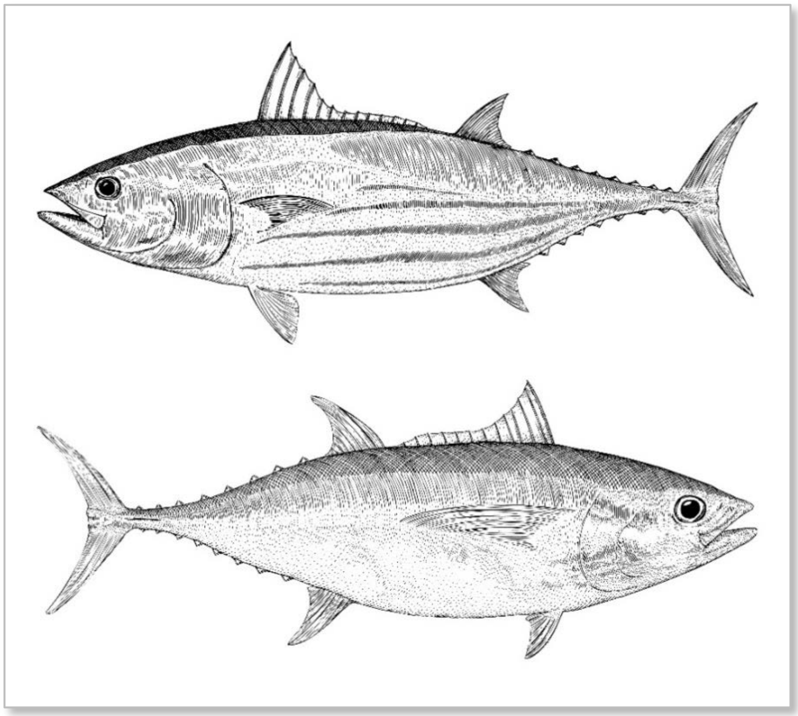
Road Map to Effective Area-Based Management of Blue Water Fisheries

Including Workshop Proceedings



January 5, 2021

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Published in the United States by the Western Pacific Regional Fishery Management Council.

ISBN# 978-1-944827-78-6

CONCEPT NOTE FOR THE INTERNATIONAL WORKSHOP ON AREA-BASED MANAGEMENT OF BLUE WATER ECOSYSTEMS

June 15-17, 2020, Honolulu, Hawaii, USA

Background and Rationale

As global demand for fisheries resources beyond continental shelves continues to increase, so does the need to effectively manage the blue water ecosystems that produce these valued resources. Blue water ecosystems span from the edge of continental shelves, often within States' exclusive economic zones, to high seas waters beyond national jurisdiction. Unlike nearshore ecosystems, where fisheries resources are usually more static in distribution, regulatory enforcement is more tenable, and fishing effort is less distributed, blue water ecosystems pose a broader and more diverse array of challenges and scientific needs. Fishery resources in blue water ecosystems are often highly mobile and traverse jurisdictional boundaries, concentrate dynamically relative to ecosystem features, such as fronts, and have time-varying spatial vulnerabilities to multiple fisheries. As international competition and fishing capacities among distant water fishing fleets increase across jurisdictional boundaries, the desire to implement area-based management measures in blue water ecosystems has become a leading topic in fisheries management. Area-based management includes, but is not limited to, the use of marine protected areas, time-area closures, selective area-based fishery/gear closures, and adaptive/real-time management.

International negotiations are underway to incorporate area-based management tools in blue water ecosystems, including closing areas to fishing, to improve the governance of natural resources in areas beyond national jurisdiction. The negotiations are a result of perceived pressures on the sustainability of natural resources in these areas, including from fisheries. **At present, science-based guidelines to plan, evaluate, identify unintended consequences, and monitor area-based management implementation discussed in these negotiations are lacking.** Such guidelines and decision-making tools are imperative for regional fisheries management organizations and arrangements (RFMO/As) to evaluate and weigh objectives, identify performance metrics, and develop plans to address consequences of spatial management. **In order to elucidate appropriate employment of area-based management measures in blue water ecosystems, the first several sections of this report, "Road Map to Effective Area-Based Management in Blue Water Ecosystems", was written by a team of experts and followed by a Workshop of global leaders on the subject matter.**

Objectives

The Workshop and its "road map" document primarily focused on three basic management objectives to expand upon: (1) sustainably managing targeted fishery resources, (2) decreasing interactions with bycatch or non-targeted species, and (3) protecting specific critical habitat. The overarching objective of the Workshop was to develop **science-based decision guidelines** for managers to identify objectives as well as practical and effective approaches to employ area-based management measures as part of governance frameworks for natural resources in blue water ecosystems. These guidelines will help managers assess ecological, social, and economic responses in addition to the performance of static and dynamic area-based management measures to make informed decisions. Additional objectives of the Workshop included determining feasible performance metrics for area-based management, defining sufficient historical and continual data streams, identifying appropriate methods of evaluating management measures, evaluating enforcement and compliance monitoring capacity, and weighing costs/benefits of management objectives.

Outcomes

The Workshop acted as a forum for (1) identifying suitable objectives and pairing them with tenable area-based management measures, (2) developing a road map of a priori criteria for implementing effective area-based management and area-based management tools, (3) creating a compendium of the "state of knowledge" of area-based management tools with respect to three focused management objectives (expanded at the workshop), and (4) selecting appropriate means of evaluating the effects of area-based management measures. Workshop outcomes are also to be promulgated through future relevant RFMO and international meetings.

Workshop Topics

The following topics related to area-based management of activities in blue water ecosystems were included at the Workshop:

- Identifying Conservation, Economic, and Social **Objectives** of Area-based Management
- Identifying Feasible **Performance Metrics**
- Weighing **Management Objectives**
- Pragmatism of Area-based Management with Respect to **Enforcement** Capacity
- Data Needs for Robust **Evaluations** on Effects of Area-based Management Measures
- Counterfactual/Potential Outcomes Analyses
- Social Implications
- **Adaptive**-Dynamic Real Time Area-based Management

Workshop Hosts, Participants, and Audience of Output

The Western Pacific Regional Fishery Management hosted the Workshop. There were twenty-five participants with expertise in research disciplines of relevance to the Workshop themes invited to participate in the invitation-only Workshop, reflecting an attempt to achieve balance by region, gender, and stakeholder groups.

Working Language

The meeting was held in English only.

Timing and Duration

The Workshop took place over three days from June 15 to 17, 2020.

Venue

The meeting venue was the conference room at the Western Pacific Regional Fishery Management Council, 1164 Bishop Street, Suite #1400, Honolulu, Hawaii, USA.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABMT – Area-Based Management Tools
ABNJ – Areas Beyond National Jurisdiction
ABFM – Area Based Fishery Management Measure
AIS – Automatic Identification System
BACI – Before-After-Control-Impact study design
BACIPS – Paired Sample BACI study design
BBNJ – Biodiversity in Areas Beyond National Jurisdiction
CBD – Convention on Biological Diversity
CCSBT – Commission for the Conservation of Southern Bluefin Tuna
DAG – Direct Acyclic Graph
DiD – Difference-in-Differences study design
DSL – Deep Scattering Layer
EA – Environmental Assessment
EBSA – Ecologically or Biologically Significant Marine Areas
EEZ – Exclusive Economic Zone
EIA – Economic Impact Assessments
EIS – Environmental Impact Statement
ENGO – Environmental Non-Governmental Organization
ENSO – El Niño Southern Oscillation
ETP – Endangered, Threatened, and Protected
FAD – Fish Aggregating Device
FAO – United Nations Food and Agriculture Organization
FIE – Fisheries-Induced Evolution
FONSI – Finding of No Significant Impact
FS – Free School Fleet
GAMM – Generalized Additive Mixed Model
GBR – Great Barrier Reef
GBRMP – Great Barrier Reef Marine Park
IATTC – Inter-American Tropical Tuna Commission
ICCAT – Inter-American Commission for the Conservation of Atlantic Tunas
IOTC – Indian Ocean Tuna Commission
ITS – Interrupted Time Series Approach
IUCN – International Union for the Conservation of Nature
IV – Instrumental Variables Regression Approach
LL – Longline Fleet
LRP – Limit Reference Point
LS – Fish Aggregating Device Fleet
MBF – Mesopelagic Boundary Community
MEI – Multivariate ENSO Index
MLPA – Marine Life Protection Act (California)
MM – Matching Methods
MPA – Marine Protected Area
MSRA – Magnuson-Stevens Reauthorization Act

NEPA – National Environmental Protection Act
NGO – Nongovernmental Organization
NGS – Next Generation Sequencing
NMSA – National Marine Sanctuaries Act
OECM – Other Effective Area-Based Conservation Measures
PIPA – Phoenix Islands Protected Area
PNA – Parties of the Nauru Agreement
RCT – Randomized Controlled Trial
RDD – Regression Discontinuity Design Approaches
RFMA – Regional Fisheries Management Arrangements
RFMO – Regional Fisheries Management Organizations
RIABR – Revillagigedo Islands Archipelago Biosphere Reserve (Mexico)
SC – Synthetic Control Approach
SIA – Social Impact Assessments
SIDS – Small Island Developing State
SMMP – Social Monitoring and Management Plan
SOPAC – South Pacific Applied Geoscience Commission
SPREP – South Pacific Regional Environmental Program
UN – United Nations
UNCLOS – UN Convention on the Law of the Sea
UNDP – UN Development Program
UNEP – UN Environmental Program
US – United States
VDS – Vessel Day Scheme
VME – Vulnerable Marine Ecosystem
VMS – Vessel Monitoring System
Workshop – International Workshop on Area-Based Management of Blue Water Ecosystems
WCPFC – Western and Central Pacific Fisheries Commission
WCPO – Western and Central Pacific Ocean
WPRFMC or Council – Western Pacific Regional Fishery Management Council

ROAD MAP TO EFFECTIVE AREA-BASED MANAGEMENT IN BLUE WATER ECOSYSTEMS

CHAPTER 1. INTRODUCTION AND SUMMARY

Authored by Mark Fitchett

Area-Based Management in Blue Water Fisheries

As global demand for fisheries resources beyond continental shelves continues to increase, so does the need to effectively manage the blue water ecosystems that produce these valued resources, which include tuna and tuna-like fisheries. Blue water ecosystems span from the edge of continental shelves, often within States' exclusive economic zones (EEZ), to high seas waters beyond national jurisdiction. Unlike nearshore ecosystems, where fisheries resources are usually more static in distribution, regulatory enforcement is more tenable, and fishing effort is less distributed, blue water ecosystems pose a broader and different array of challenges and scientific needs. Fishery resources in blue water ecosystems are often highly mobile and traverse jurisdictional boundaries, concentrate dynamically relative to ecosystem features such as fronts, and have time-varying spatial vulnerabilities to multiple fisheries. As international competition and fishing capacities among distant water fishing fleets increase across jurisdictional boundaries, the desire to implement area-based management measures in blue water ecosystems has become a leading topic in fisheries management. Area-based management includes, but is not limited to, the use of marine protected areas (MPAs), time-area closures, selective area-based fishery/gear closures, and adaptive/real-time management.

MPAs are defined by the International Union for the Conservation of Nature (IUCN) as "parts of intertidal or subtidal environments, together with their overlying waters, flora and fauna and other features, that have been reserved and protected by law or other effective means" (IUCN 2008). MPAs theoretically increase resource abundance inside the closed area and are effective if proportional to the range of the resource. However, results of MPAs depend on fishing pressure, whether they are managed by harvest or effort controls, dispersal of the species, and stock status prior to the MPA implementation. Hilborn (2004) summarized that, in practical terms, "blue water MPAs" have not been verified as an effective tool to increase fish abundance or biodiversity for highly mobile species, and this can likely be due to effort redistribution, the migratory nature of pelagic fish, and bycatch rates of non-target species.

According to the IUCN, MPAs may involve the protective management of natural areas according to predefined management objectives. MPAs can be conserved for a number of reasons including for economic resources, biodiversity conservation, and species protection. They are created by delineating zones with permitted and non-permitted uses within the area. It is vital to have in-depth knowledge of the area to define ecological boundaries and set objectives for the MPA. It is also important to have the support of the public and established techniques for surveillance and compliance monitoring. The IUCN and United Nations Food and Agriculture Organization (FAO) guidelines are to engage in advocating for the expansion of MPA networks through reliable science and by engaging with local stakeholders.

While MPAs are the most popularized concept of area-based management tools (ABMT), the concept of implementing measures that do not close statically defined spatial delineations of an ecosystem to preclude anthropogenic activity are oftentimes even more effective than MPAs in certain cases. These ABMTs can include time-area closures, which may prohibit fishing activity for certain or all gear types in a predefined area over a definitive time period or season. This approach can be incorporated to allow access over a defined time period to certain fisheries that may have a specific selectivity pattern or gear to operate without interference from other fisheries with competitive exploitation patterns. Time-area closures may also be used to seasonally protect habitat or spawning potential in a defined area for a time period. Time-area measures can be monitored and, by simple spatial definitions, may also be implemented to allocate catch or effort over spatially defined areas. This approach would require timely monitoring of catch and effort, which is not uncommon for tuna and tuna-like fisheries management through the implementation of observers, vessel monitoring systems (VMS), electronic monitoring (EM), and electronic reporting (ER). Time-area management measures place an onus on fishers to account for area-based fishing catch and effort and to report data to fishery managers on a timely basis.

Dynamic fisheries management, or real-time adaptive management, can increase the efficacy of fisheries management, as opposed to the aforementioned static time-area approaches, by precisely overlaying area-based management measures over dynamic spatial delineations that correspond to oceanographic and ecosystem features. This approach requires a keen scientific knowledge of how resource vulnerability corresponds to oceanographic or ecosystem features, and requires continuous, near-real time reporting of catch and effort. Dynamic fisheries management approaches may be used to maximize yield of target species in fisheries while minimizing catch of non-target or avoided species. However, this approach requires levels of monitoring that other static time-area approaches may not require. The implementation of these ABMT in blue water fisheries, which often involve tuna and tuna-like species, require varying levels of capacity for enforcement, monitoring of catch and effort, political will, and scientific knowledge for their justification.

International Ocean Governance and Implementation of Area-Based Management Tools

International negotiations are underway to incorporate ABMT in blue water ecosystems (including closing areas to fishing) to improve the governance of natural resources in areas beyond national jurisdiction, including the high seas. The negotiations are a result of perceived pressures on the sustainability of natural resources in these areas, including from fisheries. At present, science-based guidelines to plan, evaluate, identify unintended consequences, and monitor area-based management implementation discussed in these negotiations are lacking. Such guidelines and decision-making tools are imperative for regional fisheries management organizations and arrangements (RFMO/As) to evaluate and weigh objectives as well as identify performance metrics.

ABMT by Regional Fisheries Management Organizations

In the case of RFMOs overseeing tuna and tuna-like fisheries, each tuna RFMO (herein referred to as “RFMOs” for brevity) has a unique political structure with differing management priorities. Notable RFMOs include the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC), the Inter-American Tropical Tuna Commission (IATTC), the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), and the Western and Central Pacific Fisheries Commission (WCPFC). The WCPFC, which manages about 60% of the world’s tuna fisheries, operates by consensus and is structured such that any cooperating member country and participating territory is granted a delegation. Small Island Developing States (SIDS), which include participating territories in most cases, are also granted certain privileges in the WCPFC Convention Text agreement. SIDS and participating territories may be exempt to catch and effort limits in their respective EEZs which can span out to 200 nm from their shorelines. Additionally, fishing privileges for other fishing nations are often paid for through charter agreements and the purchase of fishing days for purse seine fisheries. The WCPFC adopted a vessel day scheme (VDS) in which fishing nations must purchase the rights to fish in the EEZs of SIDS, which is a major economic incentive for SIDS to gain revenue for tuna resources caught from their sovereign waters. In order to maintain fishing days for purchase under the VDS and to reduce extraneous effort concentration on the high seas, both the WCPFC and its member nations have implemented area-based management measures to balance fishing effort on the high seas and within EEZs. Many of these area-based management measures satisfy economic and political needs of SIDS and participating territories. The WCPFC, IATTC, and ICCAT also have explored measures for managing tuna fisheries through allocation schemes between sectors, such as longline, purse seine, ringnet/surround net, troll, and pole and line fisheries. In the case of purse seine fisheries, the implementation of fish aggregating devices (FADs), which drift and serve as an attractant for tunas, increases the propensity for increased juvenile fishing mortality for bigeye and yellowfin tunas, as the primary target of these fisheries is skipjack tuna. The implementation of FADs by region presents several management difficulties between sectors, and ABMTs to address this issue have been explored. RFMOs are also responsible for the reduction of catches for overfished species and non-target bycatch, such as marine mammals, turtles, birds, and sharks. Conservation and management measures to reduce bycatch using ABMTs have also been explored and implemented. However, closures of fishing areas remain controversial, often come with sociopolitical consequences, and may not render discernible conservation benefit. Such a situation has been demonstrated by measures in the WCPFC and the IOTC.

Spatial closures were recently implemented on the high seas for purse seine fisheries by the WCPFC in 2010. Closures were recently implemented for purse seine fisheries in an area surrounded by EEZs of nations belonging to Parties of the Nauru Agreement (PNA) and Indonesia, for waters inside the French Polynesia EEZ and high seas waters adjacent to the nation, and for all other high seas waters from 10º S to 10º N. The closures were enacted for approximately two years. Sibert et al. (2012) determined that the spatial closure for purse seine fisheries had no discernible conservation benefit, and noted other effort controls and management regimes were likely to have more positive impacts for reducing the disproportionate juvenile fishing mortality on bigeye tuna resulting from purse seine fishing. It can be surmised that if the closures were not effective for purse seine fisheries, which contribute to a disproportionate level of fishing mortality on species of interest (i.e., bigeye and skipjack), then these closures would not be effective for other fisheries, including longline. Additionally, closures do not reconcile agreements by some foreign fishing nations with small islands nations for fishing access, which may counter conservation benefits. Displacement of fishing effort can also lead to other negative conservation impacts (Vaughan, 2017).

Martin et al. (2011) evaluated the implementation of MPAs in the western Indian Ocean (a mixed network of seasonal closures and also scenarios of yearlong closures) and conservation benefits to yellowfin tuna using simulation testing. The IOTC closed off a sizeable portion of the EEZ and high seas waters off of the Somali coast in the western Indian Ocean to longlining one month a year (February) and to purse seine fishing one month a year (November). The IOTC closed area was the only one of the three areas established explicitly for fisheries management. Additionally, the British Government closed off the EEZ of the Chagos Archipelago as an MPA, and the Maldives extended closures to longline fishing to the outer extent of its EEZ.

Martin et al. (2011) used an age structured model to evaluate the effects of a number of scenarios principally related to the impact of the current IOTC closure, other closures, and an extension of the IOTC area closure to be year round. Martin et al. (2011) only considers the effects of the purse seine and longline (LL) fleets, which harvest the majority of the Indian Ocean yellowfin tuna catch. Purse seine fleets were further separated into free school (FS) and FAD (LS) fleet categories to assess the effect of changes in the distribution of fishing mortality among age classes. Martin et al. (2011) examined three scenarios while simulating the situation prior to the 2010 closures. These scenarios included: 1) All areas open, followed by two scenarios with assumptions for closures based on the 2010 networks of spatial closures (scenarios 2 and 3), and two scenarios with assumptions for yearlong closures in each spatial area (scenarios 4 and 5). Scenario 2 assumed the 2010 network closure caused catches eliminated inside the area and not be redistributed outside of closures. Scenario 3 assumed the 2010 network of closures caused effort and catches to be redistributed. Scenario 4 assumed the network of IOTC closures to be yearlong and eliminated catches with no redistribution. Scenario 5 assumed the network of IOTC closures to be yearlong and caused catch and effort inside the closures to be redistributed. The findings of Martin et al. (2011) correspond with indications that spatial closures are not effective in terms in conservation benefit (i.e., increased spawning stock biomass or recruitment) of tuna-like species without considering effort redistribution. Martin et al. (2011) stated: “neither the extant network of closures, nor a scenario where the IOTC closure is extended year round will provide sufficient management benefits for the protection of yellowfin tuna stocks” (p. 10) if effort is expected to be redistributed.

Issues faced by RFMOs in managing tuna and tuna-like species present many challenges with respect to governance for balancing sociopolitical needs while implementing conservation and management measures based on best available science, as demonstrated in the examples in the WCPFC and the IOTC. Universal governance issues in blue water ecosystems, which are commonalities among nearly all tuna RFMOs, need science-based guidelines that supersede parochial interests between SIDS and distant water fishing nations, fishing effort distributions on the high seas as opposed to fishing effort inside politicized EEZ boundaries, allocation of catch and effort by fishing sector by region, and ABMT implementation to protect spawning habitat. International and inter-RFMO cooperation is needed to identify objectives, performance metrics, appropriate ABMT tools for implementation concomitant to identified objectives, and analytical tools best suited to monitor and evaluate ABMT. At present, international negotiations are underway to formulate a management scheme of areas beyond national jurisdiction (i.e., the high seas), which may include just a portion of blue water ecosystems and areas occupied by their living resources.

International Governance in Areas Beyond National Jurisdiction

In 2015, the United Nations (UN) General Assembly agreed to develop an international legally binding instrument under the UN Convention on the Law of the Sea (UNCLOS). Negotiations are underway to develop a new legally binding convention for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction (BBNJ). There are four main themes of the new convention: 1) Marine genetic resources, 2) “Area-based Management Tools” including (but not limited to) MPAs, 3) Environmental impact assessments, and 4) Capacity-building and the transfer of marine technology. Some international groups and states are concerned that recommendations, proposals, and criteria for selecting MPAs in the open ocean are synonymous with overtures from environmental non-governmental organizations (ENGOs), SIDS, and land-locked states that are encouraging utilization of high seas closures for economic motives. Proposed criteria for selecting areas to implement ABMT on the high seas must be agreed upon prior to implementation. There are concerns that negotiations regarding BBNJ may allow ENGOs an instrument to influence or develop international fisheries policies on the high seas that would otherwise not be tenable under the purview of RFMOs. Negotiations on BBNJ have included discussion on how existing legal instruments, which may include RFMOs, "should not be undermined". The UNCLOS has negotiated the development of a Scientific and Technical Body to review proposed implementation of ABMTs and guidelines for consultation of states adjacent to proposed implementation of ABMTs. Other criteria for ABMTs include traditional knowledge, food security, social benefits, and economic equality. The UN Committee of Fisheries has affirmed that it is the foremost forum for debate and discussion on proposed actions.

FAO-led workshops and initiatives to compile knowledge and guidance on utilization of "other effective area-based conservation measures" (OECMs) which can depart from standard or commonplace MPAs. The foci of these works were not specific to blue water ecosystems, were commensurate to initiatives by the UN Convention on Biological Diversity (CBD), and may not have direct or immediate discernible relevance to issues faced by resource management in blue water ecosystems. "Decision 14/8" by the CDB defines OECMs as "A geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and, where applicable, cultural, spiritual, socio–economic, and other locally relevant values" (CDB 2018). An overarching goal of the utilizations of OECMs (and other ABMTs) under the CDB is to achieve a set of aspirational targets, known as Aichi Biodiversity Targets. OECMs are secondary to "well-connected protected areas" under Aichi Biodiversity Targets, which aspire to have 10% of marine ecosystems under some form of area-based management. Twenty Aichi Biodiversity Targets and five strategic goals were adopted by the CBD to address and mitigate global loss in biological diversity.

Aichi Biodiversity Target 11 aims to improve the status of biodiversity by safeguarding ecosystems, species, and genetic diversity through area-based conservation. According to Aichi Target 11, "at least 17 per cent of terrestrial and inland water and 10 per cent of coastal and marine areas need to be , especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes" by 2020 (FAO, 2020). The implementation of Aichi Target 11 should span multiple ecosystems and allow equitable biodiversity recovery across states and jurisdictions. Implementation should be "well-connected" to promote to a "wider landscape or seascape using corridors and ecological networks" to allow connectivity, promote an adaptation to the eventualities of climate change, and the application of the ecosystem-based approach to management. The notion of a "well-connected system" for the implementation of ABMT may be difficult in blue water ecosystems where the spatial constructs of marine resource habitat and the movement patterns of many of these species cover vast areas that may be subject to change or dynamic with respect to environmental conditions.

This Road Map is developed to satisfy a purpose and need regarding the implementation of ABMTs in managing blue water fisheries. The objectives of this work are: 1) identifying suitable objectives and pairing them with tenable area-based management measures, 2) developing a road map of *a priori* criteria for implementing effective area-based management and area-based management tools, 3) creating a compendium of the "state of knowledge" of ABMTs with respect to three focused management objectives, and 4) selecting appropriate means of evaluating the effects of area-based management measures. Additional objectives include determining feasible performance metrics for area-based management, defining sufficient historical and continual data streams, identifying appropriate methods of evaluating management measures, evaluating enforcement and compliance monitoring capacity, and weighing costs and benefits of management objectives. The following sections should provide managers with science-based guidelines on ABMT implementation while offering empirical evidence and historical context of pitfalls and successes.

CHAPTER 2. OBJECTIVES AND PERFORMANCE METRICS FOR SPATIAL MANAGEMENT

Authored by Ray Hilborn

Purpose

This section reviews the range of objectives and performance metrics that have been proposed for the conservation and management of pelagic ecosystems. Ideally, but rarely, national or international policies would explicitly specify the objectives of the policy or the problem it addresses, and, even more rarely, what attributes could be measured to evaluate the success at achieving the objectives. We review a range of published papers and documents associated with pelagic ecosystems and area-based management to summarize what objectives and performance metrics have been proposed. There are many threats to the ocean, including climate change, ocean acidification, plastic, oil spills, other pollutants, deep sea mining, coastal runoff, and fishing. For the purpose of this review, we will focus specifically on objectives related to the impact of fishing, its impact on pelagic ecosystems, and the interaction between fishing-induced changes and ecosystem status and function.

Objectives

Spatial management of pelagic ecosystems can be used to achieve a wide range of biological, social, and economic objectives. Objectives are often based on the desire to counter perceived threats to the marine system, which may include seafloor mining, fishing, climate change, ocean acidification, micro plastics, seismic surveys, shipping, and geosequestration (CEA Consulting (editor) 2019). Our review found that objectives can range from broad, such as protecting biodiversity, to specific, such as increasing the abundance of a specific stock. There are a number of traditional objectives for single species fisheries management, including providing sustainable catch, maximization of yield, maintaining size of fish, food security or employment for specific communities, and profitability.

Gilman et al. (2019a) evaluated five specific objectives of marine protected areas (MPAs):

1. Reduce or eliminate bycatch fishing mortality of pelagic species of conservation concern.
2. Reduce or eliminate fishing mortality at habitats that are important for critical life history stages of pelagic species.
3. Reduce the fishing mortality of target stocks to contribute to sustaining desired production levels (i.e., stay near target thresholds) and avoiding conditions where protracted or irreparable harm to the stock occurs (i.e., stay above limit thresholds).
4. Reduce fishing mortality of prey species of pelagic target stocks and species of conservation concern in order to stay near targets and above limits.
5. Reduce trait-based selective fishing mortality and fisheries-induced evolution (FIE).

Lester et al. (2009), in a large scale meta-analysis of MPAs, list reasonably vague objectives, such as “restoring and sustaining marine ecosystems within their boundaries” (p. 34). Lubchenco and Grorud-Colvert (2015) suggest that objectives include “more species in greater numbers and larger sizes, a control to evaluate the impact of fishing” (p. 383). In their brochure and video entitled “The Science of Marine Reserves”, the Partnership for Interdisciplinary Studies of Coastal Oceans (2002) said the “major purpose for establishing marine reserves is to protect the habitats and to restore animals and plants in particular sites.” They further stated that the "objectives of marine reserves are to restore and protect biodiversity and to enhance sustainable fisheries."

Allison et al. (1998) stated "reserves will be essential for conservation efforts because they can provide unique protection for critical areas, they can provide a spatial escape for intensely exploited species, and they can potentially act as buffers against some management miscalculations and unforeseen or unusual conditions" (Abstract section). Hilborn et al. (2004) said that "proponents argue that… marine reserves protect biodiversity, serve as an insurance policy, and benefit ecosystem and fisheries management" (p. 198).

We can look to some other area-based management systems for their stated objectives. The North Pacific Fisheries Convention states "the objective of the Convention is to ensure the long-term conservation and sustainable use of the fisheries resources in the Convention Area while protecting the marine ecosystems of the North Pacific" (FAO 2019, p. 2). FAO's website on "Sustainable fisheries management and biodiversity conservation of deep-sea living marine resources and ecosystems in the ABNJ [areas beyond national jurisdiction]" cites an objective of "reducing adverse impacts on VMEs [vulnerable marine ecosystems] and enhanced conservation and management components of EBSA [ecologically or biologically significant areas]" (FAO, 2020).

Table 1. Stated objectives from selected area-based management systems.

Reserve name	Stated objectives
California MLPA [Marine Life Protection Act] Network (California Department of Fish and Game 2009)	(1) To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems. (2) To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted. (3) To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity. (4) To protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value. (5) To ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines. (6) To ensure that the state's MPAs are designed and managed, to the extent possible, as a network.

Área de Proteção Ambiental – Brazil (Government of Brazil 2018)	(1) The purpose of providing the conservation and sustainable use of biodiversity and its biological resources and genetic resources, associated ecosystem services, including fisheries resources and other components of marine biodiversity with economic potential and scientific interest in that Archipelago and its Exclusive Economic Zone.
Phoenix Islands (PIPA; Pala 2014)	(1) A major spawning ground for tuna, so its closure will have a major contribution to the conservation and rejuvenation of fish stocks and to global food security. (2) To conserve the natural and cultural heritage of the Phoenix Islands Protected Area for the sustained benefit of the peoples of the Republic of Kiribati and the world. (3) To implement effective integrated and adaptive management that ensures the natural and cultural heritage values of PIPA are maintained, and where necessary restored, to achieve PIPA's Vision.
Ross Sea Marine Protected Area	(1) For the purpose of achieving the conservation of Antarctic marine living resources, where conservation includes rational use. (2) The MPA objectives fall into three main categories: representativeness, threat mitigation and scientific reference areas. (3) Threats to the achievement of Article II.3 and the specific objectives of this MPA are being effectively avoided or mitigated by the MPA, in locations where the risk of ecosystem impacts from harvesting activities may otherwise be high. (4) Provides opportunities to examine Antarctic marine ecosystems where no or limited fishing has taken or is taking place.
PNMN Papahānaumokuākea Marine National Monument (The White House 2016)	(1) Permanently protecting pristine coral reefs, deep sea marine habitats, and important ecological resources in the waters of the Northwest Hawaiian Islands. (2) Expansion provides critical protections for more than 7,000 marine species, including whales and sea turtles listed under the Endangered Species Act and the longest-living marine species in the world – black coral. (3) Improve ocean resilience, help the region's distinct physical and biological resources adapt, and create a natural laboratory that will allow scientists to monitor and explore the impacts of climate change on these fragile ecosystems. (4) Protect areas of historical and cultural significance. (5) Protect and preserve the marine area of the Northwestern Hawaiian Islands and the historic and scientific objects therein.

Natural Park of the Coral Sea (Pew Foundation 2018)	(1) Safeguard these waters from fishing and other extractive activities. That step would ensure that the waters remain healthy and continue to deliver ecotourism and environmental benefits. (2) Implement full protections for a variety of reefs, marks 10x increase in protected area, and represents progress towards meeting UICN. recommendations that all nations safeguard 30% of their EEZ.
Pacific Remote Islands National Marine Monument (NOAA 2020)	(1) Monument status ensures these special areas are conserved. (2) to protect the whales, seabirds, sea turtles, fishes, and corals in this region of the central and western Pacific Ocean, commercial fishing and mineral extraction will now be prohibited in this national monument. (3) The pristine waters provide a baseline comparison for important scientific research that monitors and evaluates impacts of global climate change, including benchmarking coral bleaching and ocean acidification. The scale of the adjacent areas significantly enhances opportunities for such scientific research beyond the Monument boundaries established in Proclamation 8336. (4) the adjacent areas provide habitat, migratory path, range and foraging habitat for turtles and bird.
Great Barrier Reef (Wikipedia 2020)	(1) Protects a large part of Australia's Great Barrier Reef from damaging activities. (2) This Zoning Plan aims, in conjunction with other management mechanisms, to protect and conserve the biodiversity of the Great Barrier Reef ecosystem within a network of highly protected zones, while providing opportunities for the ecologically sustainable use of, and access to, the Great Barrier Reef Region by current and future generations. (3) In addition to the protection of representative areas of biodiversity, this Zoning Plan also provides for the protection of other areas of high conservation value by assigning protective zoning to a range of habitats such as coral reefs, sponge beds, seagrass beds and deep water areas, as well as important dugong habitats and other special or unique sites.
Palau National Marine Sanctuary (PRNewswire 2020; Government of Palau 2020)	(1) We want to lead the way in restoring the health of the ocean for future generations. (2) preserve and manage Palau's waters and natural resources to maintain their health, beauty, and resources. (3) …a major spawning ground for tuna, so its closure will have a major contribution to the conservation and rejuvenation of fish stocks and to global food security.

Chagos Islands Marine Reserve (Chagos Conservation Trust 2020)	(1) It will contribute greatly to a number of globally agreed targets, such as the Convention on Biological Diversity target to protect 10% of the oceans by 2020. (2) the Chagos Islands Marine Reserve protects the world's largest coral reef atoll, which serves as a breeding ground for important populations of sharks, dolphins, and sea turtles.
French Southern Territories National Marine Reserve	(1) To preserve the marine areas of high ecological importance, "no-take" zones were set up, covering a strict protection area of more than 120,000 square kilometers. (2) The main purpose of the reserve is the protection, implementation, and management of natural areas for the maintenance of global biodiversity Southern Territories. (3) Its main objective is the effective protection and management of natural areas concerned in order to maintain biodiversity overall the Southern Territories, including ensuring the protection of cetaceans, since it is located within the southern sanctuary to them dedicated.

Table 1 shows stated objectives from legislation, official pronouncements, and secondary sources for several area-based management systems. The most common terms are "to preserve" and "to protect", but there are specific references to increasing or maintaining the condition of specific habitats and species. Protection of historical and culturally-significant sites is often mentioned. One example mentions contributing to international agreement targets for protected areas.

Performance Metrics

The most common metrics used for evaluating MPA performance have been density, biomass, size of organisms, and diversity of species as in Halpern (2003) and Lester et al. (2009). Other metrics commonly mentioned include:

- Reduce by-catch amounts
- Reduce fishing mortality rates
- Reduce selective pressure
- Biomass
- Density
- Fish size
- Species richness
- Catch
- Value of catch
- Impact on communities

The FAO workshop on impacts of MPAs (FAO 2015) suggested a wide range of metrics and are shown in Figure 1.

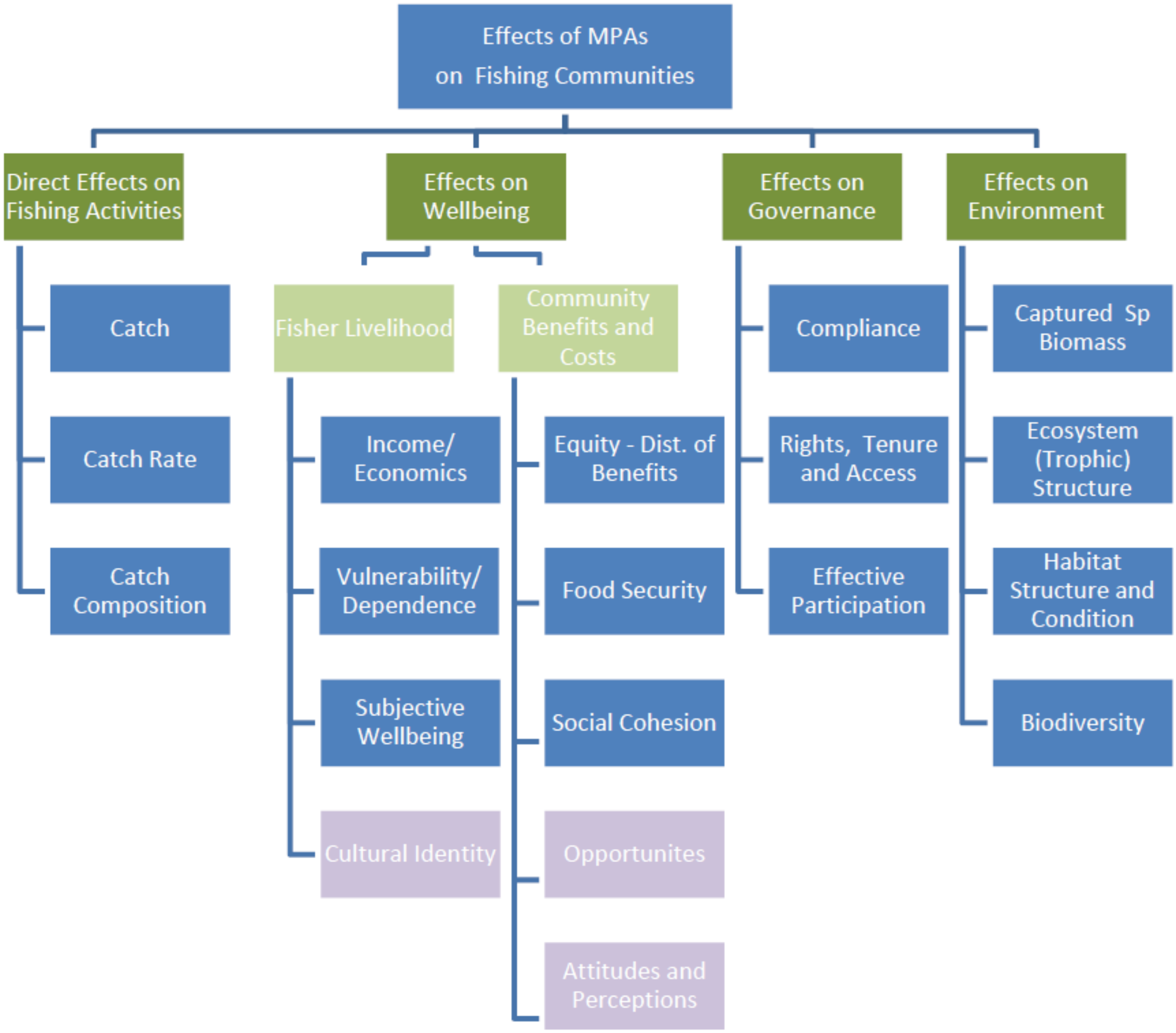

Figure 1. Priority categories and components identifies for determining the potential effects of MPA implementation on related fishing communities.

Summary Table

Synthesizing the available explicit objectives and metrics of spatial management measures for pelagic ecosystems, we propose the following list of possible objectives and metrics that could be used to evaluate success (Table 2).

Table 2. A summary of objectives and related performance metrics.

OBJECTIVE	PERFORMANCE METRIC
Protect biodiversity by reducing bycatch	Abundance of bycatch species
Increase or maintain target species abundance	Abundance of target species
Protect sensitive benthic biota	Abundance of sensitive biota
Maintain or increase abundance of prey of target species	Abundance of prey species

OBJECTIVE	PERFORMANCE METRIC
Increase size of target species	Average size of target species
Increase species diversity	Measures of species diversity
Increase catch	Measure catch
Increase profitability	Measure profitability
Reduce the magnitude of fishery induced evolution	Trend in traits of concern
Employment	Number of people employed
Cultural satisfaction	?
Food Security	?
Climate resilience	?
Increase non-consumptive recreational opportunity	Amount of such recreational use
Increase scientific or educational opportunity	Amount of scientific or educational use
Provide more natural baseline for scientific study	Full suite of anthropogenic pressures (pollution, outcomes of climate change, spread of invasive alien species, etc.) in protected site do not occur / are relatively low
Buffers from management mistakes	?

Discussion

While not exhaustive, we believe Table 2 summarizes almost all of the objectives and metrics that have been proposed or used. Perhaps the key uncertainty in objectives is whether the objective is simply to increase the metric within the closed area or within the region and thus whether success would be measured only inside closed areas or integrated across the total area.

The common words of “to preserve” and “to protect” are implicitly assumed to be achieved by the implementation of various forms of area-based management, although these objectives may not be achieved if there is inadequate enforcement of regulations or if mobile fish species are exploited outside of protected areas with no net benefit from the protection.

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CHAPTER 3. DESIGNS OF SPATIO-TEMPORAL MANAGEMENT MEASURES FOR BLUE WATER FISHERIES

Authored by Eric Gilman, Milani Chaloupka, and Michel Kaiser

Introduction

Marine protected areas (MPAs) and other spatio-temporal management measures are increasingly used as components of management frameworks to govern marine activities, including fishing, and to protect the component manifestations of marine biodiversity. This includes a relatively recent application of spatial management measures to blue water pelagic ecosystems, although few evidence-based evaluations of ecological responses have been conducted (Boerder et al. 2017; Bucaram et al. 2018; Gilman et al. 2019a, 2020). Spatially-explicit measures for managing marine capture fisheries were first employed centuries ago by some tropical Pacific Island communities (Johannes 1978). Some traditional community-based, spatially-explicit management measures as well as new approaches are widely employed today as part of fisheries management frameworks, including a recent proliferation of very large MPAs, larger than 100,000 km^2, which now make up 4.6% of the total ocean area (Johannes 2002; Atlas of Marine Protection 2019; Bingham et al. 2019; Smyth and Hanich 2019).

The broad range of ecological and socioeconomic objectives of spatially-managed marine areas include, for example, mitigating species-level extinction rates by protecting sites that are of importance to threatened, rare and endemic species, or a threatened ecosystem, community, or habitat type; serving as refugia to current and predicted pressures, including outcomes of climate change; and supporting the maintenance of entire ecosystems by providing representativeness and ecological connectivity through networks of interconnected sites (Roberts et al. 2003; Dunn 2011; Gilman et al. 2011). MPAs and other spatial management approaches may be included as a component of fisheries management frameworks and may have specific objectives such as mitigating fisheries bycatch of species of conservation concern with “slow” life history traits that form temporally- and spatially-predictable hotspots, protecting habitats important for critical life history stages; maintaining or increasing local biomass (via increased abundance and/or mean lengths); maintaining or increasing recruitment and absolute biomass; protecting and increasing species richness and diversity; and reducing or reversing the magnitude of trait-based selective fishing mortality and fisheries-induced evolution (Kaiser et al. 2018; Kenchington et al. 2018; Gilman et al. 2019a). The prioritization of objectives may be dictated by the geospatial and temporal scales of interest; prioritized components of biodiversity, conservation targets, and threats; and socioeconomic priorities, including maintaining or enhancing selected ecosystem services (Gilman et al. 2011). Governance and political considerations also dictate how spatial management measures are designed, such as selecting sites with few existing incompatible activities.

Here, we review spatial management approaches of relevance to pelagic, blue water fisheries, covering: (1) static and dynamic habitats of pelagic apex predators and their prey; (2) static and dynamic spatial management measures, including the temporal application of the static or dynamic measures; (3) categories of area-based marine conservation measures; and (4) networked spatially-managed pelagic marine areas. The identification of the range of blue water area-based management measures, including some traditional community-based approaches that have been practiced for centuries, supports the selection of measures that best meet ecological and socioeconomic management objectives and the site-specific context.

Spatial Management Measures for Pelagic Fisheries

Static and Dynamic Habitats of Pelagic Apex Predators and Their Prey

Pelagic apex predators, and in some cases different size classes and sexes within species, use different static and dynamic pelagic habitats (Polovina et al. 2004; Hyrenbach et al. 2000; 2006a, 2006b; Bailey and Thompson 2010; Muhling et al. 2011; Vandeperre et al. 2014a, 2014b; Gilman et al. 2016). Their geospatial and vertical distributions are determined, in part, by their physiology, prey availability and primary environmental variables of hydrostatic pressure, temperature, and dissolved oxygen (Beverly et al. 2009; Schaefer et al. 2009; Bernal et al. 2010; Muhling et al. 2011; Musyl et al. 2003, 2011; Brodziak and Walsh 2013; Lehodey et al. 2011, 2015). The distributions of pelagic predators, and when and where they aggregate, are also determined, in part, by physical features that determine their biophysical structure (e.g., gyres, fronts). These features structure the distribution of nutrients, levels of primary productivity, and the distributions and aggregations of prey species of pelagic apex predators (Hyrenbach et al. 2000, 2006a, 2006b; Selles et al. 2014; Vandeperre et al. 2014b, Kavanaugh et al. 2016). These static and dynamic pelagic habitats and features differ in their suitability for spatial management due to differences in their spatial and temporal predictability and their size.

Static, Place-Based Spatial Management Measures

Some pelagic species aggregate at bathymetric structures, which have fixed (static) geo-spatial locations. Such structures include shallow submerged features like seamounts and reefs, areas with steep seabed gradients such as shelf breaks, and near islands and coastal features that create small-scale eddies and fronts (i.e., island mass effect) (Doty and Oguri 1956; Worm et al. 2003; Hyrenbach et al. 2000; Bailey and Thompson 2010; Gilman et al. 2012; Kavanaugh et al. 2016). For example, the Revillagigedo Islands Archipelago Biosphere Reserve in Mexico prohibits fishing by commercial Mexican commercial fishing vessels within 12 nm around four islands, where there is high site fidelity of yellowfin tunas (i.e., the tracks of 52 yellowfin tunas that were at liberty for a mean of 411 days following tagging indicate that 49 remained within 810 nm of their points of release within the Reserve) (Schaefer et al. 2014). Depending on their physical characteristics and location, these features alter local currents and possibly isotherm distributions, create oceanographic perturbations, such as through advection and dispersion, and increase upwelling and mixing (Pitcher et al. 2007; White et al. 2007). The influence of these static features in concentrating productivity and aggregating pelagic predators can be coupled with hydrodynamic conditions, such as current direction and strength. In other words, the feature is fixed in location, but its concentration of productivity can be temporally variable.

Some pelagic MPAs are static or place-based and prohibit pelagic commercial fishing year-round. For example, the Great Barrier Reef Marine Park, the first large MPA containing pelagic habitats, prohibits pelagic longline fishing throughout the park (Australian Government 1983; GBRMPA 2004; Gilman et al. 2019a). MPAs established by some Pacific island states prohibit pelagic longline fishing within specified distances of shallow submerged features (e.g., FSM Government 2014; MIMRA 2018). Spatially- and temporally-static pelagic MPAs or MPA networks could be established at shallow seamounts, shelf breaks, or other bathymetric features that concentrate and enhance the residency time of pelagic predators and their prey (Worm et al. 2003; Genin 2004; Morato et al. 2008, 2010a, 2010b; Gilman et al. 2012; Kaplan et al. 2014).

Others are static but seasonal and are often species-specific. For instance, seasonal spatial closures to tuna purse seining adopted by tuna regional fisheries management organizations (RFMOs) were designed to reduce bigeye tuna (*Thunnus obesus*) fishing mortality, and the "Mackerel Box" off southwestern England was established to protect juvenile mackerel (*Scomber scombrus*) (Sweeting and Polunin 2005; Torres-Irineo et al. 2011; IATTC 2017). And, for example, a pelagic MPA, or network of pelagic MPAs, could be spatially static but temporally dynamic, such as a migratory corridor leading to a breeding area or a site with variable periods of upwelling (Schillinger et al. 2008). Related, rotating fishery closed areas as used in coastal habitats (e.g., Valderrama and Anderson, 2007; Plaganyi et al. 2015), theoretically might be a suitable design to contribute to achieving an objective of maintaining the local abundance of pelagic predators at desired levels, if residency times and periods for "replenishment" from fishery removals of apex predators is relatively short, such as days to months, at networks of static aggregating features (Ohta and Kakuma 2004, Dagorn et al. 2007).

Some MPAs are spatially explicit but triggered only when seasonal thresholds are exceeded. For instance, in the Hawaii tuna longline fishery, the U.S. government has adopted a seasonal limit of catching and causing mortality or serious injury to two false killer whales (*Pseudorca crassidens*) in a portion of the fishing grounds near the main Hawaiian Islands (NMFS, 2012).

Static pelagic MPAs and pelagic MPA networks could protect pelagic sites important for critical life history stages. For example, static MPAs could theoretically be designed to protect:

- Pelagic foraging hotspots of some seabird species (Hyrenbach et al. 2006a, Louzao et al. 2006; Oppel et al. 2018).
- Pelagic shark pupping, nursery, and mating aggregations (Litvinov 2006; Domeier and Nasby-Lucas 2007; Vandeperre et al. 2014a, 2014b).
- Areas where pelagic juvenile loggerhead sea turtles have prolonged residence (e.g., an area off Baja California, Peckham et al. 2007).
- Predictable, well-defined pelagic migratory corridors (Block et al. 2011).

<u>Spatially and Temporally Dynamic Spatial Management Measures</u>

Pelagic MPAs and MPA networks could be spatially dynamic but temporally static if they are protecting temporally-predictable features that are variable spatially and in intensity. Or a pelagic MPA or network of pelagic MPAs could be both spatially and temporally variable in order to restrict fishing at locations that vary in space and time. For example, spatio-temporally dynamic MPAs might be designed to restrict fishing at hydrographic features (e.g., fronts, eddies) and drifting floating objects, including fish aggregating devices (FADs), or areas with high concentrations of a pelagic predator dictated by spatio-temporally dynamic habitat preferences (Hyrenbach et al. 2000; Hobday and Hartmann 2006; Game et al. 2009; Hobday et al. 2010, 2011; Hall and Roman 2013; Gaertner et al. 2016; Gilman et al. 2019a).

Spatially dynamic hydrographic features affect the distribution of pelagic predators. Some are broad scale, such as currents and frontal systems that are temporally persistent, occurring over years to decades, and over entire ocean basins. Others are meso-scale, such as upwelling plumes, eddies, and frontal systems, persisting over tens to hundreds of days and occurring over tens to hundreds of kilometers. Others are fine scale, including fronts and eddies, which are ephemeral, lasting for days, and occurring over 100s of meters to kilometers (Hyrenbach et al. 2000; McGlade and Metuzals 2000; Polovina et al. 2001; Hazen et al. 2013; Kavanaugh et al. 2016). Aggregations of pelagic species at ephemeral, dynamic, pelagic habitats are difficult to map and manage in real-time for the exclusion of fishing effort. As with static habitats, dynamic but persistent habitats are relatively predicable, enabling dynamic pelagic MPA boundaries to be defined more easily, but they may need to be extremely large to achieve some ecological objectives (Hyrenbach et al. 2000; Della Penna et al. 2017; Gilman et al. 2019a).

Some pelagic species associate near and aggregate at individual and networks of natural and artificial floating objects, including FADs, possibly because the floating objects provide shelter, foraging opportunities, and "meeting points" (Freon and Dagorn 2000; Castro et al. 2002; Hall and Roman 2013). Floating objects that aggregate pelagic marine organisms include drifting logs, drifting algae, live and dead large marine organisms, marine debris (e.g., crates, pallets, nets), vessels, as well as anchored and drifting FADs, which are artificial floating objects that are built and deployed by fishers and are designed specifically to aggregate pelagic fishes (Castro et al. 2002; Hall and Roman 2013; Gaertner et al. 2016). Satellite buoys, now attached to almost all drifting FADs, enable the purse seine industry, and fisheries managers who receive parallel satellite buoy data feeds, to track their real-time spatial position (Gilman et al. 2018), enabling the real-time dynamic spatial management of tuna purse seine and other fisheries that fish on FADs.

Dynamic spatial management measures could be designed to protect hotspots of ratios of bycatch-to-target catch (Dolder et al. 2018; Hazen et al. 2018). One example is a near real-time dynamic spatial management of southern bluefin tuna (*Thunnus maccoyii*) bycatch by the eastern Australia pelagic longline fishery through use of a habitat model (Hobday and Hartmann 2006; Hobday et al. 2010). A retrospective analysis of the efficacy of this dynamic fisheries management system found that it has been successfully mitigating bycatch of southern bluefin tuna (Hobday and Hartmann 2006; Hobday et al. 2009, 2010).

Theoretical approaches have also been developed for dynamic temporal and spatial management of pelagic fisheries based on the variable position of pelagic habitats and variable ecosystem processes. One approach provides maps of near real-time locations of predicted thermal habitat of loggerhead and leatherback sea turtles to Hawaii's shallow-set swordfish longline vessels, information that could, theoretically, enable them to avoid these marine turtle bycatch hotspots (Howell et al. 2008, 2015). A comparable tool for the California drift swordfish gillnet fishery identifies near real-time areas with high ratios of bycatch-to-target-catch for leatherback sea turtles, California sea lions, and blue sharks (Hazen et al. 2018).

Mobile MPAs could also be designed to protect relatively small, dynamic sites that are important for critical life history stages of pelagic species if the sites are temporally- and spatially-predictable, including pelagic areas used for spawning, mating, and calving/pupping, as well as nursery and nesting areas, areas important for foraging, and migratory pathways (Gilman et al. 2019a). For example, mobile MPAs could protect eddies within bluefin tuna spawning grounds during spawning periods. Bluefin tunas may depend heavily on eddies to produce spawning schools that are above a density threshold needed for successful reproduction (Bakun 2012). Unlike other principal market tuna species, bluefin tuna species spawn in relatively small areas during relatively short periods of 1 to 2 months (Schaefer 2001; Collette et al. 2011; Muhling et al. 2011).

Categorization Schemes for Area-Based Marine Conservation Measures

There is large variability in the degree of protection afforded by different marine spatial management frameworks. Some are cross-sectoral in scope and prohibit all extractive activities. Some allow multiple uses, but zone uses, so that incompatible activities do not co-occur and restrict when uses can occur to control the level of pressures. Others prohibit a subset of extractive activities, such as prohibiting, temporally or spatially, one or more pelagic fisheries.

Some fisheries spatial management frameworks may meet the International Union for the Conservation of Nature's (IUCN's) MPA definition of 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 2018, p. 2). However, the IUCN has explicitly clarified that their MPA definition excludes fishery closures with an objective of managing target stocks if the management objective for the closure does not also address the "overall health and diversity of the ecosystem and have a stated primary aim to this effect" (Day et al. 2019, p. 18). The IUCN has developed categories based on the management objectives of protected areas, which are based in part on their degree of protection (Day et al. 2019). *Strict Nature Reserves*, for example, are protected areas established to protect biodiversity and control and limit human uses and impacts, while *Protected Landscape/Seascapes* are areas where biodiversity conservation is linked with sustainable use of natural resources, where one objective is to sustain the provision of ecosystem products and services (IUCN 2020).

Some marine areas may achieve protection of pelagic habitat as a consequence of restrictions implemented for reasons other than nature/biodiversity conservation that may also achieve ecological benefits by constraining fishing mortality of pelagic species. Examples include areas zoned for defense, prohibitions on fishing to prevent damage of data buoys, areas subject to piracy, privately protected areas, and areas protected by indigenous peoples and local communities (e.g., WCPFC 2009; Chassot et al. 2010; Gannon et al. 2017). "Other Effective Area-based Conservation Measures", originally coined by the Convention on Biological Diversity (CBD) in their *Strategic Plan for Biodiversity 2011-2020* (CBD 2010), can contribute to meeting area-based goals for global MPAs (Diz et al. 2018; Garcia et al. 2019).

The CBD has defined four types of area-based marine conservation measures (CBD 2018):

- **Marine and coastal protected areas**: A geographically defined area which is designated or regulated and managed to achieve specific conservation objectives.
- **Territories and areas governed and managed by indigenous peoples and local communities**: Some or all of the governance and/or management authority is often ceded to the indigenous peoples and local communities, and conservation objectives are often tied to food security and access to resources for indigenous peoples and local communities.
- **Area-based fishery management measures**: Formally established, spatially defined fishery management and/or conservation measures, implemented to achieve one or more intended fishery outcomes. The outcomes of these measures are commonly related to sustainable use of the fishery. However, they can also often include protection of, or reduction of impact on, biodiversity, habitats, or ecosystem structure and function.
- **Other sectoral area-based management approaches**: There are a range of area-based measures applied in other sectors at different scales and for different purposes. These

include, for example, Particularly Sensitive Sea Areas (areas designated by the International Maritime Organization for protection from damage by international maritime activities because of ecological, socioeconomic or scientific significance), Areas of Particular Environmental Interest (areas of the seafloor designated by the International Seabed Authority for protection from damage by deep-seabed mining because of biodiversity, ecosystem structure, and function), approaches within national work on marine spatial planning, as well as conservation measures in other sectors.

Only "area-based fishery management measures" are designed specifically to achieve a fishery outcome such as increased production or to manage gear conflicts. However, the other three categories can also affect pelagic marine capture fisheries and the ability to achieve fisheries management objectives, and thus must be accounted for in designing effective fisheries management systems.

Networks of Spatially-Managed Marine Areas

Site networks are collections of individual protected sites that are intended to operate cooperatively and synergistically, both ecologically and administratively, at various spatial scales, and with a range of protection levels, in order to meet objectives that single sites cannot achieve in isolation (Laffoley et al. 2008). For example, networks of spatially-managed areas may enable protecting areas important for multiple life history stages, which could not be achieved by protecting an individual site (Dunn et al. 2011). While tools for identifying dynamic protected areas are not as well developed as those for terrestrial and coastal protected areas, there has been some progress in defining systematic approaches to conservation planning for pelagic ecosystems, including to protect spatially dynamic/mobile features (Alpine and Hobday, 2007; Game et al. 2009) and the overarching objectives guiding selection of individual and networked sites are applicable across ecosystems. Representativeness, replication, ecological connectivity, size, and refugia may be minimum ecological criteria for identifying sites for inclusion in networks of pelagic marine spatially managed areas, including pelagic MPAs (Gilman et al. 2011; Green et al. 2013):

- **Representativeness**: Having a series of sites included in an MPA network that adequately represent the full range of biodiversity components provides representativeness (Margules and Pressey 2000; Gaston et al. 2002; Roberts et al. 2003; CBD 2008; Pressey and Bottrill 2009; Roberts et al. 2018). Ensuring that all components of an ecosystem are protected in the site network is a strategy for optimizing resistance and resilience, as the representation increases the chance that at least one community type, possessing disparate physical and biological features, will survive stressors.
- **Replication**: Including multiple examples of each biodiversity component within an MPA network reduces the risk of losing individual components (Gaston et al. 2002; Roberts et al. 2003; Salm et al. 2006; Wells 2006; CBD 2008; Green et al. 2013).
- **Ecological connectivity**: Functional links between sites in the network can protect connectivity between communities (Crowder et al. 2000; Stewart et al. 2003; Roberts et al. 2003; Roberts et al. 2018). The systematic selection of individual sites to include in the network to address edge effects and spacing between sites is critical (Laffoley et al. 2008). The exchange of larvae and species between sites is an example of a functional link between sites of the same ecosystem type. For example, the existence and health of coral reefs are dependent on the buffering capacity of shoreward ecosystems, which support the oligotrophic conditions needed by coral reefs to limit overgrowth by algae.

Coral reefs, in turn, buffer the soft sediment landward ecosystems from wave energy (Mumby et al. 2004; Victor et al. 2004).

- **Size:** The size of individual sites and combined area of sites within the network is of importance to ensure minimum territory requirements of certain species are protected (Kareiva and Marvier 2003), to meet targeted species richness (Groombridge and Jenkins 2000; Roberts et al. 2018), and to provide an adequate likelihood that attributes will persist following major disturbance events (Allison et al. 2003). The size of pelagic MPA networks needs to account for the extensive ranges, temporally and spatially dynamic distributions, and shifting distributions in response to outcomes of climate change of pelagic species (Gilman et al. 2019a). The size of the MPA network needs to be designed to protect an adequate proportion of the distribution of a population and protect individuals for an adequate proportion of their lifetime to cause an increase in local and absolute biomass (Blyth-Skyrme et al. 2006; Le Quesne and Codling 2009; Gruss et al. 2011; Graham et al. 2012).
- **Refugia**: Including sites in an MPA network that are relatively resistant and resilient to stressors enables the network to act as refugia to current and predicted future stresses, including outcomes of climate change (Gaston et al. 2002; Barber et al. 2004; Salm et al. 2006; Green et al. 2013). Designing effective MPA networks requires accounting for the likely changes in species' distributions over time under different climate change scenarios, as well as considering an areas' resistance and resilience to projected climate change and contributions to adaptation strategies. For example, ranges may shift to higher latitudes and different longitudes, and new spawning locations may emerge for some tuna species in response to ocean warming (Dufour et al. 2010; Lehodey et al. 2010, 2013, 2015; Gilman et al. 2016). Ranges may also change in response to variations in abundance, where it is hypothesized that, as a population's abundance declines, its distribution will contract towards the center of their ranges, where density remains stable (Collette and Russo 1984; Pitcher 1995; Brodie et al. 1998; Worm and Tittensor 2011).

Effective site networks can also provide several socioeconomic and governance benefits. Site networks can reduce adverse socioeconomic impacts from restricting incompatible activities at individual sites, as restrictions needed to achieve conservation objectives can be spread out across the sites in the network without compromising conservation and commercial benefits that result from protected areas (Laffoley et al. 2008; IOSEA 2010). Site networks might augment international recognition of the importance of a site and of conservation efforts. Also, through economies of scale from coordinated governance activities, networking protected sites can optimize the use of limited resources for governance, including outreach, monitoring, establishing secure funding mechanisms, staff training, conservation interventions, enforcement, performance evaluation, and adaptive management (Sandwith et al. 2001). For instance, given uncertainties about future climate change and responses of ecosystems, there is a need to monitor and study changes systematically. Establishing ecosystem baselines and monitoring gradual changes through site networks, using standardized techniques, can enable the separation of site-based influences from global changes to provide a better understanding of ecosystem responses to global change, and alternative adaptation options.

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CHAPTER 4. EVIDENCE OF ECOLOGICAL OBJECTIVES MET BY SPATIO-TEMPORAL MANAGEMENT MEASURES FOR PELAGIC MARINE FISHERIES

Authored by Eric Gilman, Milani Chaloupka, and Michel Kaiser

Introduction

There is extensive evidence of the biological community changes that occur within coastal, benthic, largely shallow-water marine protected areas (MPAs), MPA networks, and other spatio-temporal management measures that reduce or eliminate fishing mortality (Halpern 2003; Claudet et al. 2006; Lester et al. 2009; Stewart et al. 2009; Kaiser et al. 2018; Kenchington et al. 2018). There is, however, substantial uncertainty over the feasibility of spatio-temporal management measures for pelagic fisheries to achieve ecological objectives (Hilborn et al. 2004; Kaiser 2005; Dunn et al. 2011; Gilman et al. 2019a).

We provide a synopsis and update of Gilman et al. (2019a) to review theoretical and empirical evidence of whether static and dynamic spatial management of pelagic fisheries achieved the following ecological objectives:

- Reduce or eliminate fishing mortality of incidentally-captured bycatch species of conservation concern.
- Reduce fishing mortality at habitats that are important for critical life history stages.
- Reduce the fishing mortality of target stocks to sustain desired production levels (i.e., stay near target thresholds) and avoid conditions where protracted or irreparable harm to the stock occurs (i.e., stay above limit thresholds).
- Reduce fishing mortality of prey species of pelagic target stocks and species of conservation concern in order to stay near targets and above limits.
- Reduce trait-based selective fishing mortality and fisheries-induced evolution (FIE).

Ecological Objectives Achieved by Spatial Management Measures for Pelagic Fisheries

<u>Reduce Fishing Mortality of Bycatch Species of Conservation Concern</u>

An overarching goal of reducing fishing mortality of species of conservation concern, including endangered and threatened (ETP) species, is to increase the absolute abundance of populations. This reduces the risk of irreparable harm and permanent loss of these ETP populations and can contribute to recovering depleted populations. Augmented absolute abundance may also contribute to maintaining their community and ecosystem roles, maintaining the system in a quasi-stable and resilient state and a state selected to maintain desired provision of ecosystem services (Gilman et al. 2019a).

There is empirical evidence of static pelagic MPAs that prohibit pelagic fishing near shallow submerged features where bycatch rates of some ETP species was relatively high. Gilman et al. (2020) assessed model-standardized catch rates for species of conservation concern within and outside of MPA units of the Pacific Remote Islands Marine National Monument. Displaced effort produced multi-species conflicts: MPAs protect bycatch hotspots and hotspots of bycatch-to-target catch ratios for some at-risk species (i.e., oceanic whitetip, silky and blue sharks, and olive ridley sea turtle), but cold-spots for others (i.e., albatrosses, shortfin mako shark, and striped marlin). A Bayesian counterfactual modeling approach was also used to compare the temporal response of standardized catch rates in the MPAs to reference regions. Blue shark standardized catch rates were significantly lower than predicted had the MPAs around Johnston Atoll not been established. This response was likely due to closing areas near the shallow submerged feature because the local abundance of pelagic apex predators is higher near shallow features relative to open ocean habitats (Gilman et al. 2020).

A seasonal MPA in the U.S. exclusive economic zone (EEZ) adjacent to California and Oregon that is >500,000 km^2, referred to as the Pacific Leatherback Conservation Area, was established in 2001 with an objective of reducing leatherback fishing mortality in a thresher shark and swordfish drift gillnet fishery (NMFS 2001). The MPA may have reduced leatherback as well as marine mammal bycatch (Moore et al. 2009; Martin et al. 2015). The MPA closed driftnetting during the primary fishing season and fishing grounds, thus causing substantial socioeconomic costs to the fishery.

Spatial and temporal restrictions on purse seine fishing on fish aggregating devices (FADs) and other anchored and drifting floating objects could, theoretically, reduce bycatch of some species of conservation concern, where spatial restrictions to be effective would need to not result in effort displacement where bycatch rates were the same or higher. There is empirical evidence of a larger number of species in the catch and higher bycatch rates of silky and oceanic white tip sharks in tuna purse seine sets on drifting FADs and logs than occurs in sets in “unassociated” free swimming school sets (Dagorn et al. 2013; Hall and Roman 2013, 2016; Gilman et al. 2019b). School sets, however, have higher catch rates of mobulid rays and leatherback sea turtles (Dagorn et al. 2013; Hall and Roman 2013; Gilman et al. 2019b). Therefore, if restrictions on associated sets (i.e., sets on FADs and other floating objects) increased school set effort, this would result in cross-taxa conflicts by displacing bycatch issues onto other species of conservation concern (Gilman et al. 2019b).

Using a closed-area model to analyze historical catch data from a U.S. swordfish longline fishery in the northwest Atlantic, Worm et al. (2003) assessed what the effect would have been if the fishery had been banned in a hotspot of pelagic species richness and density (i.e., an area with a high number of species per unit of catch and a high number of species per unit of fishing effort). The area closure would have reduced catch levels of some species of pelagic sharks and teleosts without reducing swordfish catch levels when assuming displaced effort maintained either swordfish catch levels or effort (Worm et al. 2003).

The population-level effects of one existing and two hypothetical, static MPAs designed to attempt to reduce Mexican gillnet bycatch fishing mortality of the vaquitas porpoise (*Phoceana sinus*) were evaluated by Gerrodette and Rojas-Brancho (2011). They found that there was an 8% probability that the existing MPA would increase vaquita abundance in 10 years, while the two hypothetical larger MPAs had probabilities of success of 35% and >99% (i.e., the largest hypothetical MPA would eliminate vaquita gillnet bycatch).

Approaches have been developed for dynamic temporal and spatial fisheries management based on the variable position of pelagic habitats and variable ecosystem processes. The objectives of these theoretical approaches to fisheries dynamic spatial management include protecting and recovering depleted target species, mitigating fisheries bycatch of species of conservation concern, mitigating ecosystem effects of pelagic fisheries, contributing to the protection of representative habitats nationally and globally, and protecting processes that maintain and produce biodiversity (e.g., Hyrenbach et al. 2000; Alpine and Hobday 2007; Lombard et al. 2007; Pressey et al. 2007; Nel and Omardien 2008). A retrospective analysis of the efficacy of a dynamic fisheries management system for the eastern Australian yellowfin and bigeye tuna and billfish longline fishery that uses a habitat model found that it was successfully mitigating bycatch of southern bluefin tuna (Hobday and Hartmann 2006; Hobday et al. 2009; 2010). A similar, but theoretical, approach, discussed in the previous chapter provides maps of near real-time locations of predicted thermal habitat of vulnerable bycatch species (Howell et al. 2008, 2015; Hazen et al. 2018).

Reduce Fishing Mortality at Habitat Critical for Life History Stages

An overarching goal of reducing fishing mortality at habitat critical for certain life history stages is to increase the recruitment and absolute biomass of populations of species that are captured in pelagic fisheries. Protecting spawning, mating, calving, pupping, nursery and nesting sites, and migratory corridors leading to these sites, may increase reproduction. Fish eggs and larvae, and juvenile fish, seabirds, sea turtles and marine mammals, are exported from the protected area. This in turn may cause an increase in stock/population recruitment and total stock/population biomass. Networks of spatially-managed areas may enable protecting areas important for multiple life history stages, which could not be achieved by protecting an individual site (Dunn et al. 2011).

There is empirical evidence of relatively high catch rates of undersized and juvenile tunas and other pelagic fishes at shallow seamounts and other features (Fonteneau 1991; Itano and Holland 2000; Sibert et al. 2000; Adam et al. 2003; Gilman et al. 2012). Protecting these sites could reduce catch rates of these age classes, but likely would have no effect on the absolute biomass of these pelagic fish species.

A seasonal closure to purse seine fishing in an area with a high density of juvenile bigeye tunas in the eastern Pacific Ocean established by the Inter-American Tropical Tuna Commission (IATTC) may have reduced juvenile bigeye tuna catch rates (IATTC 2017). There may be interannual variability in juvenile tuna use of the area, affecting the efficacy of the static MPA.

A one-month annual closure to tuna purse seine fishing in an area in the eastern Atlantic Ocean with a high density of juvenile bigeye tunas was assessed using a Before-After-Control-Impact (BACI) study design (but without "after" sampling in the closure) (Torres-Irineo et al. 2011). During the annual one-month closure, purse seine vessels making free school sets fished the line. In the control area, juvenile tuna catch levels increased after the closure was established, possibly due to fishing-the-line by the displaced effort, or possibly due to various other variables (Torres-Irineo et al. 2011).

Discussed in the previous chapter, theoretically, mobile MPAs might be able to protect relatively small, dynamic sites that are important for critical life history stages of pelagic species.

Theoretically, for those species that exhibit consistent at-sea aggregating behavior, where the individuals of the same population aggregate during the same periods and at the same areas, mobile or static MPAs may be highly effective, such as for predictable pelagic foraging hotspots of some seabird species (Hyrenbach et al. 2006; Oppel et al. 2018). Similarly, pelagic MPAs could theoretically be designed to protect predictable pelagic foraging hotspots of pelagic shark pupping, nursery, and mating aggregations (Litvinov 2006; Domeier and Nasby-Lucas 2007; Vandeperre et al. 2014a, 2014b). Pelagic MPAs could protect areas where pelagic juvenile loggerhead sea turtles have prolonged residence (e.g., the Kuroshio Extension Bifurcation Region, Kobayashi et al. 2008, an area off Baja California, Peckham et al. 2007, and an area in the East China Sea, Kobayashi et al. 2011). Pelagic MPAs could protect predictable, well-defined pelagic migratory corridors (Block et al. 2011), for example, for post-nesting leatherback sea turtles between their nesting beaches in Costa Rica and foraging grounds in the South Pacific Gyre (Schillinger et al. 2008). Such an application has been applied to migratory right whales off the coast of New England with considerable success (Schick et al. 2009). Although this is not a fishery example, mortality was reduced through an area avoidance approach (i.e., by excluding the source of mortality, which was shipping).

The three bluefin tuna species spawn at relatively small, discrete sites and have relatively short spawning periods of 1 to 2 months (Collette et al. 2011; Muhling et al. 2011). With the exception of bluefin tuna species, there is very limited documentation of spawning aggregations for large pelagic target species (SCRFA 2019), with, for example, a handful identified for istiophorid billfishes and dolphinfish (*Corphaena hippurus*) (Alejo-plata et al. 2011; Domier and Speare 2012; Erisman et al. 2015). However, bigeye, yellowfin, skipjack, and albacore tunas are currently understood to have extensive spawning grounds in tropical and subtropical waters and protracted spawning seasons (Collette et al. 2011; Dueri and Maury 2013). While tropical tuna spawning habitat very likely occurs within tropical MPAs (e.g., Hernández et al. 2019), for these highly fecund broadcast spawners, protecting a small proportion of the distribution of spawning stock biomass likely has minimal effect on recruitment or absolute biomass, where only at extremely low population sizes would egg production likely be a limiting factor for recruitment (Gilman et al. 2019a, 2020).

<u>Maintain the Condition of Target Stocks to Sustain Desired Yields</u>

Overarching goals of maintaining the biomass and fishing mortality rate of target stocks near targeted thresholds are to increase local biomass, and to sustain production levels at targeted levels. This can also contribute to maintaining stocks of principal market species above limit reference points (LRPs) in order to avoid causing protracted or irreparable harm to the stock. The reduction or elimination of fishing mortality of target species in the MPA results in an increase in local biomass (i.e., number of individuals and size) within the MPA. This, in turn, results in spillover, benefiting fisheries adjacent to the seaward margin of the MPA, through emigration of target (as well as non-target) species from within to outside the protected area. The reduction or elimination of fishing mortality of target species in the MPA increases recruitment and reduces fishing mortality risk due to diminished catch risk of individuals who spend a proportion of their lifetime in the MPA. This then contributes to maintaining absolute stock biomass near target levels or increasing biomass if it is below the target, including recovering depleted stocks.

Gilman et al. (2020) used a Bayesian time series-based counterfactual modeling approach to compare the temporal response in MPAs of the Pacific Remote Islands Marine National Monument to reference regions. The assessment used fishery-dependent data from Hawaii’s tuna longline fishery. Catch rates of bigeye tuna, the main target species, were significantly lower than predicted had a 50 nm MPA around Kingman Reef and Palmyra Atoll not been established. This was likely due to closing areas near shallow features, which aggregate pelagic predators, as discussed in a previous section (see “Reduce Fishing Mortality of Bycatch Species of Conservation Concern” in this chapter).

Based on observations of net movements of tagged tropical tunas (Sibert and Hampton 2003; IOTC 2008; Schaefer and Fuller 2009; Kaplan et al. 2014; Schaefer et al. 2014), it is likely that a large proportion of a population of tropical tunas occurs in more than one EEZ and high seas area. It might be feasible to establish a large pelagic MPA within which a large part of the local population of tropical tunas remains for several months, a period of time during which a proportion of the total growth of these species occurs. It is unclear, however, what effect protecting areas of high tuna persistence/residency might have on local biomass within the MPA or absolute biomass of the population. Curnick et al. (2020) found no difference in standardized catch rates for yellowfin and bigeye tunas in an area surrounding the British Indian Ocean Territory MPA in the Indian Ocean eight years after establishment.

Similarly, bigeye and yellowfin tunas have residency times at networks of static aggregating features (e.g., shallow seamounts, anchored FADs and buoys, banks, and ledges) from days to months (Adam et al. 2003; Ohta and Kakuma 2004; Dagorn et al. 2007). In some locations with networks of natural and non-natural aggregating features, these tuna species, and perhaps other pelagic predators, may have sufficient persistence such that MPAs could provide protection to individuals for an adequate proportion of their lifetime to augment growth and local biomass within the MPA. Bigeye and yellowfin tunas, however, have short residency times at individual static aggregating features from days to months (Holland et al. 1999; Itano and Holland 2000; Sibert et al. 2000; Adam et al. 2003; Ohta and Kakuma 2004; Richardson et al. 2018), and residency times of days at drifting FADs (Schaeffer and Fuller 2002).

Jensen et al. (2010) modeled the response in abundance of striped marlin (*Kajikaia audax*) to two temporary closures to longline fishing established in part of the Mexican EEZ in the eastern Pacific. During the closures, local and regional abundance of striped marlin increased. This may have been a response to the MPA, as a large proportion of the stock's range might have occurred inside the MPA. Alternatively, other factors, such as effects on recruitment and stock distribution in response to large scale climate cycles and effects of changes in fishing gear and methods that affect fishing efficiency and species selectivity that were not accounted for in standardizing the catch time series, may have had significant influences on striped marlin catch rates.

High seas closures to purse seine fishing in the western and central Pacific Ocean did not reduce bigeye tuna fishing mortality because purse seine effort was displaced to areas adjacent to the closures, and effort increased by 10% following the creation of the MPAs (WCPFC 2010; Sibert et al. 2012). A *de facto* pelagic MPA from Somali piracy in the Indian Ocean resulted in reduced effort regionally, with a fishing capacity reduction of around 25% as some of the fishing fleet moved from the Indian Ocean to the Atlantic Ocean. The piracy also affected the fleet behavior and fishing areas, resulting in a switch to log-associated sets in place of sets on free swimming schools, which increased the catch rate of juvenile bigeye and yellowfin tunas (Chassot et al. 2010).

Boerder et al. (2017) observed that nominal tuna purse seine catch rates, fishing effort, and catch levels in an area adjacent to and down current of the Galapagos Marine Reserve were higher after enforcement of a ban on industrial tuna fishing within 40 nm around the Galapagos Islands began than during a period before enforcement of the closure occurred. Analyses of Automatic Identification System data from purse seine vessels also detected a higher density of sets near the reserve (i.e., fishing-the-line). Based on these observations, the authors hypothesized that the MPA caused an increase in the local abundance of tropical tunas, with spillover across the MPA boundary. However, the authors recognized that other variables may have contributed to causing these observed changes (Boerder et al. 2017). The study did not assess whether there was a local or absolute response in stock biomass to the MPA.

Similar to Boerder et al. (2017), Bucaram et al. (2018) assessed the effects of the Galapagos Marine Reserve on Ecuadorian tuna purse seine catch rates, relative local abundance of tuna species, and the spatial distribution of fishing effort. Following enforcement of the reserve, fishing-the-line was observed southwest of the reserve. In the Ecuador EEZ adjacent to the Galapagos Islands and on the high seas in "El Corralito", an area to the west of the Galapagos that is seasonally closed to tuna purse seine vessels (IATTC 2017), significantly smaller sized yellowfin tuna were caught relative to yellowfin caught by tuna purse seine vessels throughout the eastern Pacific Ocean. After the reserve was established, yellowfin and skipjack tuna catch rates with standardized effort significantly increased in the Ecuadorian EEZ adjacent to the reserve and in El Corralito, indicating that their local abundance may have increased. These studies did not assess absolute abundance responses to the MPA. Thus, the findings of Boerder et al. (2017) and Bucaram et al. (2018) support possible tuna local abundance responses to the Galapagos Marine Reserve, where a counterfactual assessment approach would provide a more certain understanding (see Chapter 6 on Counterfactual Reasoning).

While not an assessment of responses of pelagic predators to fishery closures, the findings of Le Quesne and Codling (2009) have implications for highly migratory pelagic species. Using a population model parameterized for North Sea cod (*Gadus morhua*), the authors predicted that, for overexploited stocks of highly mobile species, 85% of the distribution of the stock would need to be included in a no-take MPA in order to increase absolute biomass and yields. Furthermore, a closed area would not affect biomass and yields of stocks that are not overexploited (i.e., are fully exploited and achieving maximum sustainable yields or are underexploited) (Le Quesne and Codling 2009).

Theoretical, model-based results of the effect of high seas closures to purse seine fishing in the western and central Pacific Ocean, with effort displaced outside the closed areas, predicted a very small (0.1%) increase in stock-wide adult bigeye biomass (Sibert et al. 2012). High seas closures to both purse seine and pelagic longline fisheries, such that the longline closures were located within part of the known bigeye spawning area, with effort displacement, would result in a 1% increase in absolute adult bigeye biomass (Sibert et al. 2012). This spatially explicit population model accounted for the limited lifetime spatial movements estimated by Sibert and Hampton (2003). The effect of the closures on adult bigeye biomass was predicted to be largest within the closed areas and adjacent areas from a spillover effect (Sibert et al. 2012).

Dueri and Maury (2013) modeled the effect of the Chagos Archipelago/British Indian Ocean Territory MPA and of a hypothetical MPA covering a large portion of the western Indian Ocean where most skipjack catches currently occur, employing various assumptions on the displacement of fishing effort. The Chagos MPA had a very minor effect on absolute skipjack biomass, while the hypothetical extremely large MPA was projected to cause a large reduction in fishing mortality and stabilization of skipjack spawning biomass (Dueri and Maury 2013). Martin et al. (2011) used an age-structured model to assess the effects of the Chagos MPA, Indian Ocean Tuna Commission (IOTC) one-month closures of an area off the coast of Somalia to pelagic longline and tuna purse seine fisheries, and a longline closure in part of the Maldives EEZ, with spatial displacement of fishing effort from the Chagos and IOTC MPAs. They found that the MPAs were associated with little change in yellowfin tuna absolute stock biomass and may be causing a decrease in biomass. These findings support the idea that a static pelagic MPA would need to be larger than Chagos and located to encompass a much larger proportion of the distribution of the skipjack stock in order to affect absolute biomass. For instance, the Chagos MPA covers about 2.5% of longline and 5.5% of purse seine fishing grounds in the Western Indian Ocean (Dunne et al. 2014) and does not include areas with high concentrations of juvenile and adult spawning tunas (Kaplan et al. 2014).

Davies et al. (2017) conducted a counterfactual analysis of the IOTC's one-month closure and the Chagos MPA to assess effects on the distribution of effort. They found inconsistent short-term responses to the closures by different tuna purse seine fleets. The study did not assess ecological responses to the two MPAs.

There is empirical evidence of higher catch rates and species diversity at shallow submerged features as well as at natural and artificial floating objects (Worm et al. 2003; Dagorn et al. 2013; Hall and Roman 2013; Gilman et al. 2012). This suggests that protecting these discrete static sites and floating objects would reduce fishing mortality, assuming that displaced effort would have lower catch rates of principal market species than occur at these features.

Protect Prey Species of Large Pelagic Apex Predators

An overarching goal of protecting the prey of pelagic apex predators is to maintain the absolute biomass of stocks of large pelagic principal market species near targeted levels. Sustaining or increasing the local and absolute biomass of large pelagic predators' prey could in turn sustain or cause an increase in local and absolute biomass of pelagic predator stocks/populations.

Pichegru et al. (2010) observed that, following establishment of an MPA in South Africa that banned fishing by purse seine vessels that target sardines and anchovies within 20 km of an African penguin (*Spheniscus demersus*) colony, relative to the previous year, the penguins shifted their core feeding area from outside to inside the MPA and decreased their foraging effort by 25% to 30%. Penguins of another colony located 50 km away that remained open to purse seining increased their foraging effort. An updated study found that, two years following MPA establishment, the penguins' continued to exhibit an increased proportion (55%) of their foraging dives within the MPA relative to the year prior to MPA establishment (25% of dives). This was, however, a substantial decline from the proportion of foraging dives in the MPA during the first year the MPA was established (75%), which the authors hypothesized may have been due to fishing-the-line occurring during the second year but not the initial year (Pichegru et al. 2012). The chick survival rate increased at the colony adjacent to the MPA within three years of MPA establishment. However, the population was predicted to continue to decline despite this increased chick survival, possibly due to adult mortality from low biomass of prey (Sherley et al. 2015). Analyzing data from four 20 km intermittent MPAs around penguin colonies, including the MPA assessed by Pichegru et al. (2010, 2012) and Sherley et al. (2015), over an eight-year study period, Sherley et al. (2018) employed a BACI design, finding that the MPAs caused improved chick survival and condition, with >1% increased population growth rate at one of the colonies. The small MPAs adjacent to penguin colonies that protect pelagic forage fishes may have improved foraging efficiency (i.e., reduced foraging trip duration and distance traveled from the colony) of this coastal predator, but these reductions were smaller with a higher intensity of fishing-the-line. The local abundance of prey resources may have increased in the MPA as a result of the cessation of fishing mortality, while at the "control" colony with no MPA, there may have been increased fishing mortality due to displaced effort from the MPA. Alternatively, or in addition, other factors may have caused the observed changes in the penguins' foraging distribution and behavior. The observed changes in foraging efficiency and chick survival (whether caused by the MPA or other variables) was inadequate to reverse the population's declining trend.

There is evidence of competition for forage fish between fisheries and seabirds, where the local (not total) abundance of prey affects seabird reproductive success (Gremillet et al. 2008; Cury et al. 2011).

Reduce, Halt, or Reverse Trait-Based Selectivity and Fisheries-Induced Evolution

Pelagic MPAs may reduce, halt, or reverse FIE resulting from a fishery's intraspecific heritable trait-selective mortality, thus sustaining genetic diversity, fitness, and evolutionary characteristics of affected populations (Dunlop et al. 2009; Heino et al. 2015; Hollins et al. 2018). Ecological objectives of reducing, halting, or reversing FIE include maintaining the diversity of a population's heritable traits, fitness, resistance and resilience to stressors, and ability to evolve, and avoiding ecosystem-wide changes in structure and functioning through trophic links.

No studies were identified with model- or empirical-based evidence of the efficacy of MPAs at reducing, halting, or reversing FIE in pelagic marine species (Gilman et al. 2019a). MPAs are broadly hypothesized to provide broad protection for genetic diversity (Perez-Ruzafa et al. 2006; Gilman et al. 2011) (however, see Gilman et al. (2020), who found no difference in the Shannon diversity index between static pelagic MPAs situated around atolls and reefs and control zones in open ocean pelagic habitat). More specifically, there are several model-based studies that provide a theoretical basis for MPAs offsetting pressures for FIE in demersal and coastal fishes from selective fishing mortality of individuals with genotypes for delayed maturity, reviewed in Gilman et al. (2019a). These model-based assessments assume that the MPA serves as a source of recruits to the population, which would be a more challenging assumption to meet when modeling pelagic fishes due to differences in the life history characteristics and biology of temperate, demersal fishes and tropical, pelagic fishes. With increased mobility, a no-take MPA in foraging grounds needs to be relatively larger to reduce FIE of life history traits for growth, maturation, and reproductive investment.

CHAPTER 5. RESEARCH NEEDS FOR AREA-BASED MANAGEMENT IN PELAGIC FISHERIES, PART A – NECESSARY BIOLOGICAL INFORMATION

Authored by David Itano and Kurt Schaefer

Overview

The application of area-based management for the conservation of pelagic blue water fishery resources must consider the biology of the species of concern as well as their habits, habitats, and movement parameters with broader stock considerations. The basic consideration for area-based solutions should consider the movement patterns of a stock in relation to the fulfillment of life history parameters, such as the areal extent of feeding, spawning, and recruitment areas in relation to the extent of the proposed management boundaries. The degree to which these areas are fixed or variable due to changes in productivity and oceanographic conditions may support geographically discrete protected areas or more adaptive management systems that vary in time and space.

The need for biological information when considering area-based management tools (ABMTs) include the life history and biological considerations that drive habitat preference and movement. This section will explore these issues in relation, primarily, to principal tuna and billfish market species, but is also relevant to non-target, endangered, threatened, and protected (ETP), and forage species.

Geographic Range and Life History Movement Parameters

The geographic range of tuna and billfish species is well known from commercial fisheries data. The temperate tuna species (i.e., bluefin and albacore) are notable in that they utilize their entire ocean basin to fulfill their life history requirements, undertaking directed movements between geographically distinct adult spawning grounds and juvenile and sub-adult feeding areas. For example, Pacific bluefin tuna (*Thunnus orientalis*) spawn in discrete areas of the western tropical and subtropical Pacific Ocean, migrate to feeding/rearing areas of the northwest and northeastern Pacific as juveniles, eventually returning to the western Pacific to reproduce. In this way, they are "highly migratory" species that undergo directed movements to specific areas of the ocean at certain life history stages. The three species of bluefin tuna found globally have relatively well known spawning seasons and areas and are therefore a potential candidate for area-based seasonal management measures if protection of spawning output is the objective.

In contrast, the tropical tuna species, particularly skipjack and yellowfin tuna, do not appear to exhibit directed, seasonal migrations in tropical waters. Extensive tagging studies for those species in the central and western Pacific Ocean show some wide-ranging movements, but generally exhibit restricted displacements to less than 1,000 nm of release locations (Sibert and Hampton 2003). There is some evidence for site fidelity for yellowfin tuna at higher latitude insular areas of high productivity (Hampton and Gunn 2008; Schaefer et al. 2011; Schaefer et al. 2014; Rooker et al. 2016).

Bigeye tuna are grouped with the tropical tuna species, with the bulk of their global biomass residing in equatorial and tropical regions. There have been tagging experiments with bigeye tuna throughout the equatorial Pacific using both conventional dart tags and archival tags (Schaefer and Fuller 2009; Schaefer et al. 2015). The linear displacements and most probable tracks obtained from those experiments demonstrate constrained latitudinal dispersion principally between 10° N and 10° S, some regional fidelity, and substantial mixing of bigeye tuna between release longitudes. The amount of mixing of bigeye tuna among release areas in the equatorial central Pacific with those in adjacent areas of the equatorial eastern and western Pacific is dependent on distances between areas with, in general, the greatest mixing occurring between the areas that are closest to one another.

However, some bigeye stocks exhibit anti-tropical movements to higher latitude areas, as both juveniles and non-reproductive adults spend time in cool water feeding areas where they are targeted by handline and longline fisheries. Movements of juvenile bigeye inferred from conventional tagging studies at higher latitudes in the Australian Coral Sea (Hampton and Gunn 1998), Hawaii (Itano and Holland 2000), and Japan (Matsumoto et al. 2007) indicate that 90% or more of individuals are restricted to within about 1000 nm of their release locations.

These higher latitude areas have sea surface temperatures below that required for bigeye tuna maturation and spawning, which is considered to be above 24° C (Schaefer et al. 2005). Therefore, return movements of bigeye tuna to warm waters to spawn are assumed, but are not well documented by tagging studies.

Stock Structure and Connectivity

While the geographic ranges of exploited large pelagic fish are well known, agreement on the stock structure of each species is a continuing area of study and is highly relevant to the application of ABMTs (Moore et al. 2020). Differences in stock status, dispersion, mixing, and geographic variation in biological parameters within a currently recognized “stock” should be evaluated to determine whether finer geographic divisions within the stock structure may be appropriate for conservation and management efforts.

A critical element defining a stock is the connectivity between regions and understanding the degree to which pelagic stocks are biologically connected. This is particularly relevant to the principal tuna species, the istiophorid billfish (marlin, sailfish, spearfish), and swordfish, which all spawn in warm surface waters of at least 24° C (Collette and Graves 2019). Some of these species, notably bigeye tuna, swordfish, and striped marlin, are targeted as adults in cooler, high latitude waters that enhance fat content and commercial value. Determining their connectivity to tropical spawning grounds is an important aspect to their effective management, with implications for area-based management. Newly developed and developing genetic techniques such as Next-Generation Sequencing (NGS) and site-associated DNA sequencing are advancing knowledge of the stock structure of large pelagic fish for improved management of stocks that may or may not cross regional fisheries management organization boundaries (Grewe et al. 2015).

Habitat Preferences, Aggregation, and Residence Times

Fishermen and fisheries scientists recognize that tuna and billfish often exhibit an associative preference for physical structure (e.g., ledges, seamounts, and oceanic islands) (Kleiber and Hampton 1994; Itano and Holland 2000), floating objects (e.g., flotsam and FADs) (Le Gall et al. 2000), and oceanographic features (e.g., areas of current shear, temperature and chlorophyll fronts, upwelling, and gyres) (Bigelow et al. 1999; Chang et al. 2013; Hsu et al 2015). The length of time at which pelagic species remain at these features is highly variable but is likely influenced by shifts in local productivity, the availability of forage, and the strength and persistence of the oceanographic features. Therefore, variable attraction rates and aggregation to these features is highly relevant to the application and efficacy of area-based management.

Fish Aggregating Devices (FADs)

Several studies on the behavior, including residence times, of tropical tunas around anchored FADs have been conducted using sonic tags, FAD-mounted acoustic receivers (Ohta and Kakuma 2004; Dagorn et al. 2007), and also around drifting FADs (Schaefer and Fuller 2013; Tolotti 2020). Acoustically verified FAD residence times of tuna and bycatch species range from days to weeks, with a few examples of yellowfin and bigeye tuna remaining for more than six weeks at a FAD and 175 days within a network of monitored FADs (Filous 2020). However, residence times of investigated tuna and bycatch species are commonly short-lived and transient.

Seamounts

Seamounts located in productive areas that have certain depth characteristics can support enhanced foraging opportunities for higher trophic level predators, such as tunas, billfish, and sharks. It is theorized that intermediate seamounts that pierce the photic zone can increase access to prey items of the mesopelagic boundary community (MBF) that become trapped over the seamount summit when organisms of the deep scattering layer (DSL) descend at dawn (Holland and Grubbs 2007). A productive seamount in the Hawaii exclusive economic zone (EEZ) is known to aggregate juvenile bigeye and yellowfin tuna that form the basis of a directed fishery (Boggs and Ito 1993). Data resulting from conventional dart tagging experiments on this seamount were used to estimate attrition and movement parameters of tuna associated with this mid-ocean feature (Holland et al. 1999; Sibert et al. 2000; Adam et al. 2003). Seamount residence times of yellowfin tuna were estimated to be approximately 14 days, while residence times for bigeye tuna were roughly twice as long. Larger bigeye and yellowfin tuna tended to remain at the seamount for longer periods; however, all fish were juveniles, and both species are considered temporary visitors to the seamount with high throughput.

Oceanic Islands

Fishermen recognize that pelagic resources are often more abundant near oceanic islands, but there are few studies that investigate the issue directly. Kleiber and Hampton (1994) used conventional tagging data to estimate an island attraction parameter and determined that skipjack tuna had twice the propensity to move toward an island archipelago than away. Schaefer et al. (2014) investigated the movements, behavior, and habitat utilization of yellowfin tuna in the Revillagigedo Islands Archipelago Biosphere Reserve (RIABR), Mexico, based on 16,578 days of time-series data, downloaded from 52 archival tags recovered from yellowfin tuna (78 to 173 cm in length and 1.7 to 8.0 years of age) at liberty from 93 days to 1773 days (mean = 411 days). The most probable tracks indicated restricted movements, low levels of dispersion, and fidelity of yellowfin tuna to the RIABR, which is known to be a biologically productive area of the eastern Pacific Ocean. Rooker et al. (2016) examined natural chemical markers (i.e., stable isotopes and trace elements from otolith sampling) to investigate the spatial origin of yellowfin and bigeye tuna in the western and central Pacific Ocean (WCPO). Yellowfin and bigeye tuna samples from a west equatorial region and Hawaii were almost entirely from local recruitment. However, bigeye tuna sampled in Hawaii were associated with samples from an adjacent tropical area south of Hawaii. This is not surprising, considering that yellowfin tuna spawn seasonally throughout the Hawaiian Islands, while bigeye tuna are only known to spawn in significant numbers south of the Hawaiian Archipelago.

Oceanographic Features

Fisheries also target pelagic resources that aggregate around mid-oceanic features, such as current interfaces, temperature fronts, and gyres that mark areas of upwelling and enhanced local productivity. These features may be transient or highly persistent oceanographic systems, such as the North Pacific Subtropical Frontal Zone system. This system is a seasonally shifting east-to-west feature where swordfish are targeted by longline fisheries (Seki et al. 2002). The region has been characterized as the Transition Zone Chlorophyll Front and recognized as an important habitat for loggerhead sea turtles, albacore tuna, and neon flying squid (Polovina et al. 2017). The dynamic nature of these areas of productivity suggests that the application of spatial management to oceanic features would need to be adaptive in time and space to be effective.

Reproductive Biology and Population Biology

Information on the reproductive biology of the species of management concern is required to assess whether area-based management approaches may be appropriate. The basic information needed is the geographic extent and spawning seasonality of the species. Additional information on batch and total fecundity with size/age at maturity and spawning frequency determined by histological methods should also be utilized. Information on yellowfin, bigeye, skipjack, and billfish species is available for some oceanic regions (Schaefer 1998; Schaefer et al. 2005; Schaefer and Fuller 2018; Itano 2000; Zudaire et al. 2013; Grande et al. 2014). Additional studies are still required to define sub-regional differences in growth and maturity.

Species having discrete spawning areas and seasons would be more suitable for area-based management if the objective is to reduce fishing mortality on spawning biomass. Conversely, area-based management to enhance spawning output for species like skipjack and yellowfin tuna may not be appropriate considering their high spawning potential that is widespread in time and space. Area-based management of tuna based on spawning enhancement may be less appropriate for tuna and tuna-like species that have high spawning output, very high natural mortality at early life stages, and whose populations are determined more by large-scale environmentally driven recruitment pulses.

Diet and Forage

Pelagic resources, such as tuna and billfish, generally have high metabolic rates to fuel rapid growth, maturation, and reproduction. These pelagic species move toward areas and times of high forage abundance linked with local productivity enhanced by upwelling, nutrient mixing, and primary production. Variability in local productivity and foraging success will also have a significant impact on the strength and stability of tuna aggregations on FADs, seamounts, near oceanic islands, and along frontal zones. Lehodey (1998) demonstrated a correlation between an El Niño Southern Oscillation (ENSO) driven east-west equatorial shift of the western Pacific Warm Pool and associated equatorial upwelling system with tuna forage and biomass in the WCPO. This system develops discrete areas of high productivity characterized by a high abundance of forage fish, primarily the buccaneer anchovy (*Encrasicholina punctifer*) that tunas actively target (Hida 1973). The WCPO purse seine fishery is known to shift east during ENSO conditions and westward in response to La Niña conditions, centered around 160° E longitude in response to tuna movement (Williams and Reid 2019). Spatial variability in productivity and forage have strong implications for area-based management.

Movements and Mixing

The dispersion and mixing rates of large pelagic fish within ocean basins of blue water habitat is the "catch-all" factor when considering ABMTs for blue water ecosystems. All the issues listed above, including life history fulfillment, stock structure, movement, connectivity, aggregation, reproduction, and foraging, combine to influence and determine the movements and behavior of large pelagic fish. Extensive tagging studies in the WCPO have been essential for undertaking a spatially structured approach to stock assessments for the tropical tuna species. This information is useful when assessing the application of area-based management approaches. As an example, a recent Western and Central Pacific Fisheries Commission yellowfin tuna stock assessment estimates the movement parameters of fish between all model regions (Tremblay-Boyer 2017).

Summary - Needed Fishery Biological Information

Life history and behavior information for species and stocks of large pelagic fish is required to assess the utility of static or dynamic area-based management for blue water ecosystems. Movements and regional fidelity can be evolutionarily ingrained or modified by the fundamental biological necessities for feeding, growth, and reproduction. Local abundances will be modified by geographic shifts in productivity and forage that can also influence the location and frequency of spawning.

Blue water large pelagic fish are less suited to static area-based management due to their high degree of mobility, widespread distributions and spawning, and high rates of juvenile natural mortality. Because of these life history characteristics, the efficacy of management by closing zones to harvest is questionable, particularly when fishing effort can relocate to adjacent areas to exploit the same stock as it moves in and out of closed zones.

The amount of life history and behavior information needed to evaluate spatial management is daunting. Fortunately, a considerable amount of the information required to evaluate the efficacy of applying ABMTs has already been investigated and published. A thorough review of this literature is recommended when considering an area-based approach for the management of blue water ecosystems.

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CHAPTER 5. RESEARCH NEEDS FOR AREA-BASED MANAGEMENT IN PELAGIC FISHERIES, PART B – CLIMATE CHANGE CONSIDERATIONS

Authored by Donald Kobayashi

Pelagic habitat is spatially more expansive than neritic habitat due to both areal considerations (oceanic basins versus continental shelves/islands) and the three-dimensional nature of the habitat, with the depth dimension generally being more exploited by pelagic organisms (e.g., diel-vertical migration) (Angel and Pugh 2000), foraging dives (Howell et al. 2010), and usually more cosmopolitan habitat preferences. Similarly, pelagic organisms' relatively higher mobility and wide range of exposure tolerances compound the challenge of implementing spatial management measures that can lead to effective stewardship of these pelagic resources.

It remains of paramount importance to support and implement management measures that have the highest likelihood of buffering against habitat perturbations induced by climate change and the responses of species that are of management concern. Here, we outline a few primary considerations that should be kept in mind as pelagic areas receive more attention regarding spatial management.

Changes in productivity and species distribution are already occurring worldwide (Karp et al. 2019) and will likely increase in prevalence (Polovina et al. 2008). Effective spatial management will require continuous appraisal of efficacy and potential for timely adaptive responses for coping with these complex and rapidly moving habitat dynamics and ensuing ecological dynamics. A greater emphasis on ecosystem assessments will be needed rather than a collection of independent single-species assessments. Trophic linkages and other critical direct and indirect species dependencies cannot be ignored. Ecosystem health indices will need to be developed that take into consideration the physical characteristics of a designated volume of water, a metric of the organisms that could live there based on productivity and habitat suitability, a metric of the organisms that are living there, as well as all biophysical trends therein. The biotic components of such an ecosystem survey will not be easily estimable from fishery-dependent data streams and will require scientific survey effort that is statistically robust, not biased by focus on current or historical fishing grounds (i.e., survey effort where species are not occurring is as equally valuable as more common knowledge where species are occurring), and a comprehensive species coverage including accurate estimates of bycatch, non-commercial catch, and forage species (Gilman et al. 2019).

Subsurface conditions are often overlooked, yet these are regions of higher occupation by larger pelagic organisms that are poorly characterized from satellite remote-sensing and ocean models. Variables such as temperature, salinity, and oxygen concentration, for example, can have complex vertical structure and profound implications on the distribution and abundance of pelagic organisms. Smaller scale features with prominent subsurface signatures (e.g., eddies, meanders, and fronts) can be important but poorly resolved from satellites and computer models. Spatial management of pelagic areas will need to have accompanying oceanographic surveys from ships or autonomous vehicles with capability of subsurface measurements.

Climate change models can attempt to characterize physical conditions throughout the entire ocean over long time periods, yet many water column processes and measurements remain elusive in the present day such that anticipating how these will change in coming decades must be processed with full realization of the rarely presented but likely large degree of uncertainty. Field surveys cannot be neglected, as they are an important part of ground-truthing and tuning complex computer models as well as for calibrating satellite-borne or other remote sensors.

Objectives and Performance Metrics - Climate Change Considerations

It is imperative that fishery management actions be structured such that pelagic ecosystem integrity is well-buffered against the impacts of climate change. It is a given that there will be continual habitat “creep” for species with specific habitat preferences and requirements (Pinsky et al. 2013). Characterization of the key variables defining such habitat will be necessary for the design of spatial management measures, with the realization that the geographic domains will likely be dynamic as underlying areas change in habitat suitability.

While it may be difficult to assign a comprehensive performance metric to monitor pelagic ecosystem integrity, it is possible that certain simple indicators available in fishery catch data could provide meaningful insights into the health of the ecosystem. A relatively stable and diverse catch composition coupled with healthy abundance indices for species of management concern should indicate that management is effective. Any negative trends must be carefully monitored with respect to changing geographic distributions or changes in system productivity.

CHAPTER 6. EVALUATING CONSERATION INTERVENTION EFFECTS SUCH AS MPAS USING CAUSAL INFERENCE WHEN RANDOMISATION IS NOT AN OPTION

Authored by Milani Chaloupka

Background

Large pelagic marine protected areas (MPAs) are often promoted as an effective spatial management intervention for protecting biodiversity and for supporting sustainable pelagic fisheries (Game et al. 2009; Koldewey et al. 2010; Boerder et al. 2017; White et al. 2017; O'Leary et al. 2018). But do such blue-water MPAs actually achieve the intended conservation objectives? Surprisingly, there have been few such retrospective evaluations of the impacts of blue-water MPAs (see Gilman et al. 2019a for a comprehensive review).

An important issue in marine conservation management is how to infer the causal ecological impact attributable to the implementation of an MPA (Ferraro and Hanauer 2014). The gold standard for conducting a retrospective impact evaluation might use some form of randomized controlled trial or experiment (Pynegar et al. 2019). In fact, randomized controlled trials (RCTs) are considered in the medical, healthcare, and social sciences as the gold standard for modeling causal inference (Banerjee et al. 2015; Backmann 2017; Frieden 2017; Dal-Ré et al. 2018), but not without some issues of concern (Deaton and Cartwright 2018).

RCTs are used to estimate the counterfactual (Hofler 2005) or potential outcome (Rubin 2005) by comparing the expected outcome of the sampling units (such as patients or study sites) that received the treatment with the expected outcome of those sampling units that did not receive the treatment. Here, the causal effect is defined counterfactually using RCTs and is the basis of evidence-based medicine, for example. It is possible that pragmatic, as opposed to exploratory RCTs (Dal-Ré et al. 2018), might be appropriate for evidence-based or evidence-informed (Rose et al. 2018) evaluation of the impact of MPAs if treatment and suitable controls (or reference sites) could be randomly assigned to various sampling units.

MPAs are usually a singular policy event with no variation in the intensity of application of the intervention, so it is an "all or none" binary event. Moreover, ecological or socioeconomic policy or management interventions such as MPAs are invariably imposed rather than randomly assigned (Costello and Ballantine 2015; Hayes et al. 2019; Stevenson et al. 2020), as opposed to an RCT (Frondel and Schmidt 2005). The problem is that it is not possible to assign sampling units at random to different treatment procedures for estimating the causal effect of a binary intervention ("impact vs. control" sites or "impact vs. reference" sites). Therefore, such nonrandomized or observational studies of an intervention need to account for differences in baseline characteristics between treated and untreated (or reference or control) sampling units when estimating the treatment effect.

Evaluating the ecological or socioeconomic impact of spatial management interventions or so-called natural experiments (Craig et al. 2017; Penny et al. 2020) using observational time-dependent data is a major challenge (Ferraro and Hanauer 2014) and can lead to ambiguous conclusions (Pawson et al. 2011), especially when the binary intervention as already noted is nonrandomized, there are few treatment units affected by the intervention, and there are multiple time-dependent outcomes (Samartsidis et al. 2019).

The creation of a blue water MPA is such a nonrandomized binary policy intervention with few or only one treatment unit (Curnick et al. 2020; Lynham et al. 2020) so that any impact evaluation will need to be based on observational data and quasi-experimental statistical procedures to define the counterfactual to help infer any causal effect (Gasparrini and Lopez Bernal 2015; Boesche 2019). It is important to note that such observational data are invariably time-dependent, and that specific characteristic needs to be accounted for explicitly in any statistical procedure used for impact evaluation.

Here, we briefly outline several quasi-experimental approaches with observational data that have been applied for conservation policy evaluation. We focus mainly on the assessment of MPA impacts and especially blue water MPAs. See Imbens and Wooldridge (2009), Butsic et al. (2017), Mascia et al. (2017), Larsen et al. (2019) and Samartsidis et al. (2019) for more general details of methodologies and conceptual frameworks.

Quasi-Experimental Approaches with Observational Data

The quasi-experimental approaches to inferring causal inference that we outline below are (1) instrumental variables, (2) interrupted time series, (3) regression discontinuity design, (4) matching methods, (5) difference-in-differences, and (6) synthetic controls. These are the main approaches and statistical procedures that are used to estimate a causal effect that is attributable to a conservation policy intervention when randomization is not an option and one is dependent on the use of observational data.

<u>Instrumental Variables Regression Approaches (IV)</u>

IV is a common approach used in econometrics for modeling intervention effects (Angrist et al. 1996). Let “Y” equal the response variable and “X” equal the independent variable of which “Y” is some linear or nonlinear function. An instrument is then a covariate “Z”, for instance, that affects “X” but not the response variable, “Y”. Modeling the effect of “X” on “Y” given “Z” helps estimate the latent or unobserved correlation between “X” and “Y” (Angrist et al. 1996) and possibly also controls for measurement error (Kendall 2015). It is a statistical procedure to infer causality through indirect inference that is not commonly used in ecology (Butsic et al. 2017); however, it was used recently by Kendall (2015) to explore life history trade-offs for the Florida scrub-jay and by MacDonald et al. (2019) to help unravel the effect of forest fragmentation on Lyme disease incidence.

A plausible example in the context of blue water MPA impact evaluation is shown in Figure 2 using a direct acyclic graph (DAG) (Textor et al. 2016). Figure 2 outlines a possible instrumental variables model to assess the impact of an MPA on pelagic fish catch conditioned on effort, with effort itself conditioned on fish supply and demand predictors that are independent of the MPA intervention. This model could be readily fit using a piecewise structural equation modeling (SEM) model (Lefcheck 2016) within a Bayesian modeling framework, perhaps using Stan (Carpenter et al. 2017). As far as we are aware, this has not been done to date, but it would be a project worth exploring to develop better insight on the dynamics of a pelagic fishery and whether there is any causal impact on the fishery that is attributable to a policy intervention such as a blue water MPA. This framework can be extended to include both ecological and socioeconomic predictors.

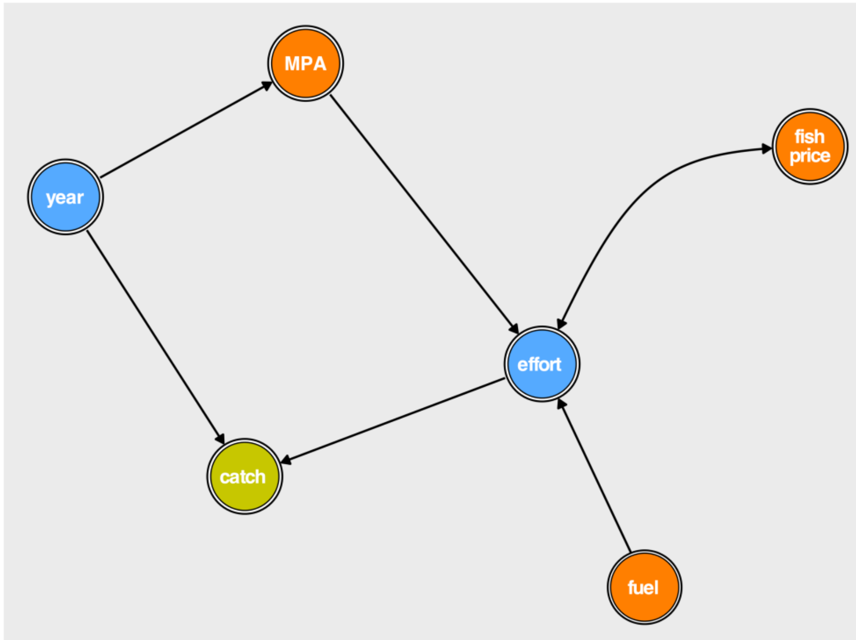

Figure 2. Directed acyclic graph or DAG (Textor et al. 2016) outlining a possible instrumental variables model to assess the impact of an MPA on pelagic fish catch conditioned on effort, with effort itself conditioned on fish supply and demand predictors that are independent of the MPA intervention.

<u>Interrupted Time Series Approaches (ITS)</u>

Here, a single time series of an outcome variable is modelled using segmented regression to estimate any trend in the sampling period prior to a known intervention date, and then is modelled again in the post-intervention period (Bernal et al. 2013; Kontopantelis et al. 2015; Hudson et al. 2019). Each segment has its own slope and intercept, and we compare the two-segmented regression models to derive any causal effect. It is a form of a before-after design (Christie et al. 2019) but with a time series structure. The ITS approach is based on the restrictive assumption that any trend prior to the intervention must be linear and continue linearly into the post-intervention period. This assumption does not apply to other, more flexible procedures such as the synthetic control approaches (see below).

As an illustrative example of an ITS impact evaluation within a MPA context, we use data from a recent study on the 2004 expansion of the Great Barrier Reef Marine Park (GBRMP) (Fletcher et al. 2015). Here, we fit a segmented regression using generalized least squares with Gaussian likelihood and AR(1) autocorrelation structure to allow the residuals to explicitly account for the time series nature of the 19-year data series of commercial fishery catch. The intervention is known (i.e., mid-2004), and the model was fitted using the nlme::gls()function in R (Pinheiro et al. 2020). The ITS model fit is summarized in Figure 3 with an estimated significant decrease in commercial catch in the GBRMP region at the intervention date of approximately 750 metric tons (95% confidence interval: 163 mt -1452 mt).

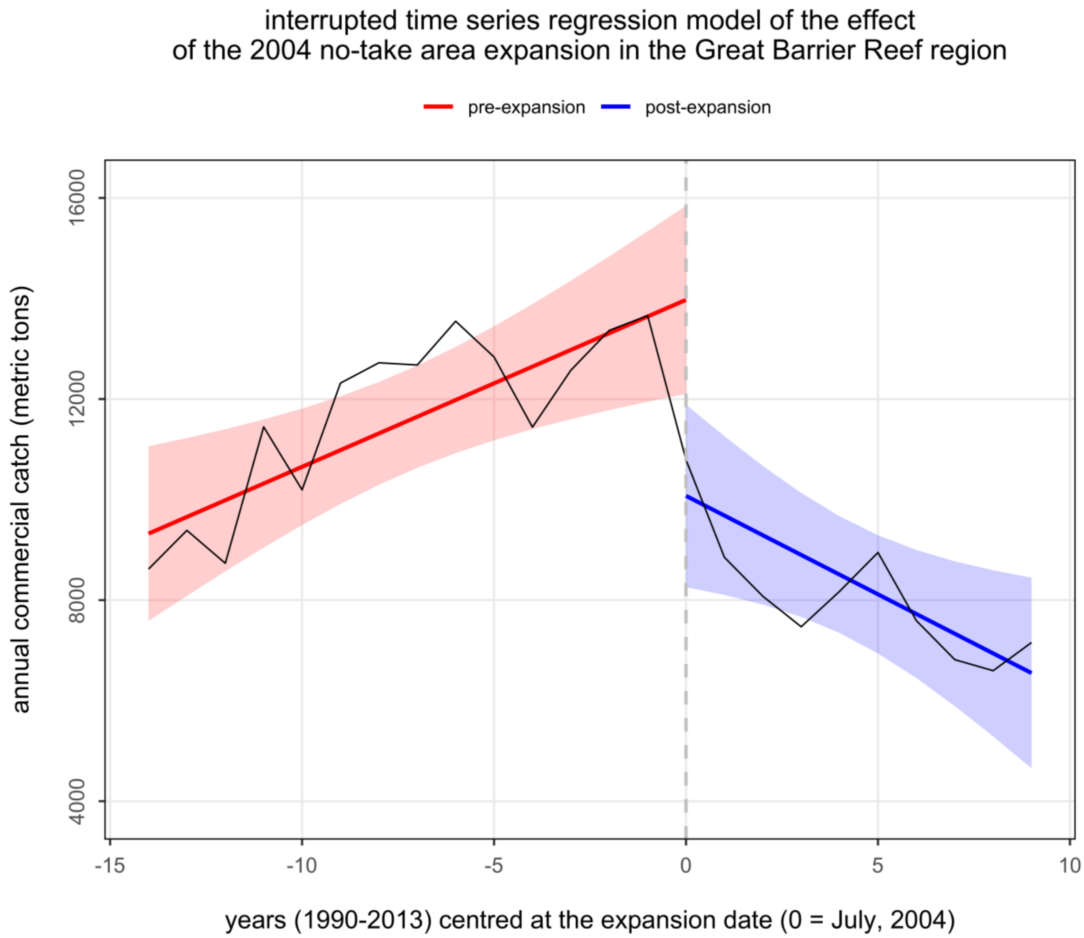

Figure 3. Interrupted time series model for evaluating the impact of the 2004 Great Barrier Reef Marine Park no-take expansion on the Great Barrier Reef commercial fishery catch rates. Data were sourced from Fletcher et al. (2015).

Regression Discontinuity Design Approaches (RDD)

In a regression discontinuity study design, the pre-intervention and post-intervention time periods are selected at some cut-off time near to the intervention date (Imbens and Lemieux 2008; Bor et al. 2014). The cut-off metric could also be a spatial boundary rather than a temporal discontinuity, and such geographic discontinuities are increasingly used in quasi-experiments in political science to estimate "local average treatment effects" (Keele and Titiunik 2015). Butsic et al. (2017) provide a useful ecological case for using RDD for modeling the impact of wildfire on nearby plant species richness. Another theoretic ecological example is provided in Larsen et al. (2018). Essentially, the RDD is a form of control-impact design (Christie et al. 2019) where the sampling units for the control and impact are very "close" to the geographic boundary; however, fish, for example, could swim across the boundary, making this a potentially poor design. The RDD may work for assessing benthic (i.e., sessile) impacts for georeferenced sampling sites, but the study design seems to be of limited prospect for assessing pelagic systems with species that are highly mobile.

Matching Methods (MM)

Regression model-based adjustment approaches, such as difference-in-differences (i.e., BACI; see below) are commonly used to account for any confounding baseline differences between impact (treatment) and reference (control) sites. Statistical MM are approaches used for matching (or at least near-matching) of treatment and control sites given covariate adjustments to account for potential baseline confounding in quasi-experiments with observational data (Stuart 2010). Propensity score matching is an MM that is the probability of the treatment or control site assignment, conditional on observed baseline covariates determined using a statistical procedure such as logistic regression or random forests (Austin 2011). Propensity score methods are not suitable when there are very few sampling units assigned to the intervention, as there will be insufficient information to estimate the parameters of such models (Samartsidis et al. 2019). Ahmadia et al. (2015) use propensity scores and covariate matching in their impact evaluation within an MPA network monitoring program in the Bird's Head Seascape in Indonesia. Butsic et al. (2017) and Hayes et al. (2019) provide further discussion of MMs for environmental impact evaluation. A before-after-control-impact paired sample study design (BACIPS) discussed in the next section on "Difference-in-Differences" is a type of manual matching or pairing for treatment/control site assignment.

Difference-in-Differences (DiD)

The most common way to evaluate the effect of a conservation policy intervention is to use some form of BACI study design (Conner et al. 2016; Chevalier et al. 2019; Christie et al. 2019). In its simplest form, BACI is a before/after sampling at the impact site compared with a simultaneous before/after sampling at a control site (Christie et al. 2019). "Before" means sampling during the pre-intervention period, and "after" means sampling during the post-intervention period. The causal impact is then assessed by the DiD method, though it is not often recognized as such in the ecological BACI literature. For a simple DiD or BACI, one must calculate the difference between the pre- and post-intervention period for the control and the difference between the pre- and post-intervention period for the impact site before calculating the difference between those two differences.

There are many variants of the BACI-type study design for impact evaluation including BACIPS (Stewart-Oaten and Bence 2001) and the progressive-change BACIPS that accounts explicitly for the time series nature of the observational data series (Thiault et al. 2016). A BACI design can also be combined with treatment/control matching to strengthen the counterfactual based inference, as used by Veríssimo et al. (2018) to evaluate social marketing interventions for biodiversity conservation. Smokorowski and Randall (2017) and Kerr et al. (2019) have identified a number of limitations of BACI-type studies to infer the causal impact of conservation policy interventions, while Chevalier et al. (2019) propose additional metrics that may be helpful for supporting BACI-based inference given some of the identified concerns.

As an illustrative example of BACI (BACIPS), we continue to use a recent study on the expansion of the Great Barrier Reef Marine Park (GBRMP). Fletcher et al. (2015) assessed the impact of a substantial expansion in 2004 of the no-take closures to commercial fisheries in the GBRMP region. The impact on commercial fishery catch four years before and four years after the mid-2004 closure was assessed using a BACIPS design, using the annual commercial catch for two non-GBR regions nearby that were combined as a composite control or reference series.

Fletcher et al. (2015) estimated that annual commercial catch declined by at least 35% between the four-year aggregated pre- and post-closure assessment periods.

Fletcher et al. (2015) had times series of commercial catch for the reference and impacts sites for 19 years (10 years pre-closure), so there was no need to use aggregated pre- and post-closure periods of four years when all 19 years of the data series could be used in an explicit time series structured BACI type form. The way that Fletcher et al. (2015) structured the BACIPS model by only using data from immediately prior and immediately after the 2004 intervention is in the spirit of a regression discontinuity design. Hughes et al. (2016) raised other methodological issues with this study, and some of these issues are addressed in the re-use of this example in the section on “Synthetic Control Approaches” (see below).

Smith et al. (2006, 2017) are also examples of the BACIPS form of DiD used to evaluate the impact of MPAs on fisheries economic outcomes. Thiault et al. (2019) utilized a progressive-change BACIPS approach to evaluate the impact of a network of small MPAs on coral reef fish communities on Moorea in French Polynesia. Chan (2020) and Lynham et al. (2020) are recent examples of the progressive-change BACIPS type of DiD for evaluating the impact of MPAs on economic or ecological outcomes.

Synthetic Control Approaches (SC)

Counterfactual prediction-based SC approaches are increasingly used to infer temporal causal impacts in a wide range of policy evaluation contexts, including public health (Bruhn et al. 2017), social policy (de Vocht et al. 2017), cigarette smoking bans (Pinilla et al. 2018), water conservation initiatives (Schmitt et al. 2018), and the impact of radioactive spills on seafood markets (Wakamatsu and Miyata 2016). The SC approach is an extension of the DiD approach.

There are two distinct counterfactual prediction-based modeling procedures using the synthetic control approach for inferring a causal effect: (1) the reduced form approach within a frequentist framework (Abadie et al. 2015), and (2) the structural component approach within a Bayesian framework (Brodersen et al. 2015). Various multivariate extensions have been proposed by Robbins et al. (2017) and Samartsidis et al. (2020). O’Neill et al. (2016) use the reduced form approach combined with MMs for evaluating health service policy interventions. Schmitt et al. (2018) used the Bayesian structural time series approach combined with MMs for evaluating water conservation policy interventions.

The Bayesian structural times series approach to inferring causal inference has very few and readily testable assumptions. The key assumption is that there is a set, or ensemble, of control time series that are not affected by the intervention, otherwise an effect might be falsely inferred. It is also assumed that any functional form between covariates in the SC ensemble and the treatment time series determined for the pre-intervention period remains stable throughout the post-intervention period.

Gilman et al. (2019a) support the Bayesian structural time series-based approach for evaluating the causal effects of blue water MPAs, and this approach was used recently in a comprehensive evaluation of the ecological and fisheries responses to expansions of the large blue water MPAs of the Pacific Remote Islands Marine National Monument (Gilman et al. 2020).

As an illustrative example of the Bayesian structural times series modeling approach, we continue to use the study by Fletcher et al. (2015) to assess the impact of a substantial expansion in 2004 of the no-take closures to commercial fisheries in the Great Barrier Reef Marine Park

(GBRMP) region. The impact on commercial fishery catch 13 years before and then six years after the mid-2004 closure was assessed using a Bayesian structural time series modeling approach (Brodersen et al. 2015), the annual commercial catch for the two nearby non-GBRMP regions (i.e., the Gulf of Carpentaria and the East Queensland coast), and several environmental predictors that were combined as a composite control or reference series. The counterfactual prediction summary is shown in Figure 4. There was a 41% decline in Great Barrier Reef (GBR) commercial catch following the 2004 no-take closure (95% uncertainty interval: -50% to -30%). The impact was gradual and permanent, at least until 2013. The cumulative catch loss was 48 kilotons (95% uncertainty interval: -60 kilotons to -36 kilotons). The posterior probability of a causal effect attributable to the no-take GBR closure was >99%.

Concluding Remarks

Causal effects estimated using counterfactual predictions are claimed to lack application beyond the specific study and, thus, lack external validity (Deaton and Cartwright 2018). The epistemological issue here is that the inference applies only to the specific MPA intervention being assessed and not to MPAs in general. If so, then perhaps a meta-analytic synthesis of many such studies is needed to draw broader deductive inference, as long as the sample for the meta-analysis is "representative" of all MPAs or specific types of MPAs; this conundrum of lack of external validity applies to all quasi-experimental approaches (Boesche 2019).

Acknowledgements

We thank Dr. R. Fletcher for providing access to the data used in Fletcher et al. (2015).

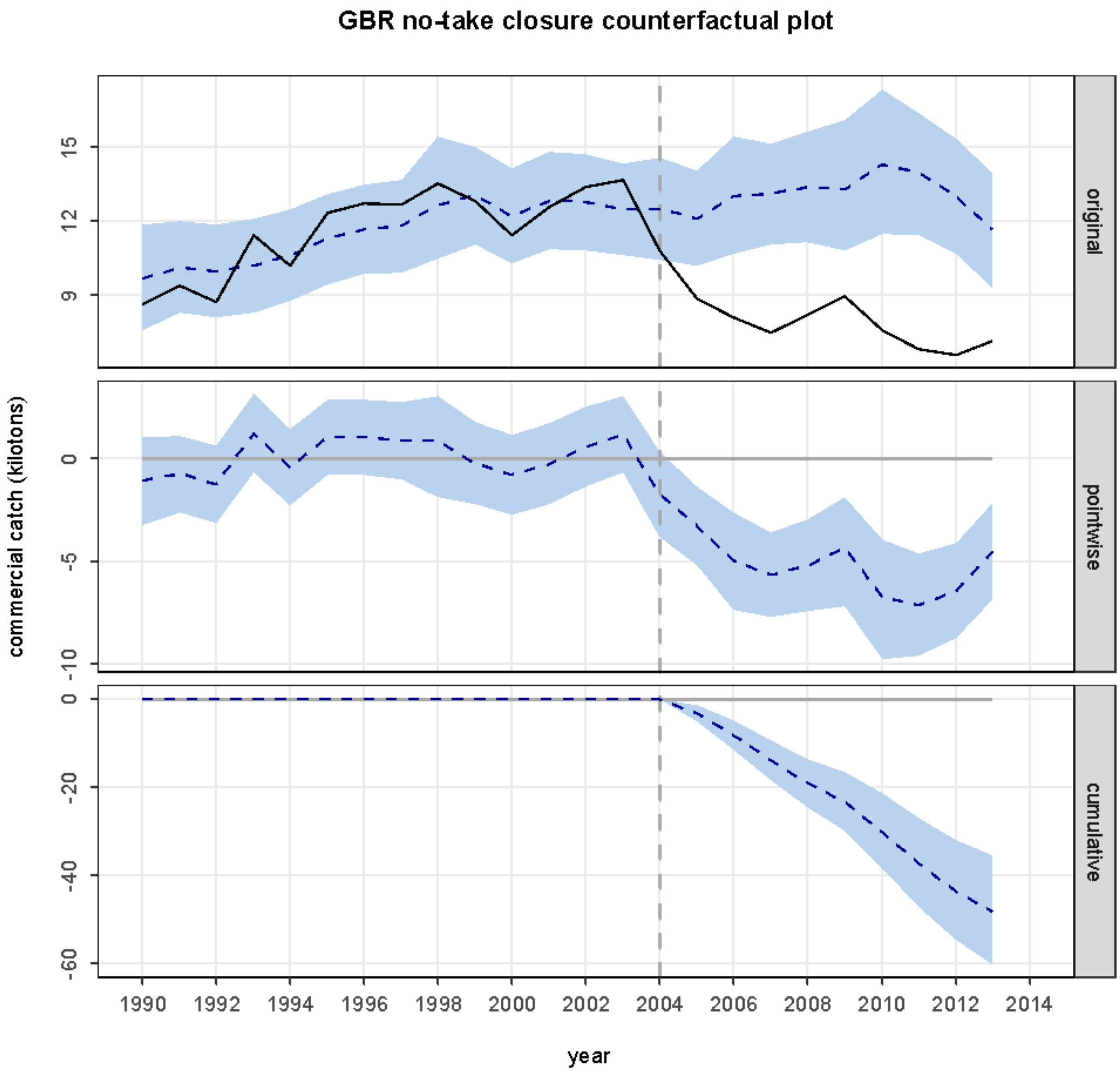

Figure 4. Counterfactual prediction summary plot for GBR commercial catch (1990-2013) conditioned on six predictors (two non-GBR catch series as controls (Gulf of Carpentaria, East Queensland coast, Australia)) and four environmental predictors (such as the Multivariate El Niño Southern Oscillation (ENSO) Index (MEI), either lagged to two years or a Generalized Additive Mixed Model (GAMM) smoothed series). (Top panel): Dashed blue curve and polygon show the counterfactual (and estimated uncertainty around the counterfactual prediction) from 50,000 stochastic realizations of a Bayesian state-space structural time series model fitted to the seven data series prior to the 2004 intervention and predicted post-intervention; the solid curve is the GBR catch series from 1990-2013. (Middle panel): pointwise difference between the two curves (i.e., GBR catch and counterfactual prediction in the top panel) with a 95% credible interval, which shows a significant loss of GBR catch following the intervention; the 95% credible band does not overlap the zero-baseline post-2004. This shows the temporal dynamics of the intervention impact. (Bottom panel): the significant cumulative negative impact on the commercial catch since closure. (Data sourced from Fletcher et al. 2015).

CHAPTER 7. SOCIAL IMPACT ASSESSMENT FOR BLUE WATER AREA-BASED MANAGEMENT TOOLS

Authored by Craig Severance

Imagining Fair and Effective Social and Economic Impact Assessments for a Blue Water Space Where Nobody Lives - Ranking Affected User Groups, Communities, and Constituencies

Social impact assessments (SIA) and economic impact assessments (EIA) use the tools and methods of the social sciences to project a range of possible scenarios and assess both positive and negative potential impacts on human communities when development projects or regulatory actions are being considered by governments, international organizations, and nongovernmental organizations (NGOs). These assessments require some baseline data on the social and economic conditions of the potentially affected groups and communities, a clear understanding of proposed actions, and the thoughtful projection of scenarios of likely impacts should a project or regulatory regime move forward. When done effectively, SIAs and EIAs can give voice to community concerns and fears and may even mitigate some negative impacts through project or regulatory regime modification. This chapter will discuss social impacts followed by economic impacts, though both kinds of assessments would ideally be done simultaneously and collaboratively.

Under U.S. law, the National Environmental Protection Act (NEPA), SIAs are expected for actions and projects that have a Federal nexus and a projected significant effect on the human environment. The projection of significant effects is done under an Environmental Assessment (EA) that may then lead to a required Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI). Often, the SIA portion of the EIS is perfunctory, shallow, and almost an afterthought in comparison to the analysis of physical and economic impacts. Better and more effective SIAs for fisheries policy development including area-based management tools (ABMTs) can improve outcomes for affected communities and constituencies.

The U.S. Magnuson-Stevens Reauthorization Act (MSRA) requires that Federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA), draft environmental and social impact statements and obtain public comment in accordance with NEPA for all fishery management actions. In addition, the MSRA National Standards require actions to provide fairness when considering the needs of fishing communities, with special attention required for fishery-dependent communities. The National Marine Sanctuaries Act (NMSA) also requires a public process and NEPA impact assessment. NOAA has produced various detailed guidelines on how to conduct SIAs, with the most recent, and perhaps most effective, being Clay et al. (in review).

Internationally, several Pacific Islands states, territories, and nation states with distant water fishing fleets do have environmental laws that may consider social impacts. A detailed analysis of various national environmental laws and their effectiveness is warranted but is beyond the scope of this discussion of the need for SIAs in national and international fishery actions that develop area-based management systems.

The United Nations Environmental Program (UNEP) and the UN Development Program (UNDP) have both general and specific guidelines and recommendations for impact assessments (UNEP UNDP 2010). South Pacific Regional Organizations, such as the South Pacific Regional

Environmental Program (SPREP) and the South Pacific Applied Geoscience Commission (SOPAC) have guidelines for specific kinds of development projects. Other NGOs have both general and specific guidelines, and some discuss the mix of social science tools and methodologies that are appropriate for different situations (e.g., Richards 2011; IUCN ESMS 2016; Schrekenberg et al. 2010). There are also literature reviews that define classes of stakeholders (e.g., National Marine Protected Areas Center 2004).

What constitutes an effective SIA, and how should fisheries managers rank the most directly affected communities and constituencies? Often, policy development for area-based management systems for fisheries may be considered to be similar to a development project that will inevitably have differential impacts and outcomes. While many of the SIA guidelines noted above come from terrestrial experience, they are relevant and can be applied to regulatory actions in blue water ecosystems. Communities impacted by the implementation of ABMTs can be either placed-based, within or adjacent to the proposed area, or be communities of practice, representing people participating in the same fisheries sector.

Defining the more directly affected place-based communities can begin with identifying direct user groups, even if the use is small scale and intermittent, especially if the use includes sustainable extraction of fish resources that benefit larger communities of consumers served by markets. Second are the members of a larger fishing community that provides businesses and services that gain extended economic and social value from the direct user group's activities. This extended social and economic value accrues throughout the supply chain, not only of fish resources, but also through the expression of lifestyle values that come from pursuing fish, eating fish, selling fish, and sharing fish.

A more distant and much less affected tier of fisheries participants are based far away from the action area but may be considered part of a community of practice that is affected by the implementation of an ABMT. These participants are not residents in communities immediately adjacent to or within the area to be protected, but their resource exploitation activities are nonetheless likely to be affected. Blue water areas in particular are likely to have distant water fleets that fall under the same community of practice or under different communities from different nations. An example would be those states and territories that fall under the jurisdiction of the Western and Central Pacific Fisheries Commission (WCPFC), with the states and territories physically closer to the blue water under consideration being those included in the Parties to the Nauru Agreement (PNA).

Other interested parties are included in a different community of practice that may receive little direct benefit but who have values focused on preserving biodiversity and wilderness values. These parties often expect to have some say and influence over policy development. Should they also be considered "stakeholders", or only a remote and minor constituency? If they are considered stakeholders and they constitute a much larger number of voices, should they be given greater, equal, or less considerations than those that are the most directly affected?

Impacts from the implementation of blue water ABMTs are likely to be widespread, affecting place-based communities in many countries. Thus, an analysis of social impacts for communities of practice will be an important component to the design of blue water ABMTs and ultimately minimizing social and economic impacts.

Effective SIA begins with considering a proposed action, perhaps with alternatives, and most importantly, having some baseline characterization of activity levels that considers both affected community conditions and attitudes. For fisheries, this needs to include some historic and current estimates of catch and effort by species and fleet, which is difficult but not impossible in international blue water ecosystems. Baselines should include fleet profiles, each fleet's community profiles, characterizations of level of dependency, economic return, alternative fishing areas, and/or employment, and community attitudes toward the action area and the proposed actions. Then, a suite of scenarios can be developed as to what is likely to happen and what might also happen with consideration of potential repercussions and unpredictable side effects. Scale and time frames should be specified, and both a short time frame and a longer time frame of potential short-term and longer-term effects is appropriate. These scenarios are projections into an uncertain future and are best when based on solid understanding of cultural and social change processes as well as the events of change in similar cases and situations. A clear understanding of theories and processes of social change is necessary for effective SIA practice.

If fleet and community profiles exist, are they current or outdated? What kinds of data are necessary to update them? How can existing attitudes be assessed, and is it possible to get a representative sample? Many of the guidelines noted above argue for a mix of both qualitative and quantitative methodologies depending on how familiar the SIA practitioners are with the affected population and affected communities. Recruiting knowledgeable members from the affected community to be team members can be quite helpful. Being known and having some level of trust is helpful. In cross-cultural situations, especially if there are language or trust barriers, it is best to use a developmental research sequence beginning with informal qualitative methods, such as focus groups, informal "talk story", or informal open-ended interviews. If possible, some participant observation through "time on the water" can help social and other fishery scientists understand fishing operations and the socioeconomic concerns of the fishers. From these methods and building trust in the communities, the appropriate language and cultural protocols can be developed to ensure that more quantitative surveys and questionnaires generate meaningful responses and are more effective. Note, however, that the use of surveys and questionnaires is expensive, time consuming, and may also distort responses. Project proponents should plan for, schedule, and adequately fund timely social and economic impact analyses and ensure that projected social impacts and affected community concerns are given fair consideration.

Fisheries scientists, social scientists, and economists should collaborate closely in the development of an appropriate suite of methods to utilize. Ideally, a mix of methodologies and using triangulation (i.e., seeing if different tools provide somewhat similar results) can be used to cross check and ensure the accuracy of results. Participatory methods that directly involve affected community members are quite useful, especially if community members become part of the research team. Insiders (i.e., fishers who have harvested the resources in the area or derived economic benefit for their families, their communities, and even larger more distant communities) can give insights not available to the outsider. Beware, however, that often, the most outspoken insider who may gravitate to the outsider team is often not representative, especially in smaller and more cohesive fishing communities. Consciousness of and attention to people's agendas is always necessary.

Although rare, there is ideally time to conduct adequate and effective SIAs before a project or regulatory regime is fully developed. Ideally, but even more rarely, there is also *post hoc* follow-up to see if the projected/predicted scenarios came to pass and to note unexpected side effects.

Some guidelines strongly recommend monitoring and having a monitoring plan, such as a social monitoring and Management Plan (SMMP) built into project development and funding. Such a plan should include descriptions of baseline social activities, measures on prevention, minimization and mitigation of social impacts, as well as measures on compensation for loss of access to resources (UNEP UNDP 2010). If such monitoring and follow-up assessments were carried out and published, there would be a much larger and more useful corpus of realistic scenarios from which to draw for making projections of potential social impacts in somewhat similar cases!

SIAs should develop reasonable assessments with alternative scenarios that have both positive and negative impacts. They should determine what the main concerns of affected groups are, especially livelihood stakeholder groups. SIAs should also create plausible narratives or stories as “what if” scenarios, and this should be done in a sustainable livelihood framework. The SIA should project probable scenarios of expected changes in the social and economic fabric of the communities. Monitoring of significant events and impacts and follow-up analyses should be done to answer three questions: (1) What changes have occurred since the project started? (2) What changes are attributable to the project? (3) What differences have the changes made in people’s lives? (Schrekenberg et al. 2010).

An important step is to determine who the important stakeholders are and how stakeholder groups and categories should be considered or ranked in terms of the amount of consideration given to their positions, hopes, and wishes. Some of the guidance noted above incudes clear statements that the most affected communities should be given the greatest consideration; this is why “livelihood stakeholder groups” are specified in some guidelines. These might also be considered “communities of practice” since they depend on the resource directly (Zador et al. 2019), which seems logical and even reasonable. An early, but classic, work states clearly that unless the more directly affected communities are clearly consulted and involved in the development of an ABMT, it is likely to fail (NRC 2004).

The term “stakeholder” is broad and sometimes considered to include all interested groups, as defined with overlapping Venn diagrams, even if they are somewhat ranked (National Marine Protected Areas Center, 2004). Such a broad use of the term may serve the purposes of some of the ABMT proponents but runs counter to the national and international guidance summarized here. Such usage also runs the risk of generating resistance, resentment, senses of disenfranchisement and injustice, and a disproportionate burden among members of the most directly affected communities. It may also generate a sense of injustice among more neutral observers, especially when campaigns use click-on websites to sway people (constituents or stakeholders) far from the action with little understanding of local conditions while far outnumbering (and thus out-swaying) the most directly affected groups. This is especially the case when national statutory requirements for EISs and SIAs, the UN, and even environmental NGO guidance is circumvented. The Pacific Marine National Monuments created by U.S. Presidential Executive Order using the Monuments Act are an example.

Incorporating Economic Impacts of New Management Regimes

Economic impact analyses and social impact analyses are inherently intertwined and should be integrated in a cooperative effort. The research methods, tools, and models may differ somewhat in practice, and the practitioners may operate from somewhat different assumptions about the behavior of people in human communities, yet both types of analyses seek to project sound and reasonable scenarios about changes expected from the proposed action, potential negative, potential positive, and mixed impacts on human communities. Economic analyses also need baselines of existing economic conditions for local communities and larger populations that receive benefits, some of which may be adversely affected. This can be done through fleet profiles, estimates of capitalization or overcapitalization, landings, revenues, catch composition, and cost-earnings studies that include fixed and variable costs as well as profit margins, market profiles, distribution channels, etc. Potentially affected community profiles should outline the base infrastructure and the degree of dependency on blue water resources through employment, marketing, and non-market distribution of target and non-target species. Economic multiplier effects should be considered.

As with SIAs, planning the information and research needed for adequate analyses should begin early in the process of management intervention development. Many of the caveats about the uses of surveys, development of trust, etc., noted above for SIA are also applicable. The primary analyst may be able to make use of a variety of existing data collection efforts by local and national governments, but heed should be given to respect for proprietary data. In an international context, access to such data from other governments may be quite difficult, but every effort should be made for the economists to work cooperatively, internationally, and through international management regimes.

As with SIAs, specialized guidance does exist (NMFS 2007; UNDP 2017; McKinnon et al. 2015). Some might argue that one difference between economists and non-economic social scientists is that economists are often concerned with efficiency, obtaining economic rent from the resources, and are sometimes proponents of privatization schemes. Non-economic social scientists are more often concerned with communities and their social stability, continuity, and cultural identities.

That said, both SIA and EIA practitioners have the same goal: to develop reasonable and empirically grounded scenarios of potential community and broader impacts. These scenarios may help guide management decisionmakers at all levels to develop fair and effective management regimes for blue water ecosystems.

Even if nobody lives in a proposed blue water affected area, there will be current resource users, potential resource users, people who transit, and even people who simply value the space and its current and future condition. Imagine an effective SIA and EIA that fairly and equitably meets and balances everyone’s expressed wants and needs. Imagine a socioeconomic impact analysis that manages or even mitigates some of the more negative impacts!

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WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL

PLENARY REPORT FOR THE INTERNATIONAL WORKSHOP ON AREA-BASED MANAGEMENT OF BLUE WATER FISHERIES

EXECUTIVE SUMMARY

The Western Pacific Regional Fishery Management Council (Council) hosted the virtual International Workshop on Area-Based Management of Blue Water Fisheries from June 15-17, 2020. The workshop included 34 participants from all over the globe. The panelists and participants included top area-based fishery management experts from Intergovernmental agencies, nongovernmental organizations (NGOs), regional fisheries management organizations (RFMOs), and academia, many of whom bridge the gap between science and policy. The workshop was co-chaired by world-renowned scientists Dr. Ray Hilborn (University of Washington) and Dr. Vera Agostini (United Nations Food and Agriculture Organization).

The workshop, preparatory papers, and resulting documents addressed emerging issues in governance with respect to blue water ecosystems that lie in areas within and beyond national jurisdictions. The workshop had a broad diversity of opinions on the utility of area-based management tools (ABMT). The workshop consisted of three plenary sessions plus two series of regional inter-sessional breakout meetings to correspond with multiple time zones throughout the globe. During the plenaries, participants split into breakout focus groups. Breakout focus groups included: Science-Policy Forum, Objectives and Performance Metrics, Empirical Evidence and Research Needs for ABMT Utility, Design of ABMT Measures, Methods to Evaluate ABMT, and Moving Forward with ABMT Implementation. The format was to allow cross-pollination of disciplines and regional perspectives despite the COVID-19 pandemic limiting in-person meetings.

Council staff, with members of its Scientific and Statistical Committee (SSC), initiated the idea over the prior year, formulating a plan to develop a high-level peer reviewed document entitled "Road Map to Effective Area-Based Management of Blue Water Fisheries." Participants were tasked to improve and expand upon the conceptual frame of the preparatory papers. The series of preparatory papers, which were drafted ahead of the meeting to serve as a starting point for discussion, included:

1. Introduction to Area-Based Management of Pelagic Fisheries
2. Objectives and Performance Metrics for Area-Based Management
3. Designs of Spatio-Temporal Management Measures for Blue Water Fisheries Empirical and Theoretical Evidence of Ecological Objectives Met by Area-Based Management Measures for Pelagic Fisheries
4. Evidence of Ecological Objectives Met by Spatio-Temporal Management Measures for Pelagic Marine Fisheries Review of Methods to Evaluate and/or Monitor Area-Based Management Measures
5. Research Needs for Area-Based Management in Pelagic Fisheries

6. Evaluating Conservation Intervention Effects Such as MPAs Using Causal Inference when Randomization is Not an Option.
7. Social Impact Assessment for Blue Water Area-Based Management Tools

Oftentimes implementation of ABMTs (such as closures or restrictions) is done without weighing objectives, having a proof-of-concept beforehand to achieve these objectives, or planning on how to evaluate area-based measures thoroughly through time. These planning steps are critical - especially for highly dynamic ecosystems that support blue water fisheries where "set it and forget it" may not be appropriate. Workshop participants discussed several "static" vs. "dynamic" AMBTs and their benefits and limitations. Static implies management an area with fixed area delineation, while dynamic implies managing area(s) that may shift in time and space. In the end, the participants all agreed that ABMTs are not a silver bullet for managing fisheries or their ecosystems. Marine Protected Areas (MPAs) are often most synonymous with ABMTs but are merely a single tool in a vast toolbox of ABMTs that are not strictly about permanent closures.

The workshop consensus agreed that economic, cultural, and social objectives need to be considered more thoroughly prior to implementation of ABMTs, and industry engagement is also critical. Alternative management measures should be explored and evaluated alongside any ABMT considered. The workshop participants identified agreeable general objectives to reach desired goals, regardless of whether the goals are conservation-based, economic, or social in nature. These objectives include: 1) Sustainable food production, both local and global; 2) Employment, both local and global; 3) Economic health and welfare; 4) Communities and culture; 5) Protect endangered, threatened, and protected species (and reduce interaction with non-target species); 6) Protecting specific habitats; 7) Maintaining ecosystem structure and function; and 8) Resilience to climate change and other stressors. Workshop participants agreed that objectives have associated performance metrics, which need to consider the state of knowledge and knowledge gaps that will require research and an improved science-policy dialogue.

After several deliberations, the workshop participants collectively agreed that two papers will emerge. A brief 3,500 word science-policy paper will focus on addressing governance issues, specifically UN Convention on Biodiversity Beyond National Jurisdiction (BBNJ), the Convention on Biological Diversity (CBD), and UN Sustainable Development Goals (SDG). More notably, a comprehensive peer-reviewed resulting document with an agreed-upon scope is in preparation by workshop participants. The paper will be published as a special edition in *Fish and Fisheries* with Dr. Ray Hilborn as the lead author. About two dozen participants volunteered to draft sections of these papers, including Council staff and some SSC members. The *Resulting* document has six chapters: 1) Introduction; 2) Objectives and Performance Metrics for Area-Based Management in Blue Water Ecosystems; 3) Spatial Management Measure for Blue Water Fisheries; 4) Review of Evidence that Objectives Met by Spatial Management Measures and their Research Needs; 5) Review of Methods to Evaluate and Monitor Area-Based Management Measures; and 6) Moving forward in implementation of area based management planning.

The resulting document will also expand upon the utility of general ABMTs, including: 1) Time-area closures; 2) Adaptive real-time closures, dynamic ocean management, 3. Permanent closures; 4) Input/Output controls; 5) Gear and fishing method changes; and 6) Access and tenure rights by area. Workshop participants will continue to collaborate throughout the COVID-19 pandemic in order to have a manuscript for publication.

WORKSHOP AGENDA

Plenary 1: June 15, 2020 9:00am HST/7:00pm GMT

Plenary Session 1 Paper Outline (120 Minutes),

45 Minutes: Paper Outline general discussion
45 Minutes: Breakout groups to prepare outlines of major paper sections
30 Minutes: Summary of breakout groups and responsibilities prior to Second Plenary

Expected Outcome: Outline for Road Map Documentation agreed upon by participants and initial outline of individual sections from breakout groups.
Expected Tasks before Second Plenary: Participants draft text to add to sections for which they wish to collaborate. Leads develop detailed outlines between Plenary Session 1 and Plenary Session 2.

Inter-Sessional Regional Meeting 1 (60 Minutes),
Discussion Theme: Identify missing components from the preparatory papers and identify sections of interest.

Plenary 2: June 16, 2020 9:00am HST/7:00pm GMT

Plenary Session 2 (120 Minutes)

20 Minutes: Summarize work since First Plenary
70 Minutes: Breakout groups on individual paper sections

- Objectives and Performance Metrics
- Management Measure Designs
- Empirical Evidence
- Research Needs

30 minutes: Conclusions

Expected Outcome: Lead authors incorporate comments into detailed outline addressing all key points for which participants share agreement.
Expected Tasks before Final Plenary: Preparatory Paper leads prepare detailed section outlines.

Inter-Sessional Regional Meeting 2 (60 Minutes)
Discussion Theme: Participants provide potential text to leads for each section for potential incorporation.

Plenary 3: June 17, 2020 9:00am HST/7:00pm GMT

Plenary Session 3 (120 Minutes)

Lead authors provide (20 minutes each) summary on each section; recap of edits, comments, and final assignments; identify collaborators for each section to produce full draft.

Expected Outcome: Identification of timeline for documents.

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WORKSHOP PLENARY AND INTER-SESSIONAL MEETING DESIGN

From June 15-17, 2020, the plenaries opened for two hours for all participants. Plenaries focused on specific themes according to the agenda and moderated by Workshop Chairs, Dr. Ray Hilborn and Dr. Vera Agostini. During the plenaries, participants were placed into Zoom virtual Breakout Rooms focused on a particular topic with specific questions to be addressed regarding area-based management of marine blue water fisheries. The topics varied between Day 1 and 2 (June 15 and 16, 2020). Each breakout group had rapporteurs who reported on agreeable responses to thematic questions.

To ensure cross-cutting of expertise and discussion from different plenary breakout sessions, small inter-sessional "regional" meetings were held virtually throughout the workshop period on Days 1 and 2. These meetings allowed participants across time zones to confer on outcomes of the plenary session earlier that day. Each inter-sessional meeting had rapporteurs taking notes to report back to the plenary on the following day. Plenary times and inter-sessional regional meeting times by respective participant time zones are indicated below.

The Day 3 (June 17, 2020) plenary focused on the design of a resultant paper, which would include volunteering participants as authors and be published in *Fish and Fisheries*, with Dr. Ray Hilborn as lead. A second resulting paper is to be a "science-policy nexus" paper focused on policy designs leading from known science on area-based management in blue water fisheries.

See the agenda for specific thematic topics for each session.

Plenary/Regional Inter-Session	Brisbane AEST	Noumea NCT	New Zealand NZST	West Coast US PST	East Coast US EST	London/ Madrid BST	Rome CET	*Local Hawaii HST*
Daily Plenary Session (2 hour)	**5am**	**6am**	**7am**	**12pm**	**3pm**	**8pm**	**9pm**	***9am***
"Americas" Inter-Sessional	9am	10am	11am	**4pm**	**7pm**	12am (+1)	1am (+1)	***1pm***
"Australia/Oceania" Inter-Sessional	**2:30pm**	**3:30pm**	**4:30pm**	9:30pm	12:30am (+1)	5:30am (+1)	6:30am (+1)	*6:30pm*
"Europe/Africa" Inter-Sessional	6pm	7pm	8pm	1am (+1)	4am (+1)	**9am (+1)**	**10am (+1)**	*10pm*

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DAY 1 PLENARY, JUNE 15, 2020

Opening and Preparatory Paper Review

Workshop Chairs, Ray Hilborn and Vera Agostini, opened the meeting by addressing the workshop and the impetus behind it. Hilborn noted that COVID-19 prohibited an in-person meeting, but also that the virtual platform allowed for much broader participation that may have otherwise been constrained by travel budgets. Hilborn began discussions about the workshop regarding cropping subject matter from the preparatory papers into a resulting document emerging from workshop discussion. One of the biggest gaps identified was that social and economic factors were considered to be a side issue. As a result, the Chairs decided to include social and economic community issues in each of the sections.

Mark Fitchett reviewed the first preparatory paper, *Introduction to Area-Based Management of Pelagic Fisheries.* This section focuses on blue water fisheries, mostly tuna and tuna-like fisheries, and introduces emerging issues with respect to governance and management. Specifically, the section introduces regional fishery management organizations and arrangements (RMFO/As) and international conventions under the auspice of the United Nations. The workshop would need to address the underlying theme of this preparatory paper: "At present, science-based guidelines to plan, evaluate, identify unintended consequences, and monitor area-based management implementation discussed in these negotiations are lacking." There is a need to define "blue water ecosystems" not just in international waters, but also in national waters. The workshop would also need to address how documents emerging from the workshop serve as a conduit from science to policy. Most objectives of area-based management tools (ABMT) implementation are ecologically-focused and can be combined while creating objectives on economic and social issues.

Ray Hilborn reviewed the second preparatory paper, *Objectives and Performance Metrics for Area-Based Management*. The objectives and metrics are mostly from marine protected area (MPA) literature, yet area-based management has a much wider range of objectives and metrics. Social objectives are not included, underscoring the need for the workshop to further address them. Criticism received on this paper was that it is too focused on threat management rather than obtaining benefits.

Eric Gilman reviewed the third preparatory paper, *Designs of Spatio-Temporal Management Measures for Blue Water Fisheries.* This paper is the driver for discussion of the breakout groups on "Area-Based Management Measure Designs". Static (place-based) spatial management measures vs. dynamic (mobile) spatial management measures are to be further contrasted in their utility to address objectives under current management regimes. There are categorization schemes for area-based marine conservation measures, including International Union for Conservation of Nature (IUCN) MPA categories – which are based on management objectives and Center for Biological Diversity (CBD) area-based marine conservation measures. The paper also provides a thorough review of networked spatially-managed pelagic marine areas. These each have ecological, socioeconomic, and governance benefits. Ecological objectives may drive site selection for management interventions.

Eric Gilman also reviewed the fourth preparatory paper, *Evidence of Ecological Objectives Met by Spatio-Temporal Management Measures for Pelagic Marine Fisheries.* This paper is the basis for discussion for workshop breakout groups on "Empirical Evidence".

David Itano reviewed the fifth preparatory paper, *Research Needs for Area-Based Management in Pelagic Fisheries*. This paper is the basis for “Research Needs” breakout groups and discussion throughout other breakout groups with respect to filling knowledge gaps before ABMT implementation and during evaluation. The paper consists of two sections: A) minimal needed fishery biological information, and B) climate change considerations. ABMT implementation should consider the biology of the species of concern as well as their habits, habitats, and movement parameters against broader stock considerations where ABMTs impacts may occur. The basic consideration for area-based solutions should consider the movement patterns of a stock in relation to the fulfillment of basic life history parameters, noting that these may vary in time and space. The minimal needs for biological information when considering ABMT interventions include life history and biological considerations that drive habitat preference and movement. Having information on population range, migratory behavior, spawning, and feeding grounds are critical to evaluate the impacts of ABMTs. Stock structure and connectivity may also define what resources and sub-populations of species are going to be impacted proportionally by ABMT interventions. Oceanographic features such as eddies, current boundaries, and shears are also important drivers not only of species distributions, but also fisheries. These are increasingly important to floating objects, which may attract some pelagic species and change bycatch dynamics of fisheries that incorporate fish aggregating devices (FADs), for instance.

Milani Chaloupka reviewed the sixth preparatory paper, *Evaluating Conservation Intervention Effects Such as MPAs Using Causal Inference when Randomization is Not an Option*. This paper was the basis for discussion in breakout groups relating to methods to evaluate ABMT implementation and empirical evidence. This paper reviews six approaches to evaluate ABMT inventions. Few evidence-informed evaluations of the impact of blue-water area-based management interventions currently exist. It is difficult to assign control groups to use as a comparative measure to evaluate ABMTs, so randomized control trials (RCTs) are not common. Quasi-experimental approaches used for inferring causal inference and are: (1) instrumental variables, (2) interrupted time series, (4) regression discontinuity designs, (5) matching methods, (5) difference-in-differences and (6) synthetic controls. Such approaches are based on observational data and lack external validity; this is a conundrum of not being generalizable to other places or times or interventions. Therefore, a meta-analytic synthesis of many such studies might be useful to draw broader deductive inference.

Craig Severance reviewed the seventh and final preparatory paper, *Social Impact Assessment (SIA) for Blue Water Area-Based Management Tools*. Social and economic impacts are a general theme that the preparatory papers did not address in full. This paper provides a starting point for workshop discussions and offers some background on the subject matter in resulting workshop documents. The workshop will fold in some of the knowledge gaps and considerations throughout the documents emerging from the workshop.

Two workshop participants inquired on the motivation of the workshop and breadth of the emerging documents that will result. It was noted that there was a previous workshop on blue water MPAs just over a year prior, and there are concerns that this workshop may overlap with it. There was also concern that the focus would lean too far towards MPAs, which are areas closed to activity by any economic sector, per United Nation (UN) lawyers. Hilborn clarified that the workshop is to be a summary of ABMTs with respect to blue water fisheries management and to address emerging issues previously discussed.

Another participant commented that international questions on equity, such as sovereign rights, developing state aspirations, and how compatible these are with international trade once area-based management is in the equation, need to be addressed. Hilborn replied that the issue of equity is difficult to address specifically and equity implications are inherent in international fisheries management.

A participant asked Hilborn what the goals and intended audience of the emerging paper would be. Hilborn stated he has not decided where the resulting paper would be submitted, but that Agostini and Fitchett developed a straw-man outline for the workshop participants to fill in. Hilborn cited the growing interest to close 30% of the high seas as a form of MPAs. The resulting paper should address consequences to these proposals.

A participant followed to ask what management landscape is the motivation and what policy or decision making the workshop is intended to drive. Hilborn replied that the UN Areas Beyond National Jurisdiction (ABNJ), including the Convention on Biodiversity Beyond National Jurisdiction (BBNJ) are major issues.

A participant also pointed out that non-fishery issues, such as deep-sea mining need to be considered. Hilborn agreed but noted fisheries management issues are the appropriate bounds for the workshop.

The plenary split into breakout groups, with notes from each breakout provided. The groups include: 1) Empirical Evidence; 2) Management Measure Designs; 3) Objectives and Performance Metrics; and 4) Research Needs. Rapporteurs provided notes from each breakout session.

Small Group Sessions

<u>Breakout Group: Empirical Evidence</u>

The scope of current knowledge covers both empirical and theoretical evidence. Assessments should cover system-wide effects of interventions, and not just the effect of a spatial management measure within the spatially-managed area. Assessment of efficacy of ABMTs should not include considerations of whether governance of an ABMT might be feasible for a given management authority. An assessment of problems encountered with implementation of spatial management methods, whether spatial management tools were more problematic to implement than non-spatial tools, and why would be interesting. Examples from the Seychelles and Parties of the Nauru Agreement (PNA) vessel day scheme (pursuant to Western and Central Pacific Fisheries Commission (WCPFC) conservation and management measures) were raised. The Seychelles did not have the capacity to monitor and enforce the MPA, and while non-governmental organizations (NGOs) augmented the capacity, it is dictated by the type of governance in which they are interested.

Most knowledge on ABMTs relate to static systems and not to pelagic or dynamic systems, therefore little is truly known from empirical studies on ABMT usage in blue water pelagic systems.

All management measures for straddling/transboundary target stocks that span multiple jurisdictions (not just highly migratory species) could be considered to be spatial management measures by design. Existing definitions of ABMTs address similar issues and participants discussed whether there is a need to include an explicit definition ABMTs. The albacore stocks in the Pacific are not managed through quotas or effort limits, so there is room for alternative management under ABMT definitions.

For non-pelagic stocks, there are continuous stocks in groundfish/cod complexes that have assessments in their full range, and countries are tasked to manage each segment of the stock within their management jurisdiction. Countries are attempting to harmonize the total catch but cannot standardize the method of managing the stock. This spatial piecemeal approach has both benefits and downfalls.

The Ecosphere article (Gilman et al. 2019a) identified many examples of evidence that area-based bycatch management methods have been effective at achieving ecological objective, but there is a need to expand these examples to assess economic and social outcomes.

Outcomes of climate change, including range shifts, are increasingly calling into question the efficacy of area-based measures, specifically static measures. The equatorial area should be prioritized because it has the biggest potential for impacts from climate change.

Do spatial management measures have the flexibility to adapt? Examples provided included how different Canada government agencies are responding to a northward-shifting species (i.e., invasive species that needs to be controlled vs. a protected species).

A lack of explicit metrics for performance of area-based management measures makes it challenging to assess performance. These challenges introduce variable interpretations of the implicit objectives against which to assess efficacy. If focusing on ABMT impacts on marine capture fisheries, it would be best for assessments to consider benefits and costs. A very large pelagic MPA may achieve relatively few or "small" benefits, but if costs are minimal, then the intervention still might be considered worthwhile. Social benefits of a very large MPA may be substantial, while ecological benefits are minimal. These are considerations that need more information.

Given the broad range of consequences of an intervention (i.e., a spatial management measure), some stakeholders may perceive the same outcome to be a cost, while other stakeholders might consider the same outcome to be a benefit.

The utility of closures in Hawaiian Islands to pelagic fisheries was discussed. Lynham et al. (2020) and Chan (2020) exhibit conflicting results because of the methodology used. Validity of empirical evidence is tied back into appropriateness of methodological approaches and designs.

Breakout Group: Management Measure Designs

There was broad consensus overall on a need for stronger focus on dynamic spatial management regimes, such as, for example, managing juvenile tuna hot-spots with industry buy-in. This would require scientific information needed to support those approaches. A dynamic management regime is tied to dynamic oceanographic processes and acquiring appropriate information to refine their designs. Better life history information is needed to support dynamic spatial management approaches (which leads into "Research Needs" breakout discussion).

Data-poor approaches need to be explored because managers and scientists may never get the appropriate data streams that are realistically needed for dynamic management. Therefore, there is a need to talk with fishers and the fishing industry for support and to use fishing vessels for better science data collection via electronic technologies.

It is best to match meaningful goals/objectives for the area-based management instrument used. For instance, some sustainable development goals (SDGs) are clear and practical, but some are too broad and vague (e.g., "avoid adverse impacts"). So, there is a need for more prescriptive objectives to support impact evaluation through target-based measures. (This theme ties into to the breakout group on Objectives and Performance Metrics).

What is it in for the industry? What are the market-based mechanisms to garner industry support such as innovative high seas financing approaches?

Breakout Group: Objectives and Performance Metrics

Fisheries management has a suite of objectives, some for which ABMTs are best suited. There is a feeling that MPAs are a buffer or an "easy fix" management measure such that other management measures may not be effective. In terms of governance issues, MPAs are much easier to enforce than nuanced size, effort, or catch limits.

What is the story the workshop trying to tell and why? Motivation remains to bring fisheries voices in, so is the message just that MPAs are not the only tool? Clarity in the purpose of ABMTs is critical.

Objectives have largely been focused on those associated with MPAs, which are about conservation. Very rarely is the dialogue on how to do the science to evaluate specific objectives. How to evaluate whether ABMTs are working is another scientific and data need. The scientific community is not always clear on what those objectives might be and is not always the best suited to determine the objectives.

Objectives must be considered in context of a fishery management plan or whether the ABMTs are the fishery management plan. There is a need to define specific targets and indicators. There is a need to consider how conservation objectives relate to fishery objectives.

Objectives need to also consider what is happening outside of the intervention area, as with respect to "spillover effects", the only things that matter are outside of the ABMT intervention area.

What are cultural objectives and how do scientists and managers measure those?

The workshop needs to determine objectives and leave it to the participants to determine suitability of ABMT tools for a given objective. Then participants may identify suitable performance metrics to evaluate them.

The "unique" focus about this workshop endeavor is answering "which of the various suite of ABMT tools are suited for which objective in blue-water ecosystems, and which metrics would we need to evaluate their performance?" Participants discussed a need to focus in on blue-water specific issues and not recycle the same general comments on MPAs. Consensus was strongly in favor of focusing attention outside of just MPAs.

Objectives can vary from "simple" objectives such as catch rates, to much more "complicated", or at least hard to measure, objectives, such as cultural and governance issues. Clarity in purpose is critical and needs to be stated initially. The participants realized that the discussion had been focused on the MPA side of things, so there is need to branch out to all ABMTs. Objectives need to be specific with clear performance metrics, otherwise they may tend to be agreeable to all parties involved and then impossible to realistically measure/evaluate.

Breakout Group: Research Needs

There is a need to track vessels and where/when fleets fish, as these are part of arising technologies across all fisheries. For example, tracking can be used to properly evaluate Hawaii marine national monument closures or could have provided some basis for the closures ahead of time.

Economics is often seen as a response to biology unless equally treated to biology as a socio-economic effort from the beginning. Managers should provide a list of questions to be answered by social and economic experts to discern possible costs relative to benefits of ABMT actions.

MPAs are often placed in areas without fishing or where little fishing occurs, and are therefore often opportunistic closures lacking scientific rationale. Social and economic costs to this approach need to be considered. Panama has closed its exclusive economic zone (EEZ) to purse seine fishing, and the Eastern Pacific's Revillagigedo Islands designated non-fishing within a 50 nm radius of its shores. It is unclear how beneficial or costly these measures are.

There is a need for input (i.e., research and data with respect to social, economic, and science) from the broader international community on sentiments towards ABMTs when management spans into the international realm. Many geopolitical constraints will need to be navigated. There needs to be an understanding of national interests of relevant countries in order to develop, negotiate, and collectively implement transboundary ABMTs. China's activity in the Arctic is a good example, where China started off with an interest to potentially expand fishing effort into Arctic waters as ice-cover shrunk, but ultimately saw geostrategic benefits in agreeing to a long term spatial moratorium of fishing. Knowledge of the geopolitical landscape is paramount.

Some participants wanted to control the scope of the "Research Needs" breakout group discussion, lest it get too unwieldy for the purpose of the workshop. They stated that there is a need for more social and economic experts, otherwise the focus should be on biology and ecology research needs. Participants had some disagreement on the scope of the discussion for "Research Needs".

However, some participants felt it was beneficial to focus not just on MPAs and biology, but that it is also important to include fishery behavior and how to collect that data. Reconciling "Research Needs" should have three prongs: biological information, fishery information, and how to collect the needed data.

Participants reinforced that ABMTs are not simply "on/off'" (closed vs. open to fishing) processes but provide many options for management. This opened range of topics within "Research Needs", particularly for island areas, including non-biological research needs; for example, understanding oceanographic dynamics that may drift FADs and fishing effort from one region to another.

It was considered important not to overlook the substantial amount of existing literature, but there is a need to summarize impacts ABMTs may have with respect to biology (e.g., reproductive responses and movement).

There were some comments on the intent of papers emerging from the workshop and the fundamental need to understand the contribution of the human element. It was commented that fishery managers do not manage fish or corals, they manage people. Even if the goal of ABMT implementation is conservation (i.e., preserving deep water corals, critical fish habitat, and/or juvenile fish), the only thing that managers may realistically change is the behavior of people. To better manage people, fishery managers need to understand them through research and understand what people are doing in a region that may impact the effectiveness of a proposed or existing management measure. There is a need to research fisher/stakeholder behavior, their motivations, and what tools would change their behavior (either voluntarily or enforced).

Continuation and Close of Plenary Main Session

Kitty Simonds, Executive Director of the Western Pacific Regional Fishery Management Council, briefly addressed the workshop and its motivations. The Council is at a management crossroad with respect to domestic and international measures. BBNJ and the Tuna Commissions are key components to future management of US fisheries under the Council's purview. The Council's fisheries are already subjected to spatial closures, many of which were not evaluated before or after their interventions. The workshop should address "best practices" to develop ABMTs so that, moving forward, ABMTs are implemented with consideration of costs and benefits rather than out of convenience.

Hilborn briefly discussed the development of a strawman paper that participants will common on in the following days. The paper will be six sections with 1,500 to 3,000 words per section.

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DAY 2 PLENARY, JUNE 16, 2020

Based on feedback from the participants and breakout session discussions, Hilborn identified objectives, performance metrics, and what kind of data is needed to inform them. This was circulated to the workshop participant in addition to tables summarizing evidence of ABMT feasibility relative to their respective objectives (note: this was revised and is available in the Day 3 Plenary section). Participants suggested that some management tools may be nested within another or perhaps share some commonalities.

Objective	Metric	How to Measure
Sustainable food production, local and global	Harvest, stock abundance, fishing mortality	Fisheries stock assessments
Employment, both local and global	Jobs	Economic surveys
Profit	Profit	Economic surveys
Communities and Culture	?	?
Reducing Bycatch and Non-Target Catches	By-catch of species, status of these species	Observers or EM, population studies of the species
Protecting Critical Habitats	Status relative to undisturbed	Surveys, models
Maintain Ecosystem Structure and Function	Trophic structure, size structure	Scientific studies
Resilience to Climate Change	?	?

Data and research needs will need to be identified to, at a minimum, achieve some of the objectives and estimate performance metrics used in ABMT evaluation.

A participant noted that sometimes straddling stocks that encompass multiple jurisdictