores dispersal rather than larvae. "Larval release zone" refers to the general spatial region where individuals spawn: intertidal (area between high and low tides), nearshore subtidal (defined as between 0 - 60 m depth), nearshore-to-offshore (spawn across a broad spatial and/or depth range) or offshore (larvae released offshore or at deeper depths > 60m). Larval duration (the time larvae - or spores - spend in the plankton) is given in hours as well as days, months, or years. Species where data was not available or larval duration is unknown are marked with a "U." Spawning mode is recorded as demersal (D), pelagic (P), live birth (LB), broadcast spawner (BS), or other (O). Release season is the months or time of year where larvae are released (or born, or broadcast) and enter the plankton (peak months in parentheses). Geographic area is the region in which the relevant studies were conducted or where the information is cited to come from, BC = British Columbia, PS = Puget Sound, Cali = California, PNW = Pacific Northwest which consists of the range between California and Alaska, and SOG = Strait of Georgia. In the column 'Data gaps,' species were marked as moderate (m) or significant (S) if the available reproductive literature was sparse or sources explicitly stated that little was known about the species' larval stages. "S" or "m" in the data gaps column suggests uncertainty for the given larval duration value.

LARVAL RELEASE ZONE	SPECIES NAME	COMMON NAME	LARVAL DURATION [hrs]	LARVAL DURATION [D,M,Y]	SPAWNING MODE	RELEASE SEASON	GEOGRAPHIC AREA	DATA GAPS	SOURCES
FISH SPECIES									
NEARSHORE SUBTIDAL	<i>Oxylebius pictus</i>	painter greenling r	720-2160	1-3mo	D	Sep-Nov	PNW		(DeMartini and Anderson 1980; Davis et al. 1981)
	<i>Clupea pallasii</i>	Pacific herring c, r, ¶	1440-2160	2-3mo	D	Mar-June (Mar-Apr)	BC		(Hourston and Haegele 1980; Hay 1985; Lassuy 1989; Hay et al. 2008)
	<i>Anarrhichthys ocellatus</i>	wolf eel ¶	2160-17520*, +	3mo-2y*, +	D	Feb-May	BC		(Eschmeyer et al. 1983; Marliave 1987; Love 1996; *Jeff Marliave pers. comm. 2013)
	<i>Ophiodon elongatus</i>	lingcod c, r, ¶	2160	3mo	D	Mar-June (Mar-Apr)	BC, PNW		(Cass et al. 1990; Marko et al. 2006)
	<i>Hypomesus pretiosus</i>	surf smelt c, r	2160	3mo	D	Spring-summer	BC, PNW	S	(Therriault et al. 2002; DFO 2012)
	<i>Scorpaenichthys marmoratus</i>	cabezon r, ¶	2160-2880	3-4mo	D	Nov-April (Dec-Jan)	Cali	m	(O'Connell 1953; Wilson et al. 2008)
	<i>Hemilepidotus hemilepidotus</i>	red Irish lord r	3686	154d	D	March	Alaska, PNW	S	(Hart 1973; Garrison and Miller 1982; Doyle and Mier 2012)
	<i>Ammodytes hexapterus</i>	Pacific sand lance r	2160-2880	3-4mo	D	Feb-Mar	PS	S	(Hiss 1985; Gotthardt et al. 2005)
	<i>Hexagrammos decagrammus</i>	kelp greenling r, ¶	4320-5040*	6-7mo*	D	Nov-Jan	BC	m	(Garrison and Miller 1982; Howard and Sillberg 2001; Hoobler 2008; *Jennifer Yakimishyn pers. comm. 2013)

(c) commercially fished species or assessed for potential commercial fishery, (r) recreationally fished species, (~) species at risk, (¶) harvested by First Nations for FSC
 (+) wolf-eel could be designated as postlarva rather than truly planktonic larva given that eggs hatch and juveniles are pelagic drifting before settlement

LARVAL RELEASE ZONE	SPECIES NAME	COMMON NAME	LARVAL DURATION [hrs]	LARVAL DURATIN [D,M,Y]	SPAWNING MODE	RELEASE SEASON	GEOGRAPHIC AREA	DATA GAPS	SOURCES
NEARSHORE SUBTIDAL	<i>Cymatogaster aggregata</i>	shiner perch c,r	n/a	n/a	P-LB	July-Aug	BC	S	(Lane et al. 2002)
	<i>Rhacochilus vacca</i>	pile perch c,r	n/a	n/a	P-LB	May-Sept	BC	S	(Lane et al. 2002)
	<i>Embiotoca lateralis</i>	striped perch c,r	n/a	n/a	P-LB	Jun-July	BC	S	(Lane et al. 2002)
	<i>Brachyistius frenatus</i>	kelp perch c,r	n/a	n/a	P-LB	May-Jul	BC	S	(Lane et al. 2002)
NEARSHORE-TO-OFFSHORE	<i>Sebastes maliger</i>	quillback rockfish c,r,⌘	1272-1512	51-63d	P-LB	Mar-Jul (Apr-May)	BC		(Love et al. 2002; Yamanaka et al. 2006a; Markel 2011)
	<i>Sebastes caurinus</i>	copper rockfish c,r,⌘	1272-1512	51-63d	P-LB	Mar-Jun (Apr-May)	BC		(Love et al. 2002; Markel 2011)
	<i>Sebastes nebulosus</i>	china rockfish c,r,⌘	720-1440	1-2mo	P-LB	Apr-Jun	Cali, BC	m	(Love et al. 2002)
	<i>Sebastes nigrocinctus</i>	tiger rockfish c,r,⌘	720-1440	1-2mo	P-LB	May	PNW, BC	S	(Matarese et al. 1989; Love et al. 2002)
	<i>Sebastes mystinus</i>	blue rockfish c,⌘	2160-3600	3-5mo	P-LB	Oct – Mar (Dec-Jan)	PNW, BC	m	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes melanops</i>	black rockfish c,r,⌘	1032-2712	43-113d	P-LB	Jan-Mar	BC		(Love et al. 2002; Lotterhos 2012)
	<i>Hippoglossus stenolepis</i>	Pacific halibut c,r,⌘	4320	6mo	D	Nov-Mar	PNW	m	(IPHC 1987; Parker 1988; Love 1996)
OFFSHORE	<i>Anoplopoma fimbria</i>	sablefish c,r,⌘	2160 [⌘]	~3mo [⌘]	D	Jan-Apr	BC		(Mason et al. 1983; Kendall and Matarese 1987)
	<i>Merluccius productus</i>	Pacific hake c,r	2688	112d	P	Mar-May	BC		(McFarlane and Beamish 1986; Hollowed 1992)
	<i>Atheresthes stomias</i>	arrowtooth flounder c,⌘	3480	145d	P	Sep-Dec	PNW	m	(Rickey 1995; Bouwens et al. 1999; Bailey and Picquelle 2002; McCain et al. 2005; Blood et al. 2007)
	<i>Gadus macrocephalus</i>	Pacific cod c,r,⌘	1656-3048	69-127d	D	Jan-Mar	PNW, Alaska	S	(Garrison and Miller 1982; Hurst et al. 2010)
	<i>Theragra chalcogramma</i>	walleye Pollock c,r,⌘	2880	70d	P	Mar-Apr	Bering Sea (Japan)		(Walline 1982; Hinckley 1987; Kim and Gunder-son 1989)

(c) commercially fished species or assessed for potential commercial fishery, (r) recreationally fished species, (~) species at risk, (⌘) harvested by First Nations for FSC

([⌘]) there is no distinct transition between sablefish larvae and epipelagic juveniles, but both are both found in ichthyoplankton at sizes ranging from 7-40 mm, which represent an interval of 12 weeks based on established growth rates (see Kendall and Matarese 1987)

LARVAL RELEASE ZONE	SPECIES NAME	COMMON NAME	LARVAL DURATION [hrs]	LARVAL DURATION [D,M,Y]	SPAWNING MODE	RELEASE SEASON	GEOGRAPHIC AREA	DATA GAPS	SOURCES
OFFSHORE	<i>Microstomus pacificus</i>	dover sole c,r,⌘	8760-17520	1-2y	D	Jan-Mar	PNW		(Butler et al. 1996; McCain et al. 2005)
	<i>Parophrys vetulus</i>	English sole c,r,⌘	1344-1680	56-70d	P	Jan-April (Feb-Mar)	PS		(McCain et al. 2005)
	<i>Sebastes ruberrimus</i>	yelloweye rockfish c,r,~,⌘	720-1440	1-2mo	P-LB	Apr-Sep (May-Jun)	BC	m	(Love et al. 2002; Yamanaka et al. 2006b)
	<i>Sebastes flavidus</i>	yellowtail rockfish c,⌘	2520	3.5mo	P-LB	Jan-Apr	PNW, BC	m	(Love et al. 2002)
	<i>Sebastes paucispinis</i>	boccacio c,~,⌘	1440-2880	2-4mo	P-LB	Jan-May (Feb)	PNW, BC	m	(Leet et al. 2001; Love et al. 2002; McCain et al. 2005)
	<i>Sebastes elongatus</i>	greenstriped rockfish c	1440-2880	2-4mo	P-LB	Begin in June	Cali, BC	m	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes proriger</i>	redstripe rockfish c,r	720-1440	1-2mo	P-LB	Apr-July	PNW	m	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes entomelas</i>	widow rockfish c,r	720-1440	1-2mo	P-LB	Apr	PNW, BC	m	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes brevispinis</i>	silvergray rockfis c,⌘	720-1440	1-2mo	P-LB	Apr-Aug (Jul)	PNW	S	(Love et al. 2002)
	<i>Sebastes pinniger</i>	canary rockfish c,r,~,⌘	2160-2880	3-4mo	P-LB	Jan-Mar	PNW	m	(Love et al. 2002)
	<i>Sebastes alutus</i>	Pacific ocean perch c	720-1440	1-2mo	P-LB	Jan-Apr	PNW	m	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes aleutianus</i>	rougeye rockfish ~	720-1440	1-2mo	P-LB	Feb-Jun	PNW, BC	m	(Love et al. 2002)
	<i>Sebastes crameri</i>	darkblotched rockfish c,~	720-1440	1-2mo	P-LB	Nov-Jun	PNW, BC	m	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes reedi</i>	yellowmouth rockfish c,~	720-2160	"months" 1-3mo	P-LB	Feb-Jun	PNW, BC	S	(Edwards et al. 2011)
	<i>Sebastolobus alascanus</i>	shortspine thornyhead c	8640-10800	12-15mo	P-LB	Jan-May (Apr)	PNW, BC	m	(Love et al. 2002; McCain et al. 2005)
	<i>Sebastes babcocki</i>	redbanded rockfish c	720-1440	1-2mo	P-LB	Mar-Sep	PNW, BC	m	(Love et al. 2002)
	<i>Sardinops sagax</i>	Pacific sardine c	1440	2mo	P	Jan-Aug (Apr-May)	PNW		(Garrison and Miller 1982; Agostini 2005; Shanks and Eckert 2005)

(c) commercially fished species or assessed for potential commercial fishery, (r) recreationally fished species, (~) species at risk, (⌘) harvested by First Nations for FSC

LARVAL RELEASE ZONE	SPECIES NAME	COMMON NAME	LARVAL DURATION [hrs]	LARVAL DURATION [D,M,Y]	SPAWNING MODE	RELEASE SEASON	GEOGRAPHIC AREA	DATA GAPS	SOURCES
OFFSHORE	<i>Thunnus alalunga</i>	albacore tuna c,r	480	20d	P	Summer	N Pacific	S	(Sund et al. 1981; Garcia et al. 2006)
	<i>Engraulis mordax</i>	Northern anchovy c	2160	3mo	P	Year round (Feb-Apr)	PNW	S	(Garrison and Miller 1982; Butler 1989; Therriault et al. 2002)
	<i>Hydrolagus coliei</i>	spotted ratfish ⌘	n/a ⌚	n/a ⌚	D	Year Round (Summer-Fall)	PNW	m	(McCain et al. 2005; Dagit 2006)
	<i>Raja rhina</i>	longnose skate c,r	n/a ⌚	n/a ⌚	D	U	PNW	S	(McCain et al. 2005; Ebert et al. 2008)
	<i>Raja binoculata</i>	big skate c,r	n/a ⌚	n/a ⌚	D	U	PNW	S	(McCain et al. 2005; Ebert et al. 2008)
	<i>Lamna ditropis</i>	salmon shark r	n/a	n/a	LB	Spring-Summer	PNW		(Goldman and Musick 2008; Wright 2011)
	<i>Squalus acanthias</i>	spiny dogfish c,r,~, ⌘	n/a	n/a	LB	Spring	PNW		(McCain et al. 2005)
	<i>Hexanchus griseus</i>	bluntnose sixgill shark ~	n/a	n/a	LB	U	PNW	m	(Cook and Compagno 2005; Dunbrack and Zielinski 2005)
	<i>Cetorhinus maximus</i>	basking shark ~	n/a	n/a	LB	U	PNW	m	(COSEWIC 2009)
INVERTEBRATE AND ALGAL SPECIES									
INTERTIDAL	<i>Tegula funebris</i>	black turban snail ⌘	144	6d	BS	Summer	PNW	m	(Strathmann 1987; Moran 1997; Grantham et al. 2003)
	<i>Pollicipes polymerus</i>	gooseneck barnacle ⌘	504	21d	BS	Apr-Oct (July)	PNW		(Strathmann 1987; Grantham et al. 2003)
	<i>Tresus spp.</i>	horse clam c,⌘	576-816	24-34d	BS	Mar-May	PNW		(Strathmann 1987)
	<i>Venerupis philippinarum</i>	Japanese littleneck clam or manila clam c,r,⌘	504-672	21-28d	BS	June-Sept	BC		(Bourne 1986; Strathmann 1987; Shanks 2009)
	<i>Crassostrea gigas</i>	Pacific oyster c,⌘	504-672	21-28d	BS	Jun-Sep (Jul-Aug)	PNW		(Strathmann 1987; Pauley et al. 1988)
	<i>Protothaca staminea</i>	Pacific littleneck clam c,r,⌘	672	28d	BS	Apr-Sept (May)	BC		(Bourne 1986; Strathmann 1987)

(c) commercially fished species or assessed for potential commercial fishery, (r) recreationally fished species, (~) species at risk, (⌘) harvested by First Nations for FSC
(⌚) larval stages are completed in the egg sac.

LARVAL RELEASE ZONE	SPECIES NAME	COMMON NAME	LARVAL DURATION [hrs]	LARVAL DURATION [D,M,Y]	SPAWNING MODE	RELEASE SEASON	GEOGRAPHIC AREA	DATA GAPS	SOURCES
INTERTIDAL	<i>Saxidomus gigantea</i>	butter clam r,⌘	672	28d	BS	Apr-Aug	PNW		(Strathmann 1987; Grantham et al. 2003)
	<i>Clinocardium nuttallii</i>	Nuttall's cockle ⌘	216	9d	BS	Apr-Nov (July-Aug)	PS		(Gallucci and Gallucci 1982; Strathmann 1987; Llu et al. 2009)
	<i>Mytilus californianus</i>	California mussel r, ⌘	216	9d	BS	U	PNW	m	(Grantham et al. 2003)
	<i>Mytilus edulis</i>	blue mussel ⌘	768-1176	32-49d	BS	Apr-May (May)	PNW		(Strathmann 1987; Grantham et al. 2003)
NEARSHORE SUBTIDAL	<i>Macrocystis pyrifera</i>	giant kelp ⌘	32	1.3d	O	U	PNW	S	(Reed et al. 2006; Shanks 2009)
	<i>Nereocystis luetkeana</i>	bull kelp ⌘	U	U	O	June-Oct	WA	S	(Springer et al. 2006)
	<i>Pterygophora californica</i>	woody-stemmed kelp ⌘	32	1.3d	O	Dec-Feb	PNW	m	(De Wreede 1984; Shanks et al. 2003; Guiry and Guiry 2013)
	<i>Haliotis kamtschatkana</i>	abalone ~,⌘	168-288	7-12d	BS	Late May-Aug	PNW		(Strathmann 1987; Sloan and Breen 1988; Grantham et al. 2003)
	<i>Panope abrupta</i>	geoduck c,⌘	384-1128	16-47d	BS	Mar-July (May-Jun)	BC, PS		(Strathmann 1987; Campbell and Ming 2003; Hand and Marcus 2004; Becker et al. 2012)
	<i>Strongylocentrotus droebachiensis</i>	green sea urchin c,⌘	672-3696	28-154d	BS	Jan-Jun (Mar-Apr)	BC		(Strathmann 1987; Meidel and Scheibling 1998; DFO 2003; Addison and Hart 2004)
	<i>Strongylocentrotus franciscanus</i>	red sea urchin c,⌘	1008-1512	42-63d	B	Mar-Jul (Apr-May)	PNW, BC		(Strathmann 1987; DFO 2001)
	<i>Strongylocentrotus purpuratus</i>	purple sea urchin c,⌘	1152-1776	48-74d	B	Dec-May (Apr)	BC		(Strathmann 1987; Grantham et al. 2003)
	<i>Parastichopus californicus</i>	sea cucumber c,⌘	1560-3000	65-125d	B	Late May- mid Jul	BC		(Strathmann 1987; Cameron and Fankboner 1989; DFO 1999)
	<i>Cancer productus</i>	red rock crab c,r, ⌘	1632-3600	68-150d	D	Mar-Apr (Jun)	PNW		(Strathmann 1987; Grantham et al. 2003)
	<i>Cryptochiton stelleri</i>	giant Pacific chiton ⌘	96-120	4-5d	B	Mar-Jun (Apr-May)	PNW	m	(Strathmann 1987; Lord 2011)
	<i>Katharina tunicata</i>	black katy chiton ⌘	144	6d	BS	Apr-Jul (Jun)	PNW	m	(Strathmann 1987; O'Clair and O'Clair 1998)

(c) commercially fished species or assessed for potential commercial fishery, (r) recreationally fished species, (~) species at risk, (⌘) harvested by First Nations for FSC

LARVAL RELEASE ZONE	SPECIES NAME	COMMON NAME	LARVAL DURATION [hrs]	LARVAL DURATIN [D,M,Y]	SPAWNING MODE	RELEASE SEASON	GEOGRAPHIC AREA	DATA GAPS	SOURCES
NEARSHORE-TO-OFFSHORE	<i>Cancer magister</i>	Dungeness crab c,r,⌘	1920-3840	80-160d	D	Dec-Jun	BC		(Strathmann 1987; Pauley et al. 1989; Grantham et al. 2003; Shanks 2009)
	<i>Chlamys rubida</i>	pink scallop c,⌘	840-1008	35-42d	B	Spring and Fall	BC		(DFO 2011)
	<i>Chlamys hastata</i>	spiny scallop c,⌘	840-1008	35-42d	B	Summer	BC		(Strathmann 1987; DFO 2011)
	<i>Crassadoma gigantea</i>	rock scallop ⌘	504-672	21-28d	B	Jun-Sept	BC		(Williams 1989)
	<i>Paralithodes camtschaticus</i>	red king crab c,r	2160	3mo	D	Apr-Jun	Russia	m	(Epelbaum et al. 2006; Gabaev 2007; Shanks 2009)
	<i>Enteroctopus dofleini</i>	giant Pacific octopus c,⌘	720-2160	30-90d	D	Mar-Apr	N Pacific, Bering Sea	m	(Cosgrove and McDaniel 2009)
	<i>Euphausia pacifica</i>	krill c	1440	2mo	B	Late Jun-Late Sept	PNW	m	(Feinberg et al. 2006)
OFFSHORE	<i>Lithodes aequispina</i>	golden king crab c,r	2160-2880	"several months" 3-4mo	D	All year	BC, Alaska	S	(Sloan 1985; Alaska Fish and Game 2013)
	<i>Chionoecetes tanneri</i>	grooved tanner crab c,r	2160-2880	3-4mo	D	May-Aug	BC, Alaska	m	(Pereyra 1968; Phillips and Lauzier 1997)
	<i>Chionoecetes bairdi</i>	inshore tanner crab c,r	1440	2mo	D	March-June	BC		(Incze et al. 1982; Krause et al. 2001)
	<i>Pandalus platyceros</i>	spot prawn c,r,⌘	480-840	20-35d	D	Apr	PNW	m	(Kelly et al. 1977; Lowry 2007)
	<i>other Pandalus spp.</i>	shrimp/prawn species c,r,⌘	720	30d	P	Mar-Apr	PNW		(Strathmann 1987; Grantham et al. 2003)
	<i>Hexactinellid spp.</i>	glass sponge	U	U	D	U		S	(Eerkes-Medrano and Leys 2006; Ereskovsky 2010; Van Soest et al. 2012)

(c) commercially fished species or assessed for potential commercial fishery, (r) recreationally fished species, (~) species at risk, (⌘) harvested by First Nations for FSC

REFERENCES

- Addison, J. A., and M. W. Hart. 2004. Analysis of population genetic structure of the green sea urchin (*Strongylocentrotus droebachiensis*) using microsatellites. *Marine Biology* 144:243-251.
- Agostini, V. 2005. Climate, ecology and productivity of Pacific sardine (*Sardinops sagax*) and hake (*Merluccius productus*). PhD Thesis. University of Washington. Washington, Seattle. 188pp.
- Alaska Fish and Game. Golden king crab (*Lithodes aequispinus*) species profile. 2013. Alaska.
- Bailey, K., and S. Picquelle. 2002. Larval distribution of offshore spawning flatfish in the Gulf of Alaska: potential transport pathways and enhanced onshore transport during ENSO events. *Marine Ecology Progress Series* 236:205-217.
- Becker, B., M. Behrens, Y. Shevalier, C. Henzler, E. Hoaglund, and B. Lemay. 2012. Determining distribution and size of larval Pacific geoduck clams (*Panopea generosa* Gould 1850) in quartermaster harbor (Washington, USA) using a novel sampling approach. *Journal of Shellfish Research* 31:711-723.
- Blood, D., A. Matarese, and M. Busby. 2007. Spawning, egg development, and early life history dynamics of arrowtooth flounder (*Atheresthes stomias*) in the Gulf of Alaska. NOAA Professional Paper NMFS 7. 28pp.
- Bourne, N. 1986. Intertidal Clams. In G. Jamieson and K. Francis (Editors), *Invertebrate and marine plant resources of British Columbia*. Canadian Special Publication of Fisheries and Aquatic Sciences. 91: 22-31.
- Bouwens, K., R. Smither, A. Paul, and W. Rugen. 1999. Maturity, spawning and seasonal movement of Arrowtooth flounder, *Atheresthes stomias*, off Washington. *Alaska Fishery Research Bulletin* 6:41-48.
- Butler, J. 1989. Growth during the larval and juvenile stages of the northern anchovy, *Engraulis mordax*, in the California Current during 1980-84. *Fishery Bulletin* 87:645-652.
- Butler, J., K. Dahlin, and G. Moser. 1996. Growth and duration of the planktonic phase and a stage based population matrix of dover sole, *Microstomus pacificus*. *Bulletin of Marine Science* 58:29-43.
- Cameron, J., and P. Fankboner. 1989. Reproductive biology of the commercial sea cucumber *Parastichopus californicus* (Stimpson) (Echinodermata : Holothuroidea). II. Observations on the ecology of development, recruitment, and the juvenile life stage. *Journal of Experimental Biology and Ecology* 127:43-61.
- Campbell, A., and M. Ming. 2003. Maturity and growth of the Pacific geoduck, *Panopea abrupta*, in southern British Columbia, Canada. *Journal of Shellfish Research* 22:85-90.
- Cass, A., R. Beamish, and G. McFarlane. 1990. Lingcod (*Ophiodon elongatus*). *Canadian Journal of Fisheries and Aquatic Science* 109:40.
- Cook, S., and L. Compagno. 2005. *Hexanchus griseus*. IUCN Red List of Threatened Species, Version 2014.2. Available online <http://www.iucnredlist.org> (Accessed Sept 2014).
- COSEWIC. 2009. COSEWIC assessment and status report on the Basking Shark *Cetorhinus maximus*, Atlantic population, in Canada. Ottawa, Canada. 56pp.
- Cosgrove, J., and N. McDaniel. 2009. Super suckers: the giant Pacific octopus and other cephalopods of the Pacific Coast. Harbour Publishing, Madeira Park, BC.
- Dagit, D. 2006. *Hydrolagus colliei*. IUCN Red List of Threatened Species. Available online <http://www.iucnredlist.org> (Accessed Sept 2014).
- Davis, B., E. DeMartini, and K. McGee. 1981. Gene flow among populations of a teleost (painted greenling, *Oxylebius pictus*) from Puget Sound to southern California. *Marine Biology* 65:17-23.
- De Wreede, R. 1984. Growth and age class distribution of *Pterygophora californica* (Phaeophyta). *Mar Ecol Prog Ser* 19:93-100.
- DeMartini, E., and M. Anderson. 1980. Comparative survivorship and life history of painted greenling (*Oxylebius pictus*) in Puget Sound, Washington and Monterey Bay, California. *Env. Biol. Fish.* 5:33-47.
- DFO. 1999. Giant red sea cucumber. Stock Status Report C6-10. Department of Fisheries and Oceans. Available online <http://www.dfo-mpo.gc.ca/csas/csas/status/1999/c6-10e.pdf> (Accessed Aug. 2014).
- DFO. 2001. Red sea urchin. Stock Status Report C6-09. Department of Fisheries and Oceans Canada. Ottawa, ON. Available online http://www.dfo-mpo.gc.ca/csas/Csas/status/2001/SSR2001_C6-09.pdf (Accessed Sept 2014).
- DFO. 2003. Green sea urchin. Stock Status Report. Department of Fisheries and Oceans, Ottawa, ON. Available online http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/SSR2003_039_e.pdf (Accessed Aug. 2014).
- DFO. 2011. Updated framework for the pink and spiny scallop (*Chlamys rubida* and *C. hastata*) dive fishery in British Columbia. Science Advisory Report - 2010/078. Department of Fisheries and Oceans. Available online <http://www.dfo-mpo.gc.ca/Library/343819.pdf> (Accessed Sept 2014).
- DFO. 2012. Pacific region integrated fisheries management plan surf smelt 2012-2014. Fisheries and Oceans Canada. Canada. 41pp.
- Doyle, M., and K. Mier. 2012. A new conceptual framework for evaluating the early ontogeny phase of recruitment processes among marine fish species. *Canadian Journal of Fisheries and Aquatic Science* 69:2112-2129.

- Dunbrack, R., and R. Zielinski. 2005. Body size distribution and frequency of anthropogenic injuries of Bluntnose Sixgill Sharks, *Hexanchus griseus*, at Flora Islets, British Columbia. *The Canadian Field Naturalist* 119:537-540.
- Ebert, D., W. Smith, and G. Cailliet. 2008. Reproductive biology of two commercially exploited skates, *Raja binoculata* and *R. rhina*, in the western Gulf of Alaska. *Fisheries Research* 94:48-57.
- Edwards, A., R. Haigh, and P. Starr. 2011. Stock assessment and recovery potential assessment for Yellowmouth Rockfish (*Sebastes reedi*) along the Pacific coast of Canada. Fisheries and Oceans Canada, DFO. Nanaimo, BC.
- Eerkes-Medrano, D., and S. Leys. 2006. Ultrastructure and embryonic development of a syconoid calcareous sponge. *Invertebrate Biology* 125:177-194.
- Epelbaum, A., R. Borisov, and N. Kovatcheva. 2006. Early development of the red king crab *Paralithodes camtschaticus* from the Barents Sea reared under laboratory conditions: morphology and behaviour. *Journal of Marine Biological Association of the UK* 86:317-333.
- Ereskovsky, A. 2010. Chapter 2: Development of sponges from the class hexactinellida Schmidt, 1870 In A. Ereskovsky (Editor), *The Comparative Embryology of Sponges*. Springer. 37-46.
- Eschmeyer, W., E. Herald, and H. Hammon. 1983. *A field guide to Pacific Coast fishes of North America*. Houghton Mifflin, Boston, Massachusetts.
- Feinberg, L., T. Shaw, B. Peterson, and H. Bi. 2006. Life history of *Euphausia pacifica* in the northern California Current: what can be learned by contrasting field and laboratory studies. Oregon State University. Newport, OR. 19pp.
- Gabaev, D. 2007. Ecology of reproduction of the red king crab. *Russian Journal of Ecology* 38:112-118.
- Gallucci, V., and B. Gallucci. 1982. Reproduction and ecology of the hermaphroditic cockle *Clinocardium nuttallii* (Bivalvia: Cardiidae) in Garrison Bay. *Marine Ecology Progress Series* 7:137-145.
- Garcia, A., D. Cortes, T. Ramirez, R. Fehri-Bedour, F. Alemany, J. Rodriguez, A. Carpena, and J. Alvarez. 2006. First data on growth and nucleic acid and protein content of field-captured Mediterranean bluefin (*Thunnus thynnus*) and albacore (*Thunnus alalunga*) tuna larvae: a comparative study. *Scientia Marina* 70S2:67-78.
- Garrison, K., and B. Miller. 1982. Review of the early life history of Puget Sound fishes. *Fish. Res. Inst. University of Washington*, Seattle, WA.
- Goldman, K., and J. Musick. 2008. Biology and ecology of the salmon shark, *Lamna ditropis*. In E. Pikitch (Editor), *Sharks of the Open Ocean* Blackwell Scientific, Maldon, MA.
- Gotthardt, T., J. McClory, and M. Booz. 2005. State conservation status, element ecology & life history; Pacific sand lance. Alaska Department of Fish and Game. Available online http://www.adfg.alaska.gov/static/species/speciesinfo/_aknhp/PacificSandLance.pdf (Accessed Sept. 2014). 5pp.
- Grantham, B., G. Eckert, and A. Shan. 2003. Dispersal potential of marine invertebrates in diverse habitats. *Ecological Applications* 13:S108-S116.
- Guiry, M., and G. Guiry. 2013. *Pterygophera californica*. AlgaeBase. Available on-line <http://www.algaebase.org/>.
- Hand, C., and K. Marcus. 2004. CSAS Potential impacts of subtidal geoduck aquaculture on the conservation of wild Geoduck populations and the harvestable TAC in British Columbia., Fisheries and Oceans Canada. Nanaimo, BC.
- Hart, J. 1973. Pacific fishes of Canada. *Bulletin of the Fisheries Research Board of Canada* 180: 740pp.
- Hay, D. 1985. Reproductive biology of Pacific herring (*Clupea harengus pallasii*). *Canadian Journal of Fisheries and Aquatic Science* 42:111-126.
- Hay, D., K. Rose, J. Schweigert, and B. Megrey. 2008. Geographic variation in North Pacific herring populations: Pan-Pacific comparisons and implications for climate change impacts. *Progress in Oceanography* 77:233-240.
- Hinckley, S. 1987. The reproductive biology of walleye pollock, *Fleragra chalcogramma*, in the Bering Sea, with reference to spawning stock structure. *Fisheries Bulletin* 85:481-498.
- Hiss, J. 1985. Summary of life history of Pacific sand lance (*Ammodytes hexapterus*) and its distribution in relation to Protection Island National Wildlife Refuge. . US Fish and Wildlife Service. Olympia, WA. 5pp.
- Hollowed, A. 1992. Spatial and temporal distribution of Pacific hake, *Merluccius productus*, larvae and estimates of survival during early life stages. *California Cooperative Oceanic Fisheries Investigations Report* 33:100-123.
- Hoobler, S. 2008. Chapter 10 Kelp Greenling. California Department of Fish and Game Marine Region. California. 8pp.
- Hourston, A., and C. Haegele. 1980. Herring on Canada's Pacific coast. *Canadian Special Publication of Fisheries and Aquatic Sciences* 48:23.
- Howard, D., and K. Sillberberg. 2001. Kelp Greenling. . In W. Leet, C. Dewees, R. Klingbeil, and E. Larson (Editors), *California's Living Marine Resources: A Status Report*. University of California, California. 183-184.
- Hurst, T., B. Laurel, and L. Ciannelli. 2010. Ontogenetic patterns and temperature-dependent growth rates in early life stages of Pacific cod (*Gadus macrocephalus*). *Fisheries Bulletin* 108:382-392.

- Incze, L., D. Armstrong, and D. Wenker. 1982. Rates of development and growth of larvae of *Chionoecetes bairdi* and *C. opilio* in the Southeastern Bering Sea. Alaska Seagrant Report. 219-232pp.
- IPHC. 1987. The Pacific halibut: biology, fishery and management. The International Pacific Halibut Commission. Seattle, Washington. 59pp.
- Kelly, R., A. Haseltine, and E. Ebert. 1977. Mariculture potential of the spot prawn, *Pandalus platyceros* Brandt. Aquaculture 10:1-16.
- Kendall, A., and A. Matarese. 1987. Biology of eggs, larvae, and epipelagic juveniles of sablefish, *Anoplopoma fimbria*, in relation to their potential use in management. Marine Fisheries Review 49:1-13.
- Kim, S., and D. Gunderson. 1989. Cohort dynamics of walleye Pollock (*Theragra chalcogramma*) in Shelikof Strait, Gulf of Alaska during the egg and larval period. Transactions of the American Fisheries Society 118:264-273.
- Krause, G., G. Workman, and A. Phillips. 2001. A phase "0" review of the biology and fisheries of the Tanner Crab. Fisheries and Oceans Canada. Nanaimo, BC. 79pp.
- Lane, E., W. Wuff, A. McDiarmid, D. Hay, and B. Rusch. 2002. A review of the biology and fishery of the Embiotocids of British Columbia. Canadian Science Advisory Secretariat Report., Department of Fisheries and Oceans. Nanaimo, BC.
- Lassuy, D. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): English sole. 82, U.S. Army Corps of Engineers. 17pp.
- Leet, W., C. Dewees, R. Kingbeil, and E. Larson. 2001. California's living marine resources: A status report. University of California. California.
- Liu, W., C. Pearce, A. Alabi, and H. Gurney-Smith. 2009. Effects of microalgal diets on the growth and survival of larvae and post-larvae of the basket cockle, *Clinocardium nuttallii*. Aquaculture 293:248-254.
- Lord, J. 2011. Larval development, metamorphosis and early growth of the gumboot chiton *Cryptochiton Stelleri* (middendorff, 1847) (Polyplacophora: Mopaliidae) on the Oregon Coast. Journal of Molluscan Studies 77:182-188.
- Lotterhos, K. 2012. Nonsignificant isolation by distance implies limited dispersal. Molecular Ecology 21:5637-5639.
- Love, M. 1996. Probably more than you want to know about the fishes of the Pacific coast. Really Big Press, Santa Barbara, CA.
- Love, M., M. Yoklavich, and L. Thornsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley, CA.
- Lowry, N. 2007. Biology and fisheries for the spot prawn (*Pandalus platyceros*, Brandt 1851). PhD Thesis. University of Washington, Seattle, WA. Pagespp.
- Markel, R. 2011. Rockfish recruitment and trophic dynamics on the west coast of Vancouver Island: Fishing, ocean climate, and sea otters. University of British Columbia, Vancouver. Pagespp.
- Marko, P., L. Rogers-Bennett, and A. Dennis. 2006. MtDNA population structure and gene flow in lingcod (*Ophiodon elongatus*): limited connectivity despite long-lived pelagic larvae. Marine Biology 150:1301-1311.
- Marliave, J. 1987. The life history and captive reproduction of the Wolf-eel at the Vancouver Public Aquarium. International Zoo Yearbook 26:70-81.
- Marliave, J. 2013. Personal Communication. Vice President Marine Science, Vancouver Aquarium.
- Mason, J., R. Beamish, and G. McFarlane. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) off the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences 40:2126-2134.
- Matarese, A., A. Kendell, D. J. Blood, and B. Vinter. 1989. Laboratory guide to early life history stages of Northeast Pacific fishes. NOAA.
- McCain, B., S. Miller, and W. Wakefield. 2005. Life history, geographical distribution, and habitat associations of 82 West Coast groundfish species: a literature review (Appendix B2). National Marine Fisheries Service. Seattle, WA. 266pp.
- McFarlane, G., and R. Beamish. 1986. Production of strong year-classes of sablefish (*Anoplopoma fimbria*) off the west coast of Canada. International North Pacific Fisheries Commission Report 47. 191-202pp.
- Meidel, S., and R. Scheibling. 1998. Annual reproductive cycle of the green sea urchin, *Strongylocentrotus droebachiensis*, in differing habitats in Nova Scotia, Canada. Marine Biology 131:461-478.
- Moran, A. 1997. Spawning and larval development of the black turban snail *Tegula funebris* (Prosobranchia: Trochidae). Marine Biology 128:107-114.
- O'Clair, R., and C. O'Clair. 1998. Southeast Alaska's rocky shores: animals. Plant Press, Auke Bay, AK.
- O'Connell, C. 1953. Life history of the cabezon, *Scorpaenichthys marmoratus*. California Department of Fish and Game. Fisheries Bulletin 93. 76pp.
- Parker, K. 1988. Pacific Halibut, *Hippoglossus stenolepis*, in the Gulf of Alaska In N. Wilimovsky, L. Incze, and S. Westheim (Editors), Species Synopsis: Life histories of selected fish and shellfish of the northeast Pacific and Bering Sea. University of Washington, Seattle, WA. 94-111.

- Pauley, G., D. Armstrong, R. Van Citter, and G. Thomas. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—Dungeness crab. TR EL-82-4, U.S. Fish and Wildlife Service Biological Report 82 (#82 11.121).
- Pauley, G., V. D. R. B, and D. Troutt. 1988. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)—Pacific oyster. U.S. Fish and Wildlife Service Biological Report 82 (#TR EL-82.4). 28pp.
- Pereyra, W. 1968. Distribution of juvenile tanner crabs (*Chionoecetes tanned Rathbun*) life history model, and fisheries management. Proceedings of the National Shellfisheries Association 58:66-70.
- Phillips, A., and R. Lauzier. 1997. Biological background for the development of a new fishery for the grooved tanner crab (*Chionoecetes tanneri*) off British Columbia. Canadian Stock Assessment Secretariat Research Document 97/148. 79pp.
- Reed, D., B. Kinland, P. Raimondi, L. Washburn, B. Gaylord, and P. Drake. 2006. A metapopulation perspective on the patch dynamics of Giant Kelp in southern California. In K. Kritzer and P. Sale (Editors), Marine Metapopulations. Elsevier, Boston, MA. 353-386.
- Rickey, M. 1995. Maturity, spawning and seasonal movement of Arrowtooth flounder, *Atheresthes stomias*, off Washington. Fisheries Bulletin 93:127-138.
- Shanks, A. 2009. Pelagic larval duration and dispersal distance revisited. Biological Bulletin 216:373-385.
- Shanks, A., G. BA, and M. Carr. 2003. Propagule dispersal distance and the size and spacing of marine reserves. Ecological Applications: S159-S169.
- Shanks, A., and G. Eckert. 2005. Life-history traits and population persistence of California Current fishes and benthic crustaceans: solution of a marine drift paradox. Ecological Monographs 75:505-524.
- Sloan, N. 1985. Life history characteristics of fjord-dwelling golden king crabs *Lithodes aequispina*. Mar Ecol Prog Ser 22:219-228.
- Sloan, N., and P. Breen. 1988. Northern abalone, *Haliotis kamtschatkana*, in British Columbia: fisheries and synopsis of life history information. Canadian Special Publication of Fisheries and Aquatic Sciences 103:46.
- Springer, Y., C. Hays, M. Carr, M. Mackey, and J. Bloeser. 2006. Ecology and Management of the Bull Kelp, *Nereocystis luetkeana*: A Synthesis with Recommendations for Future Research. Pew Charitable Trusts. Santa Cruz, CA.
- Strathmann, M. 1987. Reproduction and development of marine invertebrates of the northern Pacific coast. University of Washington Press, Seattle.
- Sund, P., M. Blackburn, and F. Williams. 1981. Tunas and their environment in the Pacific Ocean: a review. Oceanography and Marine Biology Annual Review 19:443-512.
- Therriault, T., A. McDiarmid, W. Wulff, and D. Hay. 2002. Review of surf smelt *Hypomesus pretiosus* biology and fisheries with suggested management options for BC. Department of Fisheries and Oceans. Nanaimo, BC. 37pp.
- Van Soest, R., N. Boury-Esnault, J. Vacelet, M. Dohrmann, D. Erpenbeck, N. de Voogd, N. Santodomingo, B. Vanhoorne, M. Kelly, and J. Hooper. 2012. Global diversity of sponges (Porifera). PLoS one 7:35105.
- Wallace, P. 1982. Early life history of walleye pollock in the eastern Bering Sea. Northwest Alaska Fisheries Center (NOAA) 33pp.
- Williams, G. 1989. Coastal/estuarine fish habitat description and assessment manual part 1. Fisheries and Oceans Canada.
- Wilson, J., B. Broitman, J. Caselle, and D. Wendt. 2008. Recruitment of coastal fishes and oceanographic variability in central California. Estuarine, Coastal and Shelf Science 79:483-490.
- Wright, B. 2011. Alaska predators, their ecology and conservation. Hancock House Publishing.
- Yakimishyn, J. 2013. Personal Communication. Pacific Rim National Park Reserve, Parks Canada Agency.
- Yamanaka, K., L. Lacko, K. Miller-Saunders, C. Grandin, J. Lochead, J. Martin, N. Olsen, and S. Wallace. 2006a. A review of quillback rockfish *Sebastes maliger* along the Pacific coast of Canada: biology, distribution and abundance trends Department of Fisheries and Oceans Canada.
- Yamanaka, K., L. Lacko, R. Withler, C. Grandin, J. Lochead, J. Martin, N. Olsen, and S. Wallace. 2006b. A review of yelloweye rockfish *Sebastes ruberrimus* along the Pacific coast of Canada: biology, distribution and abundance trends. Department of Fisheries and Oceans Canada.

APPENDIX E: GUIDING PRINCIPLES AND PRACTICES/STRATEGIES FOR GOVERNANCE OF MPAS AND MPA NETWORKS

- › Guiding principles summarize the literature on good governance and are organized under six thematic headings.
- › Practices or strategies for achieving governance principles are provided, drawn largely from the literature on MPAs and marine planning.
- › Illustrative examples from protected area cases around the world are provided.

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
LEGITIMACY <i>Rule makers and governance procedures should be legitimate; legitimacy can be earned as well as conferred.</i>		
The authority of actors / organizations to govern should be conferred through valid and credible institutions and clear legal frameworks.	Governance authorities have justified and accepted mandates to make and enforce decisions. Legitimacy may be legally conferred (e.g. democratic mandate) and/or earned (e.g. through longstanding connection to a place; acceptance by stakeholders). (Graham et al. 2003; Lockwood 2009)	In the Isla Natividad MPA (Mexico), effectiveness is underpinned by stakeholder acceptance of a local cooperative institution; government plays a reinforcing role. (Weisman and McCay 2011)
	Decision-making authority is devolved to local levels where capacity exists (subsidiarity principle). However, local bodies are also obliged (e.g. by environmental standards) to act in-part in the broader (e.g. national) interest. (Abrams et al. 2003; Graham et al. 2003; Lockwood et al. 2010)	Management authority within small regional areas is vested in local bodies in New Zealand and Fiji. (Dickinson et al. 2010)
	Authority is exercised with integrity and commitment. (Lockwood 2009)	Cairngorms NP (Scotland) Board members must disclose potential conflicts of interest in decisions they are involved in. (Lockwood 2009)
	Adequate enabling legislation exists to provide MPAs with “a sound legal foundation.” (Pomeroy et al. 2004)	The Great Barrier Reef Marine Park Act (1975) “establishes the GBRMPA as the agency tasked with management ... (and) ensures strong oversight and legal justification for protection of biodiversity.” (Blue Earth Consultants 2012)
Existing rights and authorities in the area should be affirmed and respected, including those of aboriginal groups.	First Nations are recognized as a level of government (i.e. have jurisdiction; must be consulted). Partnerships and co-management agreements are established. (Graham et al. 2003; Borrini-Feyerabend et al. 2004; Goetze 2004; Jessen et al. 2011).	Indigenous Partnerships Liaison Unit established within GBRMP Authority to provide guidance on indigenous issues; traditional uses, including hunting, are allowed within the Marine Park without a permit. (Dickinson et al. 2010)
	Sustainable uses of traditional lands / waters, such as harvesting for food, social and ceremonial (FSC) purposes, are protected. (Borrini-Feyerabend et al. 2004; Jessen et al. 2011)	
	Where rights (e.g., title) are unresolved, protect First Nations’ interest in interim agreements; designate MPAs as “reserves.” (Government of Canada 2000; Goetze 2004; Jessen et al. 2011)	E.g. Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
Public awareness and support should be cultivated.	Public outreach and information initiatives create awareness of MPAs and their benefits. (DFO 2011; Jessen et al. 2011; Jones et al. 2013)	Limited public awareness of problems / threats and importance of non-reef habitats needed to be addressed through education campaigns in order to build support for rezoning in GBRMP. (Thompson et al. 2005)
	Community organization and participation around MPA initiatives is supported. (Pomeroy et al. 2004)	Seaflower MPA (Columbia) employs “community promoters”, well-known to the community, to facilitate grassroots interaction. (Taylor et al. 2011)
INCLUSION AND FAIRNESS <i>Stakeholders should be meaningfully engaged at all stages of planning and implementation; costs, benefits and regulatory enforcement should be fair.</i>		
Governance processes should be inclusive of all stakeholders.	Stakeholders are included early and often in the development of MPAs, including design, implementation and ongoing monitoring. (Graham et al. 2003; Charles and Wilson 2009; Green et al. 2011)	Community participation exceeded legal requirement in creation of the Great Barrier Reef Marine Park (GBRMP) in Australia; considered cost-effective in the long term despite shorter term costs (Charles and Wilson 2009); helped managers build strong relationships with communities. (Blue Earth Consultants 2012) Fishers involved in data collection and resource management decisions in establishment of Eastport MPA (Newfoundland) and collaborative monitoring programs in the Seaflower MPA (Columbia). (Charles and Wilson 2009; Blue Earth Consultants 2012)
	Investments are made to lower the costs and increase the capacity for stakeholders – including those who are marginalized or disadvantaged – to participate in governance processes. (Pomeroy et al. 2004; Lockwood 2009)	Cairngorms NP advisory forum provides advice on promoting inclusion of people of all abilities and backgrounds. (Lockwood 2009) In the GBRMP, Community Information Sessions were informal and non-threatening, and found to be more effective for information exchange than public meetings. (Thompson et al. 2005)
	Decision-making processes do not undermine stakeholder participation by being overly complex and bureaucratic. (Hawkes 1996)	
	All interest groups have genuine representation. (Abrams et al. 2003; Pomeroy et al. 2004)	
	Inclusion of diverse sources of information / knowledge strengthen the credibility of decisions. (Lockwood et al. 2010)	See examples under Knowledge integration and adaptation, below.

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
Costs and benefits of MPA decisions should be fairly distributed.	Direct and indirect / opportunity costs of MPAs do not fall disproportionately on one group (including future generations). (Charles and Wilson 2009; Lockwood 2009)	An independent Social, Economic and Cultural Steering Committee was formed during planning of GBRMP to assess (and minimize) impacts on existing uses. (Thompson et al. 2005)
	Users who bear costs of new rules (e.g., occupational displacement; increased travel time) are compensated. (Pomeroy et al. 2006).	Structural adjustment packages for fishers and employees impacted by rezoning of GBRMP. (Day 2011)
	Benefits flow to local resource users (also see Social system section). (Hawkes 1996; Pomeroy et al. 2006; Charles and Wilson 2009; Jones et al. 2013)	Sian Ka'an Biosphere Reserve (Mexico) provides training and accreditation for tour guides; co-management training; environmental education to school children. (Pomeroy et al. 2004) 10% of conservation fee at Tubbataha Reefs Natural Park (Philippines) goes to livelihood development in adjacent community; micro-finance, eco-tourism included in management design. (Dygico et al. 2011)
Enforcement of rules should be fair and impartial.	Rules such as those governing access rights and use prohibitions, or resource area boundaries, are clear and accessible (also see Transparency and accountability). (Graham et al. 2003; Pomeroy et al. 2004)	
	Rules are applied consistently and without discrimination. (Abrams et al. 2003; Graham et al. 2003)	
	Sanctions are graduated according to the seriousness of offense. (Ostrom 2000; Mascia 2003)	In the GBRMP "inspectors have the discretionary power to decide a course of action on a case-by-case basis," with options ranging from education or infringement notices to prosecution and high maximum penalties. (Day 2011)
	Infractions can be appealed. (Abrams et al. 2003)	
Governance processes should promote tolerance and respect.	All actors, including stakeholders and government staff, are heard and treated with respect. (Abrams et al. 2003; Graham et al. 2003; Lockwood 2009)	Participatory processes combining scientific and traditional knowledge resulted in mutual respect between stakeholders in Os Miñarzos Marine Reserve (Spain). (Perez de Oliveira 2011)
	Mutual respect is promoted between different knowledge owners. (Jones et al. 2013)	"Story place" database promotes mutual respect and collective learning with hundreds of references to indigenous / traditional owner history and management practices in GBRMP. (Day 2011) The joint-expert Clayoquot Scientific Panel was successful in part because it respected / adopted traditional Nuu-cha-nulth protocols on decision-making, cultural and spiritual teachings, and social institutions. (Lertzman 2010) Perceived lack of respect for local knowledge thought to be primary reason local fishers were unwilling to engage in the Wash & North Norfolk Coast EMS. (Jones 2011)

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
	Ethical considerations are taken into account when using / sharing aboriginal or other proprietary knowledge. Applicable protocols are adhered to. (Jessen et al. 2011)	New Zealand Coastal Policy sets out to protect areas of significance to local indigenous peoples while affirming their right to not to identify all such areas. (Department of Conservation 2010)
CAPACITY AND PERFORMANCE Governance actors should have the strategic direction, leadership, and human/financial resources to effectively and efficiently meet their objectives and responsibilities.		
Governance bodies should have clear objectives (guided by legislation and/or policy), as well as strong political support.	Leadership and commitment exist at the most senior levels of government. (Graham et al. 2003; Dickinson et al. 2010; Blue Earth Consultants 2012)	The GBRMP “benefits from considerable political will and public support, which helped to establish the strong legal framework that governs the park’s management and activities and to ensure adequate funding.” (Blue Earth Consultants 2012) Reluctance of politicians to support enforcement (despite adequate legislation) “arguably the weakest element of the Galápagos Marine Reserve governance approach that critically undermines the effectiveness of all other elements.” (Torral-Granda et al. 2011).
	Goals are developed early and linked to clear, measurable and achievable targets and timelines. (Graham et al. 2003; Dickinson et al. 2010; Jessen et al. 2011)	
	Objectives are formalized in regulations, policy statements, management plans etc. (Dickinson et al. 2010)	
	Legal and / or policy frameworks at a national level provide guidance and strategic direction (also see Legitimacy theme, above). (Dickinson et al. 2010)	An explicit mandate to create a network of MPAs meant that the MLPA Initiative “did not get bogged down by debates on the merits of MPAs.” (Gleason et al. 2013)
Organizations and individuals should have the capacities and resources to deliver on their responsibilities.	Adequate and secure funding exists for governance tasks. (Graham et al. 2003; Pomeroy et al. 2004)	In California, private sources of funding for implementing the MLPA were not subject to budget fluctuations and could be more “nimble and responsive to the needs of the process.” (Gleason et al. 2013) Years were spent developing a community-based traditional hunting management plan in the GBR (Australia), but it was not until the federal government provided the financial resources and necessary political support that the plan was implemented. (Marsh 2007)
	Managers have access to adequate and applicable information to understand (a) ecosystem function and change, and (b) human-induced problems and possible solutions. (Pomeroy et al. 2004)	
	Staff have adequate technical, financial and managerial competencies to (e.g.) identify and manage risks, engage the public, and coordinate between agencies. Training is available if needed. (Abrams et al. 2003; Graham et al. 2003; Lockwood et al. 2010)	TIDE (an NGO), which is involved in the Belize MPA network through co-management agreements with the government, hires and trains reserve rangers for patrolling and enforcement. (Blue Earth Consultants 2012)

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
Monitoring and enforcement should be effective and credible.	Adequate budget, human resources and equipment for monitoring compliance exist. (Ostrom 2000; Pomeroy et al. 2004)	Fishermen support initiative to install vessel monitoring systems (VMS) on all fishing vessels operating in / around the Wash & North Norfolk European Marine Site (EMS) as it would ensure that everyone is complying with the rules. (Jones 2011)
	MPA boundaries and rules governing resource use are clear, fostering compliance and simplifying enforcement. (Ostrom 2000; Pomeroy et al. 2006; Cox et al. 2010)	Easily delineated boundaries provide clarity (navigation, mapping) in Wash & North Norfolk Coast EMS. However, prioritizing this contributed to view that local knowledge / experience was being discounted. (Jones 2011)
	System for penalizing transgressors is effective. (Jones et al. 2013)	Perceived inefficiency of authorities at prosecuting poachers in the Isla Natividad MPA (Mexico) a cause of frustration and conflict. (Weisman and McCay 2011) Legislation governing GBRMP includes potentially very high penalties, though these are not necessarily used as tool of first opportunity. (Day 2011)
	User participation in surveillance, monitoring and enforcement is enabled. (Abrams et al. 2003; Pomeroy et al. 2004; Heck et al. 2012)	At the Sapodilla Cayes Marine Reserve (Belize) local fishers volunteer their time and are provided with training, fuel and radios to supplement monitoring by MPA staff. (Pomeroy et al. 2004)
Mechanisms should be in place to effectively and fairly resolve, manage or minimize conflict.	Mechanisms for timely, fair, and low-cost conflict resolution exist. (Hawkes 1996; Ostrom 2000; Abrams et al. 2003; Lockwood et al. 2010; Jones et al. 2013)	Stakeholders in the Seaflower MPA (Columbia) provided with conflict resolution training. (Taylor et al. 2011)
	Neutral and widely-respected third-party facilitation is employed. (Jessen et al. 2011)	
	Constructive stakeholder dialogue is enabled (see Knowledge integration and adaptation).	
COORDINATION AND COLLABORATION Government actors should communicate and collaborate effectively; rules and policy initiatives should be coordinated across scales and jurisdictions.		
Effective collaboration should exist between government agencies with overlapping jurisdictions and/or complementary mandates and goals.	Effective institutional links enable communication and cooperation vertically between agencies at different levels, and horizontally between agencies including those not directly involved in MPAs, such as tourism and marine transportation. (Charles and Wilson 2009; Lockwood 2009; Jessen et al. 2011)	Ad hoc interagency work groups provided policy and legal advice to the Marine Life Protection Act (MLPA) process. (Gleason et al. 2013) Administrative framework, communications network and standard operating procedures coordinate the policies of more than 25 local, state and federal agencies in the Florida Keys National Marine Sanctuary. (Dickinson et al. 2010)
	Bodies tasked with coordinating governance activities in ocean / coastal zones are able to affect the activities of all the agencies and levels of government involved. (Cicin-Sain and Belfiore 2005)	
	Where jurisdictions overlap or are in dispute (e.g., unresolved First Nations claims) co-management agreements are established (also see Legitimacy).	

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
	Efforts are coordinated with key actors outside government (Graham et al. 2003)	Co-management agreements between government agencies charged with MPA management and local NGOs (“multi-sectoral partnerships”) in Belize “have helped to fill vital gaps in operational capacity.” (Blue Earth Consultants 2012)
Governance rules and arrangements should be integrated and harmonized.	MPAs are not established in isolation but connected to wider programs of resource management. They are “nested” within larger planning frameworks such as integrated coastal management (ICM) or ecosystem-based management. (Ostrom 2000; Cicin-Sain and Belfiore 2005; Charles and Wilson 2009; Jessen et al. 2011)	Regional approach taken by MLPA Initiative on the California coast created “manageable” and “cohesive” planning units. (Gleason et al. 2013)
	Contradictions between rules at different governance levels are avoided (i.e. local and/or traditional, provincial, federal, and international). (Pomeroy et al. 2004)	Pre-existing plans by Dept. of Parks and Recreation rolled into new MLPA initiative (rather than being implemented independently) in order to concentrate effort on areas of highest benefit. Efforts were made to co-locate MPAs with other state and federally-designated protected areas. (Gleason et al. 2010; Saarman and Carr 2011) In the GBRMP, regulations are mirrored in state and federal waters. (Blue Earth Consultants 2012) Inconsistencies between various laws and frameworks – some emphasizing participation, and others maintaining top-down approaches, for example – seen as a cause of conflict between communities and managers in Had Cho Mai National Marine Park, Thailand. (Bennett and Dearden 2012)
	Existing local and/or informal governance systems are incorporated into management planning. The compatibility between legal (formal) and local (informal) arrangements is maximized. (Pomeroy et al. 2004; Pomeroy et al. 2006)	In Fiji, in participation with university scientists, a customary tenure area (for clam harvesting) was declared out of bounds by way of a traditional ceremony with paramount chiefs and village elders; elsewhere a reef protected area, established in the absence of legislative backing by local villagers (in cooperation with WWF), was subsequently gazetted by the national government. (Veitayaki et al. 2003) In the Solomon Islands, customary sea tenure has been used to identify locations for Bumphead parrotfish conservation, including establishment of MPAs. (Aswani and Hamilton 2004).
KNOWLEDGE INTEGRATION AND ADAPTABILITY <i>Governance processes should enable learning and integration of diverse sources of knowledge, and be responsive to changing circumstances and new information.</i>		
Decision-making should be informed by the best available knowledge.	Knowledge from scientific, traditional, site-specific and commercial sources is accessed and integrated. (Hawkes 1996; DFO 2011; Jessen et al. 2011; Jones et al. 2013)	Cultural mediators facilitated knowledge-transfer between local indigenous elders and government representatives on the Clayoquot Scientific Panel.(Lertzman 2010)

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
(…continued from previous page)	Decisions are informed by local norms and values guiding the use of marine resources. (Charles and Wilson 2009; Dickinson et al. 2010)	See “visioning through appreciative inquiry” below.
	Ongoing collaboration between managers and scientists occurs at all stages of MPA planning and management (Pomeroy et al. 2004)	Dedicated Science Advisory Team (SAT) provided MLPA planning participants with best readily available information; communication skills of scientists “improved significantly over time.” (Gleason et al. 2013)
	Research capacity is built into governance arrangements. (Cicin-Sain and Belfiore 2005; DFO 2011)	
	Decision support tools (e.g., Marxan, MarineMap) are used to facilitate stakeholder participation and knowledge integration (Jessen et al. 2011)	
	Independent advice or arbitration is provided in the case of conflicting information. (Jones et al. 2013)	
Constructive stakeholder dialogue should be facilitated in order to build trust and enable learning.	Repeated opportunities are provided for stakeholders to interact. (Dickinson et al. 2010; Jessen et al. 2011; Muro and Jeffrey 2012)	Authorities met three times with stakeholders to discuss priorities before development of management plan for North East Kent Marine Site, and every 6 months subsequent to it; contributed to sense of ownership and high level of public support. (Roberts 2011)
	Information sharing is promoted to establish a common base of understanding upon which to move processes forward. (Jessen et al. 2011)	
	Open and unrestrained thinking is promoted. (Abrams et al. 2003; Muro and Jeffrey 2012)	Visioning through appreciative inquiry used to identify values and goals of indigenous people regarding marine aquaculture development in Hawaii (NOAA 2011) and forest values of a Cree nation in Manitoba. (IISD 2001)
	Egalitarian spaces are provided in which power imbalances are neutralized. (Takeda and Røpke 2010; Muro and Jeffrey 2012)	
	Third-party facilitation and conflict management is provided if needed. (Jessen et al. 2011; Muro and Jeffrey 2012; Jones et al. 2013)	

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
Strategies and arrangements should be adaptable to new information and changing circumstances.	Governing bodies have procedures to identify, assess and manage risks. (Lockwood 2009)	The National Marine Sanctuaries Act (United States) mandates that management plans and regulations are revised “as necessary to fulfill the purposes and policies” of the act. (Etheridge et al. 2010)
	Management plans are regularly reviewed and updated. (Graham et al. 2003)	
	Monitoring, evaluations and lessons are fed back into policies and processes. (Abrams et al. 2003)	Lessons-learned evaluations and experiences from phased (regional) approach fed back into subsequent phases of the MLPA planning process. (Gleason et al. 2013)
	Governance processes can be rearranged in response to changing circumstances. (Hawkes 1996; Lockwood 2009; Dickinson et al. 2010)	Small, locally-based authority managing the Cairngorms NP perceived to have “a considerable advantage in terms of its flexibility and response capabilities” relative to larger, geographically dispersed agencies. (Lockwood 2009)
TRANSPARENCY AND ACCOUNTABILITY <i>All stakeholders should have access to information about rules/decisions, and about the performance of governance actors and processes; there should be a clear answer to the question “who is accountable to whom for what?”</i>		
Decisions and decision-making processes should be transparent.	Management plans exist and are easily understood. (Pomeroy et al. 2004)	
	Information about decisions, including the reasoning behind them, is timely, clear and provided in forms that make it accessible to all stakeholders. (Pomeroy et al. 2004; Lockwood 2009)	California MLPA meetings webcasted; with additional media broadcasts. (Gleason et al. 2013) A mix of technical and layman’s information produced and targeted to specific stakeholder groups (e.g., elected representatives, media, indigenous communities) to convey information about GBRMP zoning process. (Thompson et al. 2005)
	Publicly funded information that is relevant to decisions is made readily available. Private studies are made available by purchasing access rights or through information-sharing agreements (also relevant to Knowledge integration, above). (Jessen et al. 2011)	
Governance performance should be transparent.	Regular, independent monitoring and reporting on targets and timelines is provided. Deficiencies in progress are made clear. (Dickinson et al. 2010)	“Outlook Report” required of GBRMP Authority every 5 years, “to better inform the public about the past and present condition of the reef and to re-evaluate decisions about management.” (Dickinson et al. 2010)
	Citizens, civil society and the media can access information relevant to governance performance. (Graham et al. 2003)	
	Ecological conditions and user behaviour are monitored in order to inform future decisions (see Knowledge integration) and to underpin the credibility of rules. (Ostrom 2000)	

GUIDING PRINCIPLES	PRACTICES/STRATEGIES	INTERNATIONAL EXAMPLES
Decision makers should be accountable to stakeholders (downward accountability) as well as to higher-level authorities (upward accountability).	Roles and responsibilities, including for participants in public processes, are clearly delineated. (Dickinson et al. 2010; Jones et al. 2013)	
	Accountability is downward (i.e. governing authorities are accountable to constituents) as well as upward from lower to higher levels of authority. (Lockwood et al. 2010)	

SUMMARY OF GOVERNANCE PRINCIPLES FROM SELECTED SOURCES:

DICKINSON ET AL. (2010)

Principles for integrated marine planning:

- › Inclusive participation
- › Leadership and accountability
- › Legal framework
- › Comprehensive goals w. measurable targets
- › Effective strategy
- › Progress monitoring and reporting
- › Adaptive management
- › Adequate information
- › Adaptation to context
- › Integration

FISHERIES AND OCEANS CANADA - DFO (2011)

Guiding principles for development of Canada's network of MPAs:

- › Coherent approach
- › Respect existing rights and activities
- › Ensure open and transparent processes.
- › Take socio-economic considerations into account
- › Apply appropriate protection measures
- › Conform to best management practices

GRAHAM ET AL. (2003)

Universal / normative principles of good governance:

- › Legitimacy and voice
- › Direction
- › Performance
- › Accountability
- › Fairness

HAWKES (1996)

Criteria by which co-management can contribute to the resolution of resource conflicts:

- › Ecological and cultural protection
- › Shared information
- › Clearly defined boundaries
- › Enforcement
- › Community economic development
- › Flexibility and responsiveness
- › Conflict resolution

JESSEN ET AL. (2011)

Attributes of "good" governance relevant to the Canadian MPA Governance context:

- › Commitment
- › Accountability
- › Transparency
- › Cooperation
- › Aboriginal partnerships
- › Stakeholder engagement
- › Knowledge and social learning
- › Public awareness and support

LOCKWOOD (2009)

Principles for good protected area governance (terrestrial):

- › Legitimacy
- › Transparency
- › Accountability
- › Inclusiveness
- › Fairness
- › Connectivity
- › Resilience and adaptability

LOCKWOOD ET AL. (2010)

Governance principles for natural resource management:

- › Legitimacy
- › Transparency
- › Accountability
- › Inclusiveness
- › Fairness
- › Integration
- › Capability
- › Adaptability

OSTROM (2000)

Design principles for long-enduring common property regimes:

- › Clearly defined boundaries defining who has rights to withdraw resources and the boundaries of the common resource
- › Congruence between appropriation (restricting time, place, technology, etc.) and provision rules (requiring labor, material, and money) and local conditions
- › Collective-choice arrangements
- › Monitoring of conditions and behavior
- › Graduated sanctions depending on the seriousness of an offense
- › Conflict-resolution mechanisms
- › Minimal recognition by government authorities of rights of appropriators to organize
- › Nested enterprises with monitoring, enforcement and governance activities organized in multiple levels for common-pool resources that are part of larger systems

REFERENCES

- Abrams, P., G. Borrini-Feyerabend, J. Gardner, and P. Heylings. 2003. Evaluating governance: A handbook to accompany a participatory process for a protected area. Draft for field testing. Available online http://cmsdata.iucn.org/downloads/evaluating_governance_handbook.doc (Accessed Aug. 2014).
- Aswani, S., and R. Hamilton. 2004. Integrating indigenous ecological knowledge and customary sea tenure with marine and social science for conservation of bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands. *Environmental Conservation* 31:69-83.
- Bennett, N., and P. Dearden. 2012. From outcomes to inputs: What is required to achieve the ecological and socio-economic potential of marine protected areas? (Working Paper). Marine Protected Areas Research Group, University of Victoria. Victoria, Canada. 38pp.
- Blue Earth Consultants. 2012. From design to action – Key elements and innovations for effective MPA network implementation: Lessons from successful case studies. Blue Earth Consultants. Oakland, CA.
- Borrini-Feyerabend, G., A. Kothari, and G. Oviedo. 2004. Indigenous and local communities and protected areas: Towards equity and enhanced conservation: Guidance on policy and practice for co-managed protected areas and community conserved areas. (No. 11) World Conservation Union (IUCN). Available online <http://areasprotegidas.info/upload/document/guidelinesindigenouspeople.pdf> (Accessed Aug. 2014).
- Charles, A., and L. Wilson. 2009. Human dimensions of marine protected areas. *ICES Journal of Marine Science* 66:6-15.
- Cicin-Sain, B., and S. Belfiore. 2005. Linking marine protected areas to integrated coastal and ocean management: A review of theory and practice. *Ocean and Coastal Management* 48:847-868.
- Cox, M., G. Arnold, and S. V. Tomás. 2010. A review of design principles for community-based natural resource management. *Ecology and Society* 15:38.
- Day, J. 2011. Great Barrier Reef Marine Park – governance analysis. In P. J. S. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: Getting the balance right - Volume 2*. Technical Report to Marine & Coastal Ecosystems Branch, UNEP. 1-18.

- Department of Conservation. 2010. New Zealand Coastal Policy Statement. New Zealand Government. Wellington, NZ.
- DFO. 2011. National Framework for Canada's Network of Marine Protected Areas. Fisheries and Oceans Canada. Ottawa, Ont. Available online <http://www.dfo-mpo.gc.ca/oceans/publications/dmpaf-eczpm/framework-cadre2011-eng.asp> (Accessed Aug. 2014).
- Dickinson, M., M. Rutherford, and T. Gunton. 2010. Principles for integrated marine planning: A review of international experience. *Environments: A Journal of Interdisciplinary Studies* 37:21-46.
- Dygico, M., A. Songco, A. White, and S. Green. 2011. Tubbataha Reefs Natural Park – governance analysis. In P. J. S. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: Getting the balance right - Volume 2*. Technical Report to Marine & Coastal Ecosystems Branch, UNEP. 127-135.
- Etheridge, L., T. Bowling, and S. S. Otts. 2010. The adaptive management experience of the National Marine Sanctuaries Program. *Sea Grant Law and Policy Journal* 3:9-18.
- Gleason, M., E. Fox, S. Ashcraft, J. Vasques, E. Whiteman, P. Serpa, E. Saarman, M. Caldwell, A. Frimodig, M. Miller-Henson, J. Kirlin, B. Ota, E. Pope, M. Weber, and K. Wiseman. 2013. Designing a network of marine protected areas in California: Achievements, costs, lessons learned, and challenges ahead. *Ocean & Coastal Management* 74:90-101.
- Gleason, M., S. McCreary, M. Miller-Henson, J. Ugoretz, E. Fox, M. Merrifield, W. McClintock, P. Serpa, and K. Hottman. 2010. Science-based and stakeholder-driven marine protected area network planning: A successful case study from north central California. *Ocean and Coastal Management* 53:52-68.
- Goetze, T. 2004. Sharing the Canadian experience with co-management: Ideas, examples and lessons for communities in developing areas. . Working Paper 15, Rural Poverty and the Environment Working Paper Series. Ottawa: International Development Research Centre.
- Government of Canada. 2000. Canada National Parks Act. Department of Justice, Legislative Services Branch, Ottawa, Ont. Available online <http://laws-lois.justice.gc.ca/eng/acts/N-14.01/> (Accessed Aug. 2014).
- Graham, J., B. Amos, and T. W. Plumptre. 2003. Governance principles for protected areas in the 21st century. Prepared for the Fifth World Parks Congress, Durban, South Africa. Institute on Governance. Available online http://mercury.ethz.ch/serviceengine/Files/ISN/122197/ipublicationdocument_singledocument/638144bd-f4ba-4324-9c83-b63ac434726e/en/pa_governance2.pdf (Accessed Aug. 2014).
- Green, S., A. White, P. Christie, S. Kilarski, B. Meneses, G. Samonte-Tan, L. Bunce Karrer, H. Fox, S. Campbell, and J. Claussen. 2011. Emerging marine protected area networks in the coral triangle: Lessons and way forward. *Conservation and Society* 9:173-188.
- Hawkes, S. 1996. The Gwaii Haanas Agreement: From conflict to cooperation. *Environments* 23:87-100.
- Heck, N., P. Dearden, and A. McDonald. 2012. Stakeholder evaluation priorities for demonstrating marine protected area effectiveness at the Pacific Rim National Park Reserve, Canada. *Coastal Management* 40:55-72.
- IISD. 2001. Integrating aboriginal values into land-use and resource management., Third Quartly Report by the International Institue for Sustainable Development. Winnipeg. 46pp.
- Jessen, S., K. Chan, I. Côté, P. Dearden, E. De Santo, M. Fortin, F. Guichard, W. Haider, G. Jamieson, D. Kramer, A. McCrea-Strub, M. Mulrennan, W. Montevocchi, J. Roff, A. Saloman, J. Gardner, L. Honka, R. Menafr, and A. Woodley. 2011. Science-based guidelines for MPAs and MPA networks in Canada. Canadian Parks and Wilderness Society. Vancouver, B.C. 58pp.
- Jones, P. 2011. The Wash & North Norfolk Coast European Marine Site – governance analysis. In P. Jones, W. Qiu, and E. De Santo (Editors), *Governing Marine Protected Areas: getting the balance right - Volume 2*. Technical Report to Marine & Coastal Ecosystems Branch, UNEP. 40-59.
- Jones, P., E. De Santo, W. Qiu, and O. Vestergaard. 2013. Introduction: An empirical framework for deconstructing the realities of governing marine protected areas. *Marine Policy* 41:1-4.
- Lertzman, D. 2010. Best of two worlds: Traditional ecological knowledge and western science in ecosystem-based management. 10:104-126.
- Lockwood, M. 2009. Governance assessment of terrestrial protected areas: A framework and three case studies. University of Tasmania. Available online [http://www.geog.utas.edu.au/geography/nrmgovernance/Documents/Lockwood 2009.pdf](http://www.geog.utas.edu.au/geography/nrmgovernance/Documents/Lockwood%202009.pdf) (Accessed Aug. 2014).
- Lockwood, M., J. Davidson, A. Curtis, E. Stratford, and R. Griffith. 2010. Governance principles for natural resource management. *Society and Natural Resources* 23:986-1001.
- Marsh, H. 2007. Progress towards the cooperative management of marine hunting in the Great Barrier Reef. In T. McClanahan and J. Castilla (Editors), *Fisheries Management: Progress Towards Sustainability*. Blackwell. 186-203.
- Mascia, M. 2003. The human dimension of coral reef marine protected areas: Recent social science research and its policy implications. *Conservation Biology* 17:630-632.
- Muro, M., and P. Jeffrey. 2012. Time to talk? How the structure of dialog processes shapes stakeholder learning in participatory water resources management. *Ecology & Society* 17.
- NOAA. 2011. Visioning the future of aquaculture in Hawaii; Workshop, Jun 27. University of Hawaii Aquaculture Program. National Ocean and Atmospheric Administration. Manoa. 62pp.
- Ostrom, E. 2000. Collective action and the evolution of social norms. *Journal of Economic Perspectives* 14:137-158.

- Perez de Oliveira, L. 2011. Marine reserves of fishing interest – governance analysis. In P. Jones, W. Oiu, and E. De Santo (Editors), *Governing Marine Protected Areas: Getting the balance right - Volume 2. Technical Report to Marine & Coastal Ecosystems Branch UNEP*. 147-155.
- Pomeroy, R., M. Mascia, and R. Pollnac. 2006. Marine protected areas the social dimension. Expert workshop on marine protected areas and fisheries management: Review of issues and considerations. Food and Agricultural Organization (FAO)
- Pomeroy, R., J. Parks, and L. Watson. 2004. How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness. World Conservation Union (IUCN).
- Roberts, T. 2011. North East Kent European Marine Site - governance analysis. In P. Jones, W. Qiu, and E. De Santo (Editors), *Governing Marine Protected Areas: getting the balance right - Volume 2. Technical Report to Marine & Coastal Ecosystems Branch, UNEP*. 31-39.
- Saarman, E., and M. Carr. 2011. The California Marine Life Protection Act MPA Network - governance analysis. In P. J. S. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: getting the balance right - Volume 2. Technical Report to Marine & Coastal Ecosystems Branch, UNEP, Nairobi*. 65-75.
- Takeda, L., and I. Røpke. 2010. Power and contestation in collaborative ecosystem-based management: The case of Haida Gwaii. *Ecological Economics* 70:178-188.
- Taylor, E., M. Baine, M. Howard, and A. Killmer. 2011. Seaflower Marine Protected Area; governance analysis. In P. J. S. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: Getting the balance right – Volume 2. Technical Report to Marine & Coastal Ecosystems Branch, UNEP*. 87-96.
- Thompson, L., B. Jago, L. Fernandes, and J. Day. 2005. Barriers to communication: How these critical aspects were addressed during the public participation for the rezoning of the Great Barrier Reef Marine Park. Staff Paper. Great Barrier Reef Marine Park Authority, Townsville, Australia. Available online http://www.gbrmpa.gov.au/__data/assets/pdf_file/0019/6175/Breaking_through_the_barriers_15April0420FINAL.pdf (Accessed Aug. 2014).
- Toral-Granda, V., A. Hearn, S. Henderson, and P. J. S. Jones. 2011. Galapagos Marine Reserve - governance analysis. In P. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: getting the balance right. Volume 2. Technical Report to Marine & Coastal Ecosystems Branch, UNEP, Nairobi*. 97-104.
- Veitayaki, J., B. Aalbersberg, A. Tawake, E. Rupeni, and K. Tabunakawai. 2003. Mainstreaming resource conservation: The Fiji Locally Managed Marine Area Network and its influence on national policy development.
- Weisman, W., and B. McCay. 2011. Isla Natividad Marine Protected Area – governance analysis. In P. J. S. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: getting the balance right – Volume 2. Technical Report to Marine & Coastal Ecosystems Branch, UNEP*. 156-163.

APPENDIX F: ASSESSMENT OF MARINE PLANNING POLICY DOCUMENTS USING GOVERNANCE PRINCIPLES AND GUIDELINES

The following documents are assessed below using the Governance Principles (Appendix E).

1. Canada – British Columbia Marine Protected Area Network Strategy (2014)
2. Letter of intent to collaborate on coastal and marine planning in the Pacific North Coast
3. West Coast Aquatic (WCA) Management Board – Governance document
4. Memorandum of Understanding on Pacific North Coast Integrated Management Area (PNCIMA) Collaborative Oceans Governance

Acronyms used in tables below:

- › AMB – Aquatic Management Board
 - › CFN – Coastal First Nations
 - › CCFN – Central Coast First Nations
 - › DFO – Department of Fisheries and Oceans / Fisheries and Oceans Canada
 - › MOU – Memorandum of Understanding
- › MPA – Marine Protected Area
 - › NCSFNSS – North Coast - Skeena First Nations Stewardship Society
 - › PNCIMA – Pacific North Coast Integrated Management Area
 - › WCA – West Coast Aquati

1. Canada – British Columbia Marine Protected Area Network Strategy (Canada and British Columbia 2014)

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
LEGITIMACY <i>Rule makers and governance procedures should be legitimate; legitimacy can be earned as well as conferred</i>		
The authority of actors / organizations to govern should be conferred through valid and credible institutions and clear legal frameworks.	<p>“Canada’s Oceans Act directs multi-agency collaboration and coordination on broad oceans management, including marine protected areas” (p. 5).</p> <p>“In British Columbia, MPA network planning will play an important role in fulfilling government mandates (p. 5).</p> <p>“The role of MPAs in advancing progress towards meeting international, national and regional commitments and agreements is also driving governments’ desire to formalize their approach to network planning” (p. 5).</p>	
Existing rights and authorities in the area should be affirmed and respected, including those of aboriginal groups.	<p>“Network planning must also recognize the legal obligations and commitments to First Nations in regards to decision-making (e.g. British Columbia’s New Relationship approach to shared decision-making)” (p. 22).</p> <p>“The approach to network planning is meant to build collaboration and partnerships; it is not intended to fetter the statutory responsibility or authority, nor the interests and obligations of any governments to establish or manage such areas” (p. 6).</p>	<p>“The special relationship between the Crown and First Nations will be provided for; both governments will respect the continued use of MPAs by First Nations for food, social and ceremonial purposes and other traditional practices, provided that these uses are consistent with the objectives for the MPA. The establishment of any MPA will not affect ongoing or future treaty negotiations or agreements” (p. 17).</p>

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
Public awareness and support should be cultivated.	<p>Goal #6: "To provide opportunities for scientific research, education and awareness." (p. 9).</p> <p>"There is still a significant need for public education to instill greater awareness of the role everyone can play in the conservation of marine environments" (p. 13).</p>	<p>"Recreation, tourism and education activities that are consistent with the objectives of an MPA may be permitted, facilitated or promoted, improving public awareness, understanding and appreciation of Canada's marine heritage." (p. 11).</p>
INCLUSION AND FAIRNESS <i>Stakeholders should be meaningfully engaged at all stages of planning and implementation; costs, benefits and regulatory enforcement should be fair</i>		
Governance processes should be inclusive of all stakeholders.	<p>"Government agencies will provide meaningful opportunities for participation, consultation, and information exchange with marine stakeholders, coastal communities and the public from early planning stages through to design and implementation" (p. 1).</p>	<p>"Implementation plans may be developed at the bioregional scale in collaboration with First Nations, and with input from local governments and stakeholders to allow for the development of approaches that respect the unique ecological, socio-political, economic, and cultural characteristics found in different regions of coastal British Columbia" (p. 24).</p> <p>"New governance frameworks may need to be developed or modified where [existing processes] do not exist or where they are not inclusive of key partners" (p. 22).</p>
Costs and benefits of governance arrangements should be fairly distributed.	<p>"MPA network planning will include identification of opportunities to contribute positively to protection of sustainable socioeconomic activities, and cultural and spiritual values" (p. 15).</p> <p>"MPA network design should ... balance conservation objectives with social and economic opportunities" (p. 17).</p> <p>"The establishment of any MPA will ... seek to address opportunities for First Nations to benefit from MPAs" (p. 17).</p>	<p>"Economic analyses can identify design measures that maximize conservation success while minimizing costs" (p. 17).</p> <p>"The availability of various designation options provides additional opportunity to customize the level of protection to achieve goals and objectives for an area while minimizing impact on human activities" (p. 17).</p> <p>"Where there is a choice of several sites, which if protected would add a similar ecosystem or habitat to the MPA network, the site(s) chosen should minimize adverse impacts on existing users" (p. 17).</p>
Enforcement of rules should be fair and impartial.		
Governance processes should promote tolerance and respect.		

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
CAPACITY AND PERFORMANCE <i>Governance actors should have the strategic direction, leadership, and human / financial resources to effectively and efficiently meet their objectives and responsibilities.</i>		
Governance bodies should have clear objectives (guided by legislation and/or policy), as well as strong political support.	<p>"The primary goal for BC's network of MPAs (is) to protect and maintain marine biodiversity, ecological representation, and special natural features" (p. 15).</p> <p>"Canada's Oceans strategy ... provides the overall strategic framework for Canada's oceans-related programs and policies, commits federal governments with complementary protected area mandates to identify areas of interest for MPAs" (p. 5).</p>	"...Canada has agreed to [CBD] Target 11, which commits parties to conserve by 2020, 'at least ... 10% of coastal and marine areas ...' (p. 5).
Organizations and individuals should have the capacities and resources to deliver on their responsibilities.	"Funding requirements should be identified at the bioregional, or finer scale" (p. 25).	
Monitoring and enforcement should be effective and credible.	<p>MPA networks "will incorporate design elements that help to ensure effective and cost efficient management, enforcement and compliance to achieve network goals and safeguard the public's investment" (p. 17).</p> <p>"To be considered for inclusion in a network, it must be demonstrated that a given MPA ... has a management plan or protection guidance explicitly specified in supporting legislation or regulations and is being effectively managed for achievement of the MPA network goals" (p. 7).</p>	<p>"Partnerships with and among First Nations, local authorities, stakeholders, coastal communities, and resource users will be key to success" (p. 17).</p> <p>"Managing authorities should work in partnership with First Nations and others to develop and employ appropriate scientific skills, tools and training to systematically monitor MPAs and MPA networks" (p. 27).</p>
Mechanisms should be in place to effectively and fairly resolve, manage or minimize conflict.	"MPA network design should strive to minimize user conflict" (p. 17).	
COORDINATION AND COLLABORATION <i>Government actors should communicate and collaborate effectively; rules and policy initiatives should be coordinated across scales and jurisdictions.</i>		
Effective collaboration should exist between government agencies with overlapping jurisdictions and/or complementary mandates and goals.	<p>"The approach to network planning is meant to build collaboration and partnerships" (p. 6).</p> <p>"Government agencies responsible for implementation will coordinate their efforts" (p. 17).</p> <p>"A multi-agency, systematic approach will provide regional consistency for planning and establishing new MPAs" (p. 6).</p>	<p>2004 MOU between Canada and BC provides "for further collaboration among the parties to advance the implementation of specific activities and objectives identified in Canada's Oceans strategy" (p. 5).</p> <p>"The Strategy has been developed jointly by federal and provincial agencies and reflects the need for governments to work together to achieve common marine protection and conservation goals" (p. 1).</p>

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
<p>Governance rules and arrangements should be integrated and harmonized.</p>	<p>The strategy “will ... complement more traditional management tools” (p. 1).</p> <p>“MPA network planning will take into account the broader movement towards ecosystem-based management (EBM) of marine areas (p. 19).</p> <p>“Governments will seek opportunities to capitalize on existing federal and provincial MPAs and other spatially defined conservation measures to achieve network goals and objectives” (p. 19).</p> <p>“MPA networks must build upon both formal arrangements, and informal interactions and norms between many different parties that are in place or developing on the Pacific coast” (p. 22).</p>	<p>Pacific Region’s network of MPAs will be composed of a number of smaller networks based on four high-level spatial units or ‘bioregions’ (p. 20). Consideration should be given to the network objectives of adjoining bioregions to ensure a measure of coast-wide consistency” (p. 26).</p> <p>Existing First Nations, local, provincial, or federal ocean and/or coastal management processes or integrated marine spatial planning initiatives can serve as a venue for discussion and/or collaborative recommendations (p. 22).</p> <p>“Existing governance structures should be adopted or expanded as appropriate” (p. 25).</p>
<p>KNOWLEDGE INTEGRATION AND ADAPTABILITY <i>Governance processes should enable learning and integration of diverse sources of knowledge, and be responsive to changing circumstances and new information.</i></p>		
<p>Decision-making should be informed by the best available knowledge.</p>	<p>MPA network planning will be informed by information relating to ecological, environmental, social, cultural and economic aspects of the marine environment that is available without unreasonable cost, effort, or time” (p. 26).</p> <p>“This approach will allow for the flexibility needed to develop objectives that derive from local conservation and sustainability concerns” (p. 13).</p> <p>“Functional networks of MPAs will recognize the fundamental relationship between the environment and human activities, cultures and values, requiring an understanding of the value of ecosystem goods and services as well as the intensity and pattern of human uses across time and space.” (p. 15).</p>	<p>“Network design should take advantage of best available knowledge (e.g. traditional, local and scientific), bio-economic models and decision support tools (e.g. MARXAN) to support MPA site selection in order to reduce potential conflicts and ensure more equitable distribution of the costs and benefits of conservation between communities and user” (p. 17).</p> <p>“Network objectives that reflect ecological, social, economic, cultural and practical considerations should be developed in collaboration with local First Nations and with input from other invested and informed parties who are best placed to understand the characteristics and circumstances that are unique to each bioregion” (p. 25).</p>
<p>Constructive stakeholder dialogue should be facilitated in order to build trust and enable learning.</p>	<p>“Government agencies will provide meaningful opportunities for participation, consultation, and information exchange with marine stakeholders, coastal communities and the public from early planning stages through to design and implementation” (p. 1).</p>	
<p>Strategies and arrangements should be adaptable to new information and changing circumstances.</p>	<p>“Including adaptive strategies (i.e. learning by doing) in MPA network planning processes allows for adjustments in management approach and/or alterations to protected area boundaries as science evolves and the dynamics of the marine environment change. In addition, flexibility and adaptability will be required to effectively and efficiently consider the interests of marine resource users now, and into the future” (p. 19).</p>	<p>“Increased monitoring should lead to increased knowledge about MPAs and networks, which can then enable an adaptive management approach” (p. 27).</p>

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
TRANSPARENCY AND ACCOUNTABILITY <i>All stakeholders should have access to information about rules / decisions, and about the performance of governance actors and processes; there should be a clear answer to the question “who is accountable to whom for what?”</i>		
Decisions and decision-making processes should be transparent.	“Government agencies responsible for implementation will ... ensure that the process and flow of information is transparent and accessible” (p. 17).	
Governance performance should be transparent.	“Objectives should be easily understood, written in terms of what will be accomplished to attain a related goal, realistically achievable, time bound, and measurable. It should be easy to associate objectives with management actions and measurable outcomes” (p. 25).	“At a minimum, management plans should clearly define the purpose of the MPA, its goals and objectives and the actions to be taken to achieve goals and objectives. Plans should be subject to periodic review to assess effectiveness of the management regime in place as well as the site’s contribution to network goals and objectives. (p. 27).
Decision makers should be accountable to stakeholders (downward accountability) as well as to higher-level authorities (upward accountability).		

2. Letter of Intent (LOI) to Collaborate on Coastal and Marine Planning in the Pacific North Coast (FLNRO et al. 2011)

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
LEGITIMACY <i>Rule makers and governance procedures should be legitimate; legitimacy can be earned as well as conferred</i>		
The authority of actors / organizations to govern should be conferred through valid and credible institutions and clear legal frameworks.		<p>Authority and responsibility is exercised, through an Executive Committee, which “will be comprised of a senior representative(s) from the Province and senior representatives from each of the Coastal First Nations-Great Bear Initiative, North Coast Skeena First Nations Stewardship Society and the Nanwakalos Council (p. 5).</p> <p>“This Letter of Intent, and the implication thereof, is to be informed by the following: Coastal First Nations Reconciliation Protocol (2010), Kunst’aa Guu – Kunst’aayah Reconciliation Protocol (2009), the Nanwakolas / British Columbia Framework Agreement (2009) & the Nanwakolas Reconciliation Protocol (2011)” (p. 4).</p>
Existing rights and authorities in the area should be affirmed and respected, including those of aboriginal groups.	“For the purpose of collaborative planning, the Parties intend to work together, irrespective of jurisdiction, treaty, rights and title issues, in the interests of arriving at the best decisions ... Neither this document, nor any act performed in connection with it, are to be used, construed or relied on by anyone as evidence, acceptance or admission of the existence, nature, scope or content of any Treaty or Aboriginal Rights or Title and Crown Rights or Title” (p. 4).	See above.
Public awareness and support should be cultivated.		See Inclusion and Fairness, below.
INCLUSION AND FAIRNESS <i>Stakeholders should be meaningfully engaged at all stages of planning and implementation; costs, benefits and regulatory enforcement should be fair</i>		
Governance processes should be inclusive of all stakeholders.	“The Parties intend to undertake stakeholder and public engagement with respect to sub-regional coastal and marine planning ... based on the principles of openness, transparency, inclusiveness, responsiveness and informed input” (p. 3).	“Public and stakeholder engagement ... may include tools such as advisory committees, open houses, bilateral sessions, and a central website” (p. 7).
Costs and benefits of governance arrangements should be fairly distributed.		

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
Enforcement of rules should be fair and impartial.		
Governance processes should promote tolerance and respect.		
CAPACITY AND PERFORMANCE <i>Governance actors should have the strategic direction, leadership, and human / financial resources to effectively and efficiently meet their objectives and responsibilities.</i>		
Governance bodies should have clear objectives (guided by legislation and/or policy), as well as strong political support.	"The role of the Executive Committee is to exchange information and resolve strategic issues" (p. 5). "The role of the four sub-regional Technical Teams will be to develop individual sub-regional plans" ... "The role of the Marine Coordination Team is to promote consistency in the work of the four sub-regional teams" (p. 6).	
Organizations and individuals should have the capacities and resources to deliver on their responsibilities.	"The Parties intend to work with external funders to modify the original, existing PNCIMA funding agreement ... to provide for common administrative support, technical and scientific support, stakeholder support, and public communications programs" (pp. 6-7).	
Monitoring and enforcement should be effective and credible.		
Mechanisms should be in place to effectively and fairly resolve, manage or minimize conflict.	"Where areas of disagreement exist, the Parties intend to seek appropriate conflict resolution processes or agree to disagree" (p. 4).	
COORDINATION AND COLLABORATION <i>Government actors should communicate and collaborate effectively; rules and policy initiatives should be coordinated across scales and jurisdictions.</i>		
Effective collaboration should exist between government agencies with overlapping jurisdictions and/or complementary mandates and goals.	"The Parties intend to collaborate on all planning products ... and share information relevant to the planning process and outputs, where appropriate" (p. 4).	"If any of the Parties continue to engage in the PNCIMA planning process, then the Executive Committee representatives of those Parties will be responsible for liaising with federal ministers and/or senior officials related to (PNCIMA) ... (and) Marine Working Group representatives of those Parties are responsible for representing (the Parties) on the existing PNCIMA Steering Committee" (p. 6).

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
Governance rules and arrangements should be integrated and harmonized.	"The Parties intend to ... integrate collaborative marine planning with the protocols and agreements identified" (p. 4).	The Parties will respect each others' decision making structures and authorities, and intend to extent possible, make joint recommendations to their respective executive / leadership" (p. 4) "The parties intend to develop a broadier regional planning document that may serve as a basis for informing the ongoing PNCIMA planning process" (p. 3).
KNOWLEDGE INTEGRATION AND ADAPTABILITY <i>Governance processes should enable learning and integration of diverse sources of knowledge, and be responsive to changing circumstances and new information.</i>		
Decision-making should be informed by the best available knowledge.		"The Parties intend to establish an independent marine science and technical committee ... to provide advice on sub-regional, regional and PNCIMA reports, studies and draft products" (p. 7).
Constructive stakeholder dialogue should be facilitated in order to build trust and enable learning.	"The Parties intend to undertake stakeholder and public engagement with respect to sub-regional coastal and marine planning ... based on the principles of openness, transparency, inclusiveness, responsiveness and informed input" (p. 3).	"Public and stakeholder engagement ... may include tools such as advisory committees, open houses, bilateral sessions, and a central website" (p. 7).
Strategies and arrangements should be adaptable to new information and changing circumstances.		
TRANSPARENCY AND ACCOUNTABILITY <i>All stakeholders should have access to information about rules / decisions, and about the performance of governance actors and processes; there should be a clear answer to the question "who is accountable to whom for what?"</i>		
Decisions and decision-making processes should be transparent.		
Governance performance should be transparent.		
Decision makers should be accountable to stakeholders (downward accountability) as well as to higher-level authorities (upward accountability).		Roles and responsibilities are outlined for Executive Committee, Marine Working Group, Sub-regional Technical Teams, and Marine Coordination Team (pp. 4-6).

3. West Coast Aquatic (WCA) Management Board – Governance document (WCA 2012))

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
LEGITIMACY <i>Rule makers and governance procedures should be legitimate; legitimacy can be earned as well as conferred</i>		
The authority of actors / organizations to govern should be conferred through valid and credible institutions and clear legal frameworks.		<p>"Government members on the Aquatic Management Board (AMB) will be appointed by each of the Governments of Canada, the Province of British Columbia, Nuu-chah-nulth Tribal Council, and regional districts." "The (AMB) will be subject to the final decision making authority of the responsible ministers of the governments of Canada and British Columbia, as set out by law" (p. 2).</p> <p>Shared decision-making does not fetter the discretion or affect the legal authority of the participating governments (p. 7).</p> <p>"Board members are obliged to use the Board's principles and objectives as the primary means for evaluating proposed agreements, though this does not need to be formally done in all cases" (p. 8).</p>
Existing rights and authorities in the area should be affirmed and respected, including those of aboriginal groups.		The management board's composition and shared decision-making process affirms the authorities of federal, provincial, aboriginal and local district governments. The Nuu-chah-nulth Tribal Council is recognized as a government actor.
Public awareness and support should be cultivated.	"Management committees are forums for inclusive public and/or stakeholder participation, as defined in the Board's Terms of Reference..." (p. 4)	
INCLUSION AND FAIRNESS <i>Stakeholders should be meaningfully engaged at all stages of planning and implementation; costs, benefits and regulatory enforcement should be fair</i>		
Governance processes should be inclusive of all stakeholders.	"WCA's purpose is to provide a forum where communities and other bodies can participate more effectively with governments for the integrated management of aquatic resources in the WCVI area" (p. 3).	<p>"The (Management) Board is founded on a shared decision-making process ... (which) means that on a certain set of issues, for a defined period of time, those with authority to make a decision and those who will be affected by that decision will jointly seek an outcome that accommodates the interests of all concerned (p. 7).</p> <p>"8 non-government members will be jointly appointed (to AMB) by the governments pursuant to nominations solicited from coastal communities and other persons and bodies affected by aquatic resource management in the management area... Non-government members will be generally representative of the diverse geography and range of aquatic resource interests in the management area" (p. 3).</p> <p>"Management committees are forums for inclusive public and/or stakeholder participation" (p. 4).</p>

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
Costs and benefits of governance arrangements should be fairly distributed.		
Enforcement of rules should be fair and impartial.		
Governance processes should promote tolerance and respect.		"Members' conduct and language must be free from any discrimination or harassment ... conduct should be, courteous, dignified and respectful towards other people's or species' basic needs and interests" (p. 9).
CAPACITY AND PERFORMANCE <i>Governance actors should have the strategic direction, leadership, and human / financial resources to effectively and efficiently meet their objectives and responsibilities.</i>		
Governance bodies should have clear objectives (guided by legislation and/or policy), as well as strong political support.	WCA's purpose and decision approach require ... strong commitment from participants (p. 1).	
Organizations and individuals should have the capacities and resources to deliver on their responsibilities.		<p>"The governments will resource administrative costs and core activities of the Board, subject to an appropriation being available for that purpose in the relevant fiscal year" (p. 2).</p> <p>"The Board will be supported by an administrative secretariat" (p. 3).</p>
Monitoring and enforcement should be effective and credible.		
Mechanisms should be in place to effectively and fairly resolve, manage or minimize conflict.		"Should the members of the Board or a management committee reach a consensus on a set of recommendations that resolves most but not all of the issues that are being addressed, they will actively seek agreement on a statement describing the areas of disagreement, any lack of information or data that prevents such agreement and, where possible, a process for achieving agreement" (p. 6).

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
COORDINATION AND COLLABORATION <i>Government actors should communicate and collaborate effectively; rules and policy initiatives should be coordinated across scales and jurisdictions.</i>		
Effective collaboration should exist between government agencies with overlapping jurisdictions and/or complementary mandates and goals.		<p>"The members of the Board and its management committees will make decisions by consensus" (p. 6). "Board members will encourage their agencies and related groups to work through the Board's consensus based process rather than work positionally or unilaterally" (p. 10).</p>
Governance rules and arrangements should be integrated and harmonized.		
KNOWLEDGE INTEGRATION AND ADAPTABILITY <i>Governance processes should enable learning and integration of diverse sources of knowledge, and be responsive to changing circumstances and new information.</i>		
Decision-making should be informed by the best available knowledge.		
Constructive stakeholder dialogue should be facilitated in order to build trust and enable learning.	<p>"The members of the Board and its management committees are expected to seek integrated outcomes based on interests ... rather than positions and demands ... This approach ... is designed to produce innovative solutions to problems and strengthen understanding and relationships between the parties" (p. 1).</p>	<p>"Members (of the AMB) will seek to...listen carefully, ask pertinent questions and educate themselves regarding the interests of other members whether or not they are in agreement with them; identify solutions that meet the interests of the other members as well as their own... The members of the Board and its management committees will allow each other the freedom to test ideas without prejudice to future discussion or negotiations and will not hold tentative ideas or exploratory suggestions against those who made them" (p. 7).</p> <p>"Members must not reveal or divulge confidential information" (p. 9).</p>
Strategies and arrangements should be adaptable to new information and changing circumstances.		

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
TRANSPARENCY AND ACCOUNTABILITY <i>All stakeholders should have access to information about rules / decisions, and about the performance of governance actors and processes; there should be a clear answer to the question “who is accountable to whom for what?”</i>		
Decisions and decision-making processes should be transparent.		
Governance performance should be transparent.		
Decision makers should be accountable to stakeholders (downward accountability) as well as to higher-level authorities (upward accountability).		<p>“Statutory authorities will provide timely, written responses to the Board’s recommendations” (p. 2).</p> <p>“Agreement [to Board or management committee decisions] obliges members to strongly represent the benefits of the agreement to their constituents” ... [If] a member withholds agreement that member is re-sponsible for explaining how its interests are adversely affected or how the proposed agreement fails to meet those interests. The member withholding agreement must propose alternatives and the other members must consider how all interests may be met” (p. 6).</p> <p>“Members are expected to act at all times in good faith ... (and) to regularly attend meetings and to adequately prepare for the duties expected” (p. 8).</p> <p>“Work on the board should not result in any direct personal or private financial or other substantive gain” (p. 9).</p> <p>“Members will not agree to anything that they do not believe will be supported by their constituencies” (p. 6).</p>

4. Memorandum of Understanding on Pacific North Coast Integrated Management Area (PNCIMA) Collaborative Oceans Governance - between the Department of Fisheries and Oceans and First Nations of the Pacific North Coast (DFO et al. 2008)

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
LEGITIMACY <i>Rule makers and governance procedures should be legitimate; legitimacy can be earned as well as conferred</i>		
The authority of actors / organizations to govern should be conferred through valid and credible institutions and clear legal frameworks.	<p>"The Parties recognize that they each bring authorities and mandates to the PNCIMA initiative and they will respect, and will together benefit from, those authorities and mandates" (p. 7).</p>	<p>"DFO has a mandate through the Oceans Act and Canada's Oceans Strategy to implement initiatives which establish institutional governance mechanisms ... implement integrated management planning ... (and) promote stewardship and public awareness. The CFN and NCSFNSS have a mandate on behalf of their member First Nations to coordinate and develop an integrated marine use planning process ... (to) maximize benefits of marine resources and areas while preserving ecological integrity, economies and the well being of coastal people" (p. 1).</p>
Existing rights and authorities in the area should be affirmed and respected, including those of aboriginal groups.	<p>"The Parties recognize that they each bring authorities and mandates to the PNCIMA initiative and they will respect, and will together benefit from, those authorities and mandates in the PNCIMA process" (p. 7).</p> <p>"Aggregate bodies create a mechanism through which integrated management discussions can take place, but they do not alter any relationship or obligation that federal or provincial governments have with individual First Nations" (p. 6).</p> <p>"The PNCIMA initiative reflects a relationship between the federal and First Nations governments that is of a different character than that between governments and stakeholders" (p. 7). "Alternative approaches may need to be considered if [some] First Nations choose not to participate (in PNCIMA process)" (p. 8).</p> <p>"Efforts (will) be made to include BC in a governance model in the future" (p. 2).</p>	<p>"Communication [between governments and First Nations] may take place through aggregate groupings, although in some cases it will take place through bilateral discussions with individual First Nations" (p. 8).</p>
Public awareness and support should be cultivated.		

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
INCLUSION AND FAIRNESS <i>Stakeholders should be meaningfully engaged at all stages of planning and implementation; costs, benefits and regulatory enforcement should be fair</i>		
Governance processes should be inclusive of all stakeholders.	"A diversity of stakeholder interests will be included and engaged in a meaningful way" (p. 7).	<p>A PNCIMA forum could be used to provide a mechanism for (all) interests to come together ... Working groups will be struck to examine specific issues ... [a] Stakeholder Advisory Committee (SAC) would provide leadership and coordination among stakeholder participants ... [and] work to develop consensus as a basis for effective stakeholder participation (p. 11).</p> <p>In order to support participation from stakeholders in remote geographic locations alternative options for meetings like telephone or videoconferences would be encouraged (p. 12).</p>
Costs and benefits of governance arrangements should be fairly distributed.	"The CFN and NCSFNSS have a mandate ... (to) maximize benefits of marine resources and areas while preserving ecological integrity, economies and the well being of coastal people" (p. 1).	
Enforcement of rules should be fair and impartial.		
Governance processes should promote tolerance and respect.		
CAPACITY AND PERFORMANCE <i>Governance actors should have the strategic direction, leadership, and human / financial resources to effectively and efficiently meet their objectives and responsibilities.</i>		
Governance bodies should have clear objectives (guided by legislation and/or policy), as well as strong political support.	"DFO has a mandate through the Oceans Act and Canada's Oceans Strategy to implement initiatives" (p. 1).	"The Steering Committee will ... provide strategic direction and executive oversight to the bilateral (Federal government and First nations) process" (p. 9).
Organizations and individuals should have the capacities and resources to deliver on their responsibilities.		<p>"Support for these processes may come from funding provided through (DFO), through a number of programs (...), or through outside revenue or funding generated by individual or aggregate groups of First Nations ... The extent of government financial support for these processes will be related to the availability of funds, and will need to be negotiated between the parties over time" (p. 8).</p> <p>"Many First Nations have developed local marine capacity, supported by a community and/or regional level planning team" (p. 8).</p>

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
Monitoring and enforcement should be effective and credible.		
Mechanisms should be in place to effectively and fairly resolve, manage or minimize conflict.	"Co-chairs should have the ability to be neutral when dealing with issues among multiple sectors or parties, have the confidence and respect of the members, and be able to resolve conflict and move a diverse group toward consensus" (p. 12).	
COORDINATION AND COLLABORATION <i>Government actors should communicate and collaborate effectively; rules and policy initiatives should be coordinated across scales and jurisdictions.</i>		
Effective collaboration should exist between government agencies with overlapping jurisdictions and/or complementary mandates and goals.	<p>"Federal/Provincial collaboration will be critical to the success of the PNCIMA initiative" (p. 8).</p> <p>"Integrated management is expected to enhance communications and create linkages, especially in instances where decision-making would clearly benefit from increased coordination and communication between federal, provincial and First Nations governments, along with stakeholders. Mechanisms for meeting these governance objectives may vary among different scales and within different units" (p. 6).</p>	<p>"Under this agreement the Province of BC is not identified as a formal participant in the PNCIMA work" "Various forums or processes exist for securing federal/provincial collaboration ... [and] Once the sub-MOU (re. Canada/BC MOU Respecting the Implementation of Canada's Oceans Strategy on the Pacific Coast of Canada) is completed it will provide advice (on planning)" (pp. 8-9).</p> <p>"An opportunity for more efficient dialogue and collaborative management is created when First Nations participate in aggregate groups" (p. 6).</p> <p>"Federal government representatives will meet regularly with representatives of aggregate groupings of PNCIMA First Nations governments" through a Bilateral Steering Committee and Secretariat (p. 9). "The BC government will be invited to provide observer representation [on the bilateral Steering Committee / Secretariat]" (p. 9)</p> <p>Many First Nations are working cooperatively to share technical support, pursue harmonized planning, and to select PNCIMA First Nations Governance Committee representatives (p. 8).</p>
Governance rules and arrangements should be integrated and harmonized.	"The model developed for Integrated Management and Coastal Planning within PNCIMA needs to link to the larger Integrated Management approach for Canada and Canada's Pacific waters and to planning objectives of the First Nations; to various scales of ocean/marine planning, and is expected to link with terrestrial Integrated Management initiatives. It is recognized that within PNCIMA there will be processes that will operate at smaller scales" (p. 5).	" Aboriginal Aquatic Resource and Oceans Management (AAROM) bodies ... have been developed at the Geographic Management Area (GMA) scale" (p. 8).

GUIDING PRINCIPLES	MENTIONS	ELABORATION OR STRATEGY
KNOWLEDGE INTEGRATION AND ADAPTABILITY <i>Governance processes should enable learning and integration of diverse sources of knowledge, and be responsive to changing circumstances and new information.</i>		
Decision-making should be informed by the best available knowledge.	"Recommendations are based on best available information and will include both science based and traditional ecological / local ecological knowledge information and data" (p. 7).	
Constructive stakeholder dialogue should be facilitated in order to build trust and enable learning.		"The PNCIMA Forum ... could serve as a network for multi-stakeholder communications, information sharing and input to the PNCIMA Initiative" (p. 11).
Strategies and arrangements should be adaptable to new information and changing circumstances.	"Integrated Management is expected to reflect an adaptive management approach, and therefore the proposed governance model may change over time to reflect new information and changing circumstances" (p. 5).	"The process is designed to permit and support evolution and will be monitored and evaluated to support shared learning and adaptation" (p. 7).
TRANSPARENCY AND ACCOUNTABILITY <i>All stakeholders should have access to information about rules / decisions, and about the performance of governance actors and processes; there should be a clear answer to the question "who is accountable to whom for what?"</i>		
Decisions and decision-making processes should be transparent.	"Recommendations are made openly, with information and results shared with all participants" (p. 7).	
Governance performance should be transparent.		
Decision makers should be accountable to stakeholders (downward accountability) as well as to higher-level authorities (upward accountability).	"The Parties are committed to being accountable to their constituents and to each other" (p. 7).	

REFERENCES

- Canada and British Columbia. 2014. Canada-British Columbia Marine Protected Area Network Strategy. No. Fs23-585/2012E. Available on-line http://www.for.gov.bc.ca/tasb/SLRP/pdf/ENG_BC_MPA_LOWRES.pdf (Accessed Aug. 2014).
- DFO, CFN, and NCSFNSS. 2008. Memorandum of Understanding on Pacific North Coast Integrated Management Area Collaborative Oceans Governance. Department of Fisheries and Oceans, Coastal First Nations, and North Coast-Skeena First Nations Stewardship Society. Available online http://www.pncima.org/media/documents/pdf/mou_-pncima_-collaborative_-oceans_-governance_-11dec08.pdf (Accessed Aug. 2014).
- FLNRO, CFN, Nanwakolas, and NCSFNSS. 2011. Letter of Intent to collaborate on coastal and marine planning in the Pacific North Coast. Ministry of Forests, Lands and Natural Resource Operations, Coastal First Nations, North Coast-Skeena First Nations Stewardship Society, Nanwakolas Council. Available online http://mappocean.org/wp-content/uploads/2013/10/LOI_Completed_Nov_28_2011-signatures-removed.pdf (Accessed Aug. 2014).
- WCA. 2012. West Coast Aquatic Governance. West Coast Aquatic, January 31, 2012. Available on-line <http://westcoastaquatic.ca/wp-content/uploads/2012/03/WCA-Governance-2012.pdf> (Accessed Aug. 2014).

APPENDIX G: EXAMPLES OF SOCIAL GOALS THAT COMPLEMENT, SUPPLEMENT OR PRESENT TRADE-OFFS WITH DESIRED ECOLOGICAL OUTCOMES OF MPAS

EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES	CASE EXAMPLES
MARINE LIVELIHOODS AND FOOD SECURITY <i>Enhance capabilities and assets for income and subsistence activities.</i>		
<p>Enhance or maintain contributions of sustainable fisheries to employment, income, and food security.</p> <p>(Leisher et al. 2007; Klein et al. 2008a; Klein et al. 2008b; Cinner et al. 2009; Klein et al. 2009; Mascia et al. 2010; Grantham et al. 2013)</p>	<p>Consider the economic importance of fishing in MPA design and placement – costs of reduced access, benefits from spillover.</p> <p>(Smith and Wilen 2003; Stewart and Possingham 2005; Richardson et al. 2006; Klein et al. 2008a; Cinner et al. 2009; Mascia et al. 2010; Weeks et al. 2010; Grantham et al. 2013; White et al. 2013)</p>	<p>In California, important components of MPA network planning and design included information from fisherman interviews (worst case potential socio-economic impacts) and from complex bioeconomic models (account for fish population dynamics, spillover, fisher movement, and fishery management). (Scholz et al. 2004; Klein et al. 2008b; White et al. 2013)</p> <p>In the process of identifying zoning configurations for the Raja Ampat MPA network in Eastern Indonesia, potential areas for no-take zones were identified that have a small and equitable impact across the fishing grounds of different fishing communities whilst ensuring each community has access to a 'sustainable fishing zone.' (Grantham et al. 2013)</p>
	<p>Consider aspects of marine area access and adjacency by local marine users.</p> <p>(Cinner 2007a, 2007b; Mascia and Claus 2008; Cinner et al. 2009; Weeks et al. 2010; Grantham et al. 2013)</p>	<p>No-take areas in the Philippines are usually located near villages so that the communities can benefit from spillover and tourism. (Russ et al. 2004; Alcala and Russ 2006)</p> <p>In an effort to make the Nosy Atafana marine park in Madagascar more reflective of local needs, managers demonstrated flexibility in developing locally appropriate temporal restrictions that compliment taboos about farming during certain days (i.e. important local fishing days). (Cinner 2007b; Cinner et al. 2009)</p> <p>In the island Province of Siquijor, Philippines, spatial zoning software (Marxan with Zones) was used to design an MPA network configuration that considered local marine tenures. By setting the minimum area of fishing grounds to be retained by each community, the MPA network design was more equitable in terms of impacts on resource users. (Weeks et al. 2010)</p>
<p>Support or enhance existing local 'non fisheries-based' livelihoods and possible alternative livelihood strategies.</p> <p>(Goodwin 2002; Pomeroy et al. 2004; Brondo and Woods 2007; Leisher et al. 2007; Mascia and Claus 2008; Mulongoy and Gidda 2008)</p>	<p>Identify areas that are key sites/routes for current and prospective marine tourism and include them in the MPA network.</p> <p>(Agardy 1993; Hoyt 2005; White et al. 2006; Lucas and Kirit 2009; Plummer and Fennell 2009; McCook et al. 2010)</p>	<p>In the Great Barrier Reef Marine Protected Area, income from tourism is estimated to be about 36 times greater than commercial fishing. (McCook et al. 2010)</p> <p>On Olango Island in the Philippines, a multiple-use zoning plan has designated certain parts of the coral reef available to diving and therefore tourism opportunities. (White et al. 2006)</p> <p>In the Philippines, MPAs were initially created for protection and enhancement of local fisheries stocks; however, local governments and communities have benefited from increasing revenue as tourism continues to increase. (White et al. 2006)</p>
	<p>Support local initiatives to grow the tourism industry.</p> <p>(Agardy 1993; Goodwin 2002; Pomeroy et al. 2004; Hoyt 2005; White et al. 2006; Lucas and Kirit 2009)</p>	<p>To enhance the economic benefits derived from tourism activities and help provide a local financing mechanism, a ticket-system user-fee system was implemented through municipal government legislation for diving within the Saavedra and Basdiot MPAs in the Philippines. (Lucas and Kirit 2009)</p> <p>Sian Ka'an Biosphere Reserve (Mexico) provides training and accreditation for tour guides, co-management training, and environmental education to school children. (Pomeroy et al. 2004)</p> <p>In a global study of 78 coral reef MPAs, survey respondents (MPA managers and researchers) estimated that 75% of tourism related employment was retained locally. (Hargreaves-Allen et al. 2011)</p>

EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES	CASE EXAMPLES
(...continued from previous page)	Identify and develop alternate economic opportunities linked to marine resources within and outside of the MPA network. (Goodwin 2002; Mous et al. 2004; Leisher et al. 2007; Torell et al. 2010)	In Indonesia, the Komodo National Park worked with the Nature Conservancy to promote alternate livelihood options (developed a new pelagic fishery, a local seaweed farming industry, and a local mariculture project) to lower the dependency on extractive reef fishing. (Mous et al. 2004) 10% of conservation fee at Tubbataha Reefs Natural Park (Philippines) goes to livelihood development in adjacent communities, including micro-financing and eco-tourism that are included in management design. (Dygico et al. 2011)
	Provide entrepreneurship and marketing training for new local marine-based enterprises. (Leisher et al. 2007; Torell et al. 2010)	In the Aranavon Islands (Solomon Islands) a donor-funded Fisheries Center trained people in deep-sea grouper fishing techniques, management of the center, and commercialization. (Leisher et al. 2007)
Support local employment in the implementation and management of the MPA network. (Goodwin and Roe 2001; Goodwin 2002; Leisher et al. 2007; Hargreaves-Allen et al. 2011)	Support employment opportunities related to cultural information and sharing.	In Gwaii Haanas, Parks Canada supports the Haida Gwaii Watchmen program with operating funds and with a training program. (Parks Canada 2012) In Egypt's network of protected areas, including marine protectorates, local indigenous inhabitants are employed as community guards or rangers, and they are recognized for contributing their knowledge as well as maintaining connections to local communities. (Nature Conservation Sector 2006)
	Support local organizations and/or employment of local people in monitoring ecological conditions.	In the Philippines, local people are hired and trained to assist in managing MPAs. Although locally collected monitoring data shows higher variance and fish abundance than data collected by biologists, it still identifies areas of management concern and areas needing organizational strengthening. (Uychiaoco et al. 2005) In parts of the Philippines, the Coastal Conservation and Education Foundation is a nongovernmental organization that assists in the annual monitoring of several MPAs. The Research and Monitoring Team (ReMoTe) lead SCUBA fish visual census and substrate surveys, train locals to conducting the surveys, gather community perception data, and conduct information, education, and communication campaigns. (Lucas and Kirit 2009)
NON-MONETARY AND INTANGIBLE BENEFITS <i>Understand and incorporate non-monetary benefits of MPAs.</i>		
Support local goals of poverty reduction, health and well-being as indirect benefits of protected areas.	Consider poverty reduction strategies as a potential indirect benefit or long-term goal of MPAs. (Scherl et al. 2004; Leisher et al. 2007; Mulongoy and Gidda 2008; Dudley et al. 2010)	Poverty reduction occurred by MPAs in Fiji, the Solomon Islands, Indonesia, and Philippines due to increased fish catches and increased jobs in tourism. It was found that most programs promoting alternative livelihoods helped to offset the initial loss of income from no-fishing areas, but were not sustainable because they did not improve incomes or deter from fishing livelihoods in the long run. (Leisher et al. 2007)
	Consider how MPAs can support goals to improve local health and well-being. (Gjertsen 2005; Mulongoy and Gidda 2008)	In the Solomon Islands research has shown that villages with MPAs are characterized by higher energy and protein intake than those with no MPAs or ineffective MPAs. (Aswani and Furusawa 2007; Leisher et al. 2007) A review of MPA literature identified that food security and resource control as two indicators of social well-being increased as a result of MPAs. Trends were not significant for employment, community organization and income. (Mascia et al. 2010)

EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES	CASE EXAMPLES
Enhance opportunities for recreational activities.	Collect information (e.g. surveys, studies, expert opinion) to identify areas that are key sites/routes for current recreational use, and areas of future prospective marine recreation. (Pomeroy et al. 2004; Jessen et al. 2011)	Review process of the management plan for the Channel Islands National Marine Sanctuary in California sets out to describe all human use activities, including recreation. (Pomeroy et al. 2004)
	Create “buffer zones” within which recreational activities can be pursued with reduced impacts on sensitive ecological areas. (Agardy 1993)	The Saba Marine Park (Netherlands Antilles) is divided into four zones in which different recreational activities are allowed. This serves both to control environmental impacts as well as minimize user conflicts. (Agardy 1993)
	Situate MPAs close to population centers in order to facilitate access for recreational users. (Elliot et al. 2001; Klein et al. 2008a; Giakoumi et al. 2011)	In the Cyclades Archipelago in the northeastern Mediterranean Sea, a socio-economic analysis identified that marine reserves should be based in areas of high tourism because of the available infrastructure and because fishers tended to have secondary livelihoods already in place. (Giakoumi et al. 2011) The remote location and limited facilities of the Wakatobi Marine National Park of Sulawesi, Indonesia, are considered significant barriers to tourism and recreation. (Elliot et al. 2001)
Maintain / enhance the services provided by healthy ecosystems.	Protect natural areas (e.g. mangroves, coral reefs, kelp forests) that provide important supporting services. (Pomeroy et al. 2004; Mulongoy and Gidda 2008; Angulo-Valdes and Hatcher 2010)	The destruction of mangroves in the Gulf of California has had a strong negative impact on fishing communities due to their (underestimated) importance as nursery / feeding grounds for many commercial species. (Aburto-Oropeza et al. 2008)
Conserve natural areas for their non-use (e.g. existence; option) values.	Conduct research (e.g. surveys) and/or learn from experience elsewhere to understand how marine areas are valued and incorporate findings into MPA decision-making. (Harmon and Putney 2003; Charles and Wilson 2009) (English and Lee 2003; Pomeroy et al. 2004; Angulo-Valdes and Hatcher 2010; Jessen et al. 2011).	One of the goals of California’s MPA system is “to protect marine natural heritage, including protection of representative and unique marine habitats in California waters for their intrinsic value” (CDFG - California Department of Fish and Game 2008). In New South Wales, Australia, the Cultural Heritage Division of the Parks and Wildlife Service shifted the focus of its work from archaeology to the connections of living people to place, in order to better understand intangible values. (English and Lee 2003)
CULTURE AND HISTORY <i>Protect cultural and historic features and support traditional practices and connections to natural / sacred areas.</i>		
Protect cultural heritage and traditional practices. (continued on next page)	Support local efforts to protect and present local culture and history. (Harmon and Putney 2003; Mulongoy and Gidda 2008)	The Gwaii Haanas NMCA reserve in Canada has a cultural resource management program to support a variety of locally run and maintained activities and infrastructure. The Haida Gwaii Watchmen are locally trained stewards of the culturally significant sites in the NMCA reserve; they work in the park from spring until fall protecting the sites and educating visitors on the natural and cultural heritage of Gwaii Haanas (IUCN-WCPA 2012; Parks Canada 2012).

EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES	CASE EXAMPLES
<p>Protect cultural heritage and traditional practices.</p> <p>(English and Lee 2003; Harmon and Putney 2003; Harmon 2004; Mulongoy and Gidda 2008; Angulo-Valdes and Hatcher 2010; Davies et al. 2012; IUCN-WCPA 2012)</p>	<p>Identify areas of cultural or historical importance and accommodate them within the boundaries of the protected areas.</p> <p>(English and Lee 2003; Harmon and Putney 2003; Angulo-Valdes and Hatcher 2010; Jessen et al. 2011; IUCN-WCPA 2012).</p>	<p>Historic Scotland, an executive agency of the Scottish Government, has developed guidelines for identifying and designating “Historic MPAs” within its national MPA network (e.g. ancient fish traps, ship wrecks). (Historic Scotland 2014)</p> <p>Globally, Indigenous and Community Conserved Areas (ICCAs) are increasingly being recognized as part of national protected area systems. This movement is generating novel encounters between indigenous customs/institutions and formal protected area management planning.(Davies et al. 2012; Kothari et al. 2012)</p> <p>In the U.S., a Cultural Heritage Resources Working Group (CHRWG) consisting of government and non-government archaeologists and historians, as well as tribal, Pacific Islanders, Alaska Natives, and other representatives has been established under the MPA Federal Advisory Committee. The CHRWG provides expertise and recommendations on the development of the cultural heritage component of the National System of MPAs.(Grussing 2013)</p>
	<p>Use indigenous names for fauna, flora, and landscape features.</p> <p>(English and Lee 2003).</p>	<p>One of the largest marine sanctuaries in the world, the Northwest Marine Hawaiian Islands (NWHI) was designated a national marine monument in 2006, and renamed in 2007 to a traditional Hawaiian name of Papahānaumokuākea (Rieser 2011)</p>
	<p>Accommodate traditional practices that are compatible with conservation objectives.</p> <p>(Beltran 2000).</p>	<p>In Nicaragua the Biosphere Reserve classification allows for traditional uses, including resource extraction, along with “the strict protection of habitats and species of conservation interest.” (Beltran 2000).</p>
<p>Protect spiritual sites and values in the marine environment.</p>	<p>Identify and encompass spiritually significant areas or sacred natural sites within marine protected areas or networks.</p> <p>(Harmon and Putney 2003; Dudley et al. 2005; Wild and Mcleod 2008; Jessen et al. 2011; IUCN-WCPA 2012)</p>	<p>Misali Island in Zanzibar is considered a holy island in local Islamic belief. To help encourage sustainable fishing in the Misali Island Marine Conservation Area it was proposed that the management of the area be based on Islamic ethical principles. (Dudley et al. 2005)</p> <p>Zoning in the Rila Monastery Natural Park (Bulgaria) includes a specific category for religious values, and an important component of the management plan is to “preserve the unity between nature and the Rila Monastery” (Wild and Mcleod 2008).</p> <p>Over 70 members from 24 countries participated in an IUCN World Commission on Protected Areas (WCPA) task force on Cultural and Spiritual Values that resulted in a publication of guidelines to support the efforts of faith groups and indigenous peoples in the long-term conservation of their sacred natural sites (Wild and Mcleod 2008)</p>
	<p>Where necessary, protect the confidentiality of site location and/or associated cultural/spiritual information by, for example, locating sacred natural sites “within larger strictly protected zone so exact locations remain confidential” (Wild and Mcleod 2008).</p>	<p>Some of the aboriginal sites around Uluru, Australia, are unmarked as they cannot be specifically identified or publicly discussed. (Wild and Mcleod 2008)</p>

EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES	CASE EXAMPLES
EDUCATION AND KNOWLEDGE SHARING <i>Foster education, research, and knowledge sharing opportunities within the MPA Network</i>		
Foster knowledge sharing between interest groups.	<p>Make use of local ecological knowledge (LEK) and/or fishers' ecological knowledge (FEK) in identifying critical habitat for protection within the MPA network.</p> <p>(Johannes 2002; Aswani and Hamilton 2004; Scholz et al. 2004; Aswani and Lauer 2006; Haggen et al. 2007; Gerhardinger et al. 2009; Brattland 2013)</p> <p>*see Section 5.0 Knowledge Integration</p>	<p>In tropical nearshore waters, fishers knowledge of reef fish spawning aggregations has been helpful in siting suitable areas for MPAs (Johannes et al. 2000; Haggen et al. 2007)</p> <p>In Solomon Islands, local indigenous fishermen provided information on the parrotfish and certain habitat areas that were important for its management (Aswani and Hamilton 2004)</p> <p>Integrating fishermen's knowledge using geospatial analysis was used to inform MPA design in Oceania and California (Scholz et al. 2004; Aswani and Lauer 2006)</p> <p>Following the implementation of an ecosystem approach to management in Norway, management authorities are obliged to integrate fishers' ecological knowledge (e.g. experience-based knowledge of the Sami people) in fisheries management. (Brattland 2013)</p>
	<p>Facilitate dialogue and empower stakeholders to participate in decision-making.</p> <p>(Mascia 2003; Leisher et al. 2007)</p> <p>*see also Governance Design Principles, Appendix E</p>	<p>Participation in citizen forums and a greater say in management decisions has lead to a major reduction in conflict levels around the Bunaken National Marine Park, Indonesia. (Leisher et al. 2007)</p> <p>In the MPAs of the Pacific Islands, the development and nurturing of community relationships and interactions led to better local governance according to local authorities. (Leisher et al. 2007; Mulongoy and Gidda 2008)</p>
Foster public understanding and appreciation of marine systems and marine heritage. (Granek and Brown 2005; Angulo-Valdes and Hatcher 2010; Baltic Environmental Forum 2010)	<p>Establish services, facilities that provide local residents and visitors with the opportunity to better understand, appreciate and protect the marine system and cultural heritage.</p> <p>(Erdogan and Tosun 2009)</p>	<p>In Italy along the Gulf of Naples, Gaiola Underwater Park marine protected area provides a research and visitor centre that describes the value of protecting biological communities and historical archaeological sites (Simeone et al. 2012).</p> <p>In Wadi el Gemal National Park, along the Red Sea in Egypt, traditional architectural designs extending back 2000 years were used for park infrastructure, and were built by local people (Nature Conservation Sector 2006)</p> <p>In Goreme Historical National Park in Turkey, tourist accommodations that were rated as being environmentally conscious and that were hosted by knowledgeable managerial staff were associated with higher environmental awareness of tourists. (Erdogan and Tosun 2009)</p>
	<p>Support the development of educational content linked to the awareness of the marine system and local protected areas that can be used by schools and educational institutions.</p>	<p>Considerable educational content (e.g. curriculum, learning materials, grants, workshops) has been developed in association with the National Marine Sanctuaries in the U.S. to provide resources and training to teachers and educators to support ocean literacy. (NOAA 2013)</p> <p>A special edition of CURRENT – the Journal of Marine Education – was devoted to the educational content linked to the National Marine Sanctuaries in the US (Current: the Journal of Marine Education 2010)</p> <p>In the marine protected areas of the Baltic Sea, several public outreach materials were created under the 'Public Awareness' project and made available in multiple languages. These materials included information flyers, an interactive project website, project films, books, public events, a birding conference, a layman's report, and a final project presentation (Baltic Environmental Forum 2010)</p> <p>In the Wadi el Gimal National Park of Egypt, Junior Ranger volunteers from the Red Sea Parks Association visited local schools to teach the youth and public about marine conservation and indigenous history of the Park, as well as they conducted field trips and clean-up campaigns. (Ghazali 2012)</p>

EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES	CASE EXAMPLES
	<p>Provide information and education to visitors on low-impact recreational practices.</p> <p>(Marion and Rogers 1994; Medio et al. 1997; Mayes et al. 2004)</p>	<p>At the Virgin Islands National Park interpreters developed an environmental education program that incorporates low-impact messages into a variety of communication media (brochures, special flyers, interpretation center video, educational displays). Directed at snorkelers, divers, and boaters these messages describe appropriate practices reinforced with explanations of how visitor use affects marine resources and why such problems are of concern. (Marion and Rogers 1994)</p> <p>The effectiveness of a tourist briefing towards decreasing coral reef damage caused by divers was high in the Ras Mohammed National Park in Egypt (Medio et al. 1997)</p> <p>Following a discussion of human impacts to dolphins, visitors were less likely to think it was appropriate to touch wild dolphins during a an interpretive feeding display (Mayes et al. 2004)</p>
	<p>Develop supportive communication, education and public awareness programs that integrate different ways of knowing, expression, and appreciation regarding the protection of sacred natural sites.</p> <p>(Wild and Mcleod 2008)</p>	<p>In Uluru National Park of northern Australia, a sign written in multiple languages identifies that the local indigenous people, the Anangu, do not want visitors to climb Uluru. Their views as the 'Traditional Owners' are also published in the Park's 'visitor's guide' and in the Management Plan. (James 2007)</p>
	<p>Provide resources to promote accurate and thorough media and multimedia coverage of the MPA Network.</p> <p>(Mous et al. 2004)</p>	<p>In the Komodo National Park it was found domestic media sources often focused on short-term economic losses from the implementation of no-take zones and also misinterpreted information about the Collaborative Management Initiative. To improve the accuracy of media coverage, the Nature Conservancy helped provide media coordination, orientation and resources to provide accurate information and documentation. (Mous et al. 2004)</p> <p>A collaborative five year project between the three countries of the Eastern Baltic Sea promoted their materials by developing an ongoing relationship with local media through writing articles and communicating with journalists. In addition, they created 20 short video films on various aspects of marine diversity that were shown on national television, made available by DVD, and available by download off the project website (Baltic Environmental Forum 2010)</p>
Enhance marine research capacity.	<p>Establish community-based participatory research programs.</p> <p>(Huntington et al. 2011; Mulrennan et al. 2012)</p>	<p>Researchers were requested by the community living around the Tarawa Atoll of Kiribati to assist in developing a marine resource management plan based on local ecological knowledge of old fishers. The support provided by the researchers and funding agency (US Agency for International Development) led to community action of enforcing fishing restrictions, which were then recognized officially by the central government several years later (Johannes and Yeeting 2000)</p> <p>A management plan and scientific appraisal of a beach and sand-dune ecosystem was developed with a local community in northern Ireland based on based on the previous successful efforts of a local organization that had developed agreements and codes of conduct between stakeholders limiting access and use of the area (Power et al. 2000)</p> <p>In the Navakavu MPA in Fiji, local fisherman have been trained to assist with research groups and with ecological monitoring. (Leisher et al. 2007)</p> <p>In the Eastport Marine Protected Area in Newfoundland, Canada, local fishers work with scientists from Memorial University of Newfoundland, Parks Canada, the Department of Fisheries and Oceans, and a local high school class to assist with collecting and analyzing data. (Collins and Lien 2002; Charles and Wilson 2009)</p>

EXAMPLES OF SOCIAL GOALS	STRATEGIES AND PRACTICES	CASE EXAMPLES
	Consider designating or including sites specifically for monitoring and research.	<p>Zoning in the Great Barrier Reef Marine Park includes a “Scientific Research Zone” that allows for research in areas primarily around scientific research facilities that are relatively undisturbed by extractive activities.(GBRMPA 2011)</p> <p>In the process of designing a network of marine protected areas along California’s central coast, planning units that were adjacent to scientific monitoring sites, research institutions, and educational institutions were used in a Marxan analysis (spatial planning software) to develop and evaluate different MPA planning scenarios (Klein et al. 2008a; Klein et al. 2008b)</p>

REFERENCES

- Aburto-Oropeza, O., E. Ezcurra, G. Danemann, V. Valdez, J. Murray, and E. Sala. 2008. Mangroves in the Gulf of California increase fishery yields. *Proceedings of the National Academy of Sciences* 105:10456-10459.
- Agardy, T. 1993. Accommodating ecotourism in multiple use planning of coastal and marine protected areas. *Ocean and Coastal Management* 20:219-239.
- Alcala, A., and G. Russ. 2006. No-take marine reserves and reef fisheries management in the Philippines: A new people power revolution. *AMBIO: A Journal of the Human Environment* 35:245-254.
- Angulo-Valdes, J., and B. Hatcher. 2010. A new typology of benefits derived from marine protected areas. *Marine Policy* 34:635-644.
- Aswani, S., and T. Furusawa. 2007. Do marine protected areas affect human nutrition and health? A comparison between villages in Roviana, Solomon Islands. *Coastal Management* 35:545-565.
- Aswani, S., and R. Hamilton. 2004. Integrating indigenous ecological knowledge and customary sea tenure with marine and social science for conservation of bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands. *Environmental Conservation* 31:69-83.
- Aswani, S., and M. Lauer. 2006. Incorporating fishermen’s local knowledge and behavior into geographical information systems (GIS) for designing marine protected areas in Oceania. *Human Organization* 65:81-102.
- Baltic Environmental Forum. 2010. Marine protected areas in the Eastern Baltic Sea. 54pp.
- Beltran, J. 2000. Indigenous and traditional peoples and protected areas: Principles, guidelines and case studies. IUCN, Gland, Switzerland and Cambridge, UK and WWF International, Gland, Switzerland. 133pp. Available online <https://portals.iucn.org/library/efiles/documents/PAG-004.pdf> (Accessed Sept. 2014). IUCN.
- Brattland, C. 2013. Proving fishers right. Effects of the integration of experience-based knowledge in ecosystem-based management. *Acta Borealia: A Nordic Journal of Circumpolar Societies*.
- Brondo, K., and L. Woods. 2007. Garifuna land rights and ecotourism as economic development in Honduras’ Cayos Cochinos Marine Protected Area. *Ecological and Environmental Anthropology* 3:2-18.
- CDFG - California Department of Fish and Game. 2008. California Marine Life Protection Act: master plan for marine protected areas (revised draft). California Department of Fish and Game. Sacramento, CA. 99pp.
- Charles, A., and L. Wilson. 2009. Human dimensions of marine protected areas. *ICES Journal of Marine Science* 66:6-15.
- Cinner, J. 2007a. Designing marine reserves to reflect local socioeconomic conditions: lessons from long-enduring customary management systems. *Coral Reefs* 26:1035-1045.
- Cinner, J. 2007b. The role of taboos in conserving coastal resources in Madagascar. *Traditional Marine Resource Management and Knowledge Information Bulletin* 22:15-23.
- Cinner, J., M. Fuentes, and H. Randriamah. 2009. Exploring social resilience in Madagascar’s marine protected areas. *Ecology and Society* 14:41.
- Collins, R., and J. Lien. 2002. In our own hands: community-based lobster conservation in Newfoundland (Canada). *Biodiversity* 3:11-14.
- Current: the Journal of Marine Education. 2010. The National Marine Protected Areas Centre - Special issue focused on networks of marine protected areas. 26:45pp. Available online http://marineprotectedareas.noaa.gov/pdf/helpful-resources/education/current/current_jun_2010.pdf (Accessed Sept. 2014).

- Davies, J., R. Hill, F. Walsh, M. Sandford, D. Smyth, and M. Holmes. 2012. Innovation in management plans for community conserved areas: experiences from Australian indigenous protected areas. *Ecology and Society* 18:14.
- Dudley, N., L. Higgins-Zogib, and S. Mansourian. 2005. Beyond belief, linking faiths and protected areas to support biodiversity conservation. WWF, Equilibrium and The Alliance of Religions and Conservation (ARC).
- Dudley, N., S. Mansourian, S. Stolton, and S. Sukuwana. 2010. Do protected areas contribute to poverty reduction? *Biodiversity* 11:5-7.
- Dygico, M., A. Songco, A. White, and S. Green. 2011. Tubbataha Reefs Natural Park – governance analysis. In P. J. S. Jones, W. Qiu, and E. M. De Santo (Editors), *Governing Marine Protected Areas: Getting the balance right - Volume 2. Technical Report to Marine & Coastal Ecosystems Branch, UNEP*. 127-135.
- Elliot, G., B. Mitchell, B. Wiltshire, I. Manan, and S. Wismer. 2001. Community participation in marine protected area management: Wakatobi National Park, Sulawesi, Indonesia. *Coastal Management* 29:295-316.
- English, J., and E. Lee. 2003. Managing the intangible. In D. Harmon and A. Putney (Editors), *The full value of parks from economics to the intangible*. Rowman and Littlefield.
- Erdogan, N., and C. Tosun. 2009. Environmental performance of tourism accommodations in the protected areas: Case of Goreme Historical National Park. *International Journal of Hospitality Management* 28:406-414.
- GBRMPA. Zone guide to using the marine park > Interpreting zones (Website). Available online <http://www.gbrmpa.gov.au/visit-the-reef/zoning/zoning-guide-to-using-the-marine-park/interpreting-zones> (Accessed Sept 2014). 2011.
- Gerhardinger, L., E. Godoy, and P. Jones. 2009. Local ecological knowledge and the management of marine protected areas in Brazil. *Ocean and Coastal Management* 52:154-165.
- Ghazali, U. 2012. WHV – Red Sea junior rangers in Wadi El-Gimal National Park, Egypt. Red Sea Parks Association, World Heritage Convention.
- Giakoumi, S., H. Grantham, G. Kokkoris, and H. Possingham. 2011. Designing a network of marine reserves in the Mediterranean Sea with limited socio-economic data. *Biological Conservation* 144:753-763.
- Gjertsen, H. 2005. Can habitat protection lead to improvements in human well-being? Evidence from marine protected areas in the Philippines. *World Development* 33:199-217.
- Goodwin, H. 2002. Local community involvement in tourism around National Parks: Opportunities and constraints. *Current Issues in Tourism* 5:338-360.
- Goodwin, H., and D. Roe. 2001. Tourism, livelihoods and protected areas: opportunities for fair-trade tourism in and around National parks. *International Journal of Tourism Research* 3:377-391.
- Granek, E., and M. Brown. 2005. Co-management approach to marine conservation in Mohéli, Comoros Islands. *Conservation Biology* 19:1724-1732.
- Grantham, H., V. Agostini, J. Wilson, S. Mangubhai, N. Hidayat, A. Muljadi, C. Rotinsulu, M. Mongdong, M. Beck, and H. Possingham. 2013. A comparison of zoning analyses to inform the planning of a marine protected area network in Raja Ampat, Indonesia. *Marine Policy* 38:184-194.
- Grussing, V. 2013. Cultural heritage resources and marine protected areas. NOAA - Cultural Heritage MPAs National Marine Protected Areas Center. Available online http://marineprotectedareas.noaa.gov/pdf/helpful-resources/factsheets/cultural_heritage_mpas_mar2011x2.pdf (Accessed Sept 2014).
- Haggen, N., B. Neis, and I. Baird. 2007. Fishers' knowledge in fisheries science and management. *Coastal Management Sourcebooks* 4. United Nations Educational, Scientific and Cultural Organization. Paris. 58pp.
- Hargreaves-Allen, V., S. Mourato, and E. Milner-Gulland. 2011. A global evaluation of coral reef management performance: Are MPAs producing conservation and socio-economic improvements? *Environmental Management* 47:684-700.
- Harmon, D. 2004. Intangible values of protected areas: What are they? Why do they matter? *The George Wright Forum* 21:9-22.
- Harmon, D., and A. Putney. 2003. *The full value of parks: From economics to the intangible*. Rowman and Littlefield, Lanham, MD.
- Historic Scotland. 2014. Marine protected areas in the seas around Scotland: Guidelines on the selection, designation and management of historic marine protected areas. Historic Scotland. Available online <http://www.historic-scotland.gov.uk/historic-mpa-guidelines.pdf> (Accessed Sept 2014).
- Hoyt, E. 2005. Sustainable ecotourism on Atlantic islands, with special reference to whale watching, Marine Protected Areas and sanctuaries, for cetaceans. *Biology & Environment: Proceedings of the Royal Irish Academy* 105:141-154.
- Huntington, H., S. Gearheard, A. Mahoney, and A. Salomon. 2011. Integrating traditional and scientific knowledge through collaborative natural science field research : Identifying elements for success. *Arctic* 64:437-445.
- IUCN-WCPA. 2012. The Whakatane Mechanism: An IUCN "One Programme" initiative to support conflict resolution on protected areas and indigenous peoples and local communities. Draft Framework v5.0. Available online <http://whakatane-mechanism.org/> (Accessed Aug. 2014).

- James, S. 2007. Constructing the climb: visitor decision-making at Uluru. *Geographical Research* 45:398-407.
- Jessen, S., K. Chan, I. Cote, P. Dearden, E. De Santo, M. Fortin, F. Guichard, W. Haider, G. Jamieson, D. Kramer, A. McCrea-Stub, M. Mulrennan, W. Montevercchi, J. Roff, A. Salomon, J. Gardner, L. Honka, R. Menafrá, and A. Woodley. 2011. Science-based Guidelines for MPAs and MPA Networks in Canada. Canadian Parks and Wilderness Society. Vancouver, BC.
- Johannes, R. 2002. The renaissance of community-based marine resource management in Oceania. *Annual Reviews of Ecology, Evolution, and Systematics* 33:317-340.
- Johannes, R., M. Freeman, and R. Hamilton. 2000. Ignore fishers knowledge and miss the boat. *Fish and Fisheries* 1:257-271.
- Johannes, R., and B. Yeeting. 2000. I-Kiribati knowledge and management of Tarawa's lagoon resources. . Smithsonian Institution, National Museum of Natural History.
- Klein, C., A. Chan, and L. Kircher. 2008a. Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. *Conservation Biology* 33:691-700.
- Klein, C., C. Steinback, A. Scholz, and H. Possingham. 2008b. Effectiveness of marine reserve networks in representing biodiversity and minimizing impact to fishermen: a comparison of two approaches used in California. *Conservation Letters* 1:44-51.
- Klein, C., C. Steinback, M. Watts, A. Scholz, and H. Possingham. 2009. Spatial marine zoning for fisheries and conservation. *Frontiers in Ecology and the Environment* 8:349-353.
- Kothari, A., C. Corrigan, H. Jonas, A. Neumann, and H. Shrumm. 2012. Recognizing and supporting territories and areas conserved by Indigenous peoples and local communities: Global overview and national case studies. Secretariat of the Convention of Biological Diversity, ICCA Consortium, Kalpavriksh, and Natural Justice, Montreal, Canada. Technical Series no. 64, 160pp. Available online <http://www.cbd.int/doc/publications/cbd-ts-64-en.pdf> (Accessed Sept 2014).
- Leisher, C., P. van Beukering, and L. Scherl. 2007. Nature's investment bank: How marine protected areas contribute to poverty reduction. The Nature Conservancy. 52pp.
- Lucas, E., and R. Kirit. 2009. Fisheries-marine protected area-tourism interactions in Moalboal, Cebu, Philippines. *Coastal Management* 37:480-490.
- Marion, J., and C. Rogers. 1994. The applicability of terrestrial visitor impact management strategies to the protection of coral reefs. *Ocean and Coastal Management* 22:153-163.
- Mascia, M. 2003. The human dimension of coral reef marine protected areas: Recent social science research and its policy implications. *Conservation Biology* 17:630-632.
- Mascia, M., and C. Claus. 2008. A property rights approach to understanding human displacement from protected areas: the case of marine protected areas. *Conservation Biology* 23:16-23.
- Mascia, M., C. Claus, and R. Naidoo. 2010. Impacts of marine protected areas on fishing communities. *Conservation Biology* 24:1424-1429.
- Mayes, G., P. Dyer, and H. Richins. 2004. Dolphin-human interaction: Pro-environmental attitudes, beliefs and intended behaviours and actions of participants in interpretation programs: A pilot study. *Annals of Leisure Research* 7:34-53.
- McCook, L., T. Ayling, M. Cappel, H. Choat, R. Evans, D. De Freitas, M. Heupel, T. Hughes, G. Jones, B. Mapstone, H. Marsh, M. Mills, F. Molloy, R. Pitcher, R. Pressey, G. Russ, S. Sutton, H. Sweatman, R. Tobin, D. Wachenfeld, and D. Williamson. 2010. Adaptive management of the Great Barrier Reef: A globally significant demonstration of the benefits of networks of marine reserves. *Proceedings of the National Academy of Sciences* 107:18278-18285.
- Medio, D., R. Ormond, and M. Pearson. 1997. Effect of briefings on rates of damage to corals by SCUBA divers. *Biological Conservation*.
- Mous, P., A. Halim, G. Wiadnya, and J. Subijanto. 2004. Progress report on The Nature Conservancy's Komodo marine conservation project - July 2004. The Nature Conservancy. 102pp.
- Mulongoy, K., and S. Gidda. 2008. The value of nature: Ecological, economic, cultural and social benefits of protected areas. Secretariat of the Convention on Biological Diversity. Montreal, CA. 40pp.
- Mulrennan, M., R. Mark, and C. Scott. 2012. Revamping community-based conservation through participatory research. *The Canadian Geographer / Le Géographe canadien* 56:243-259.
- Nature Conservation Sector. 2006. Protected areas of Egypt: Towards the future. EEAA, Ministry of State for Environmental Affairs. Cairo, Egypt.
- NOAA. 2013. National Marine Sanctuaries: Education for teachers (Website - updated Mar. 2013). NOAA. Available online <http://sanctuaries.noaa.gov/education/teachers/welcome.html> (Accessed Sept 2014).
- Parks Canada. 2012. Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site: Cultural Resources (Website - Updated Dec. 2012). Available online <http://www.pc.gc.ca/eng/pn-np/bc/gwaiihaanas/plan/Plan3.aspx> (Accessed Sept 2014).
- Plummer, R., and D. Fennell. 2009. Managing protected areas for sustainable tourism: Prospects for adaptive co-management. *Journal of Sustainable Tourism* 17:149-168.
- Pomeroy, R., J. Parks, and L. Watson. 2004. How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness. World Conservation Union (IUCN).
- Power, J., J. McKenna, M. MacLeod, A. Cooper, and G. Convie. 2000. Developing integrated participatory management strategies for Atlantic dune systems in County Donegal, Northwest Ireland. *AMBIO* 29:143-149.
- Richardson, E., M. Kaiser, G. Edwards-Jones, and H. Possingham. 2006. Sensitivity of marine-reserve design to the spatial resolution of socioeconomic data. *Conservation Biology* 20:1191-1202.

- Rieser, A. 2011. The Papahānaumokuākea precedent: Ecosystem-scale marine protected areas in the EEZ. *Asia Pacific Law and Policy Journal* 13:210-251.
- Russ, G., A. Alcala, A. Maypa, H. Calumpong, and A. White. 2004. Marine reserve benefits local fisheries. *Ecological Applications* 14:597-606.
- Scherl, L., A. Wilson, R. Wild, J. Blockhus, P. Franks, J. McNeely, and T. McShane. 2004. Can protected areas contribute to poverty reduction? Opportunities and limitations. IUCN. Gland, Switzerland and Cambridge, UK. 60pp.
- Scholz, A., K. Bonzon, R. Fujita, N. Benjamin, N. Woodling, P. Black, and C. Steinback. 2004. Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California. *Marine Policy* 28:335-349.
- Simeone, M., C. De Vivo, and P. Masucci. 2012. An interdisciplinary approach to the preservation of the Gaiola Archaeological Underwater Park and the Posillipo coastline, Bay of Naples (Southern Italy). *International Journal of Heritage in the Digital Era* 1:373-378.
- Smith, M., and J. Wilen. 2003. Economic impacts of marine reserves: the importance of spatial behavior. *Journal of Environmental Economics and Management* 46:183-206.
- Stewart, R., and H. Possingham. 2005. Efficiency, costs and trade-offs in marine reserve system design. *Environment Modeling and Assessment* 10:203-213.
- Torell, E., B. Crawford, D. Kotowicz, M. Herrera, and J. Tobey. 2010. Moderating our expectations on livelihoods in ICM: Experiences from Thailand, Nicaragua, and Tanzania. *Coastal Management* 38:216-237.
- Uychiaoco, A., H. Arceo, S. Green, M. De La Cruz, P. Gaite, and P. Alino. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. *Biodiversity and Conservation* 14:2775-2794.
- Weeks, R., G. Russ, A. Bucol, and A. Alcala. 2010. Incorporating local tenure in the systematic design of marine protected area networks. *Conservation Letters* 3:445-453.
- White, A., P. Aline, and A. Meneses. 2006. Creating and managing marine protected areas in the Philippines. Fisheries Improved for Sustainable Harvest, Coastal Conservation and Education Foundation and the University of the Philippines Marine Science Institute. Cebu City, Philippines. 83pp.
- White, J., A. Scholz, A. Rassweiler, C. Steinback, L. Botsford, S. Kruse, C. Costello, S. Mitarai, D. Siegal, P. Drake, and C. Edwards. 2013. A comparison of approaches used for economic analysis in marine protected area network planning in California. *Ocean & Coastal Management* 74:77-89.
- Wild, R., and C. Mcleod. 2008. Sacred natural sites: Guidelines for protected area managers. IUCN, Gland, Switzerland.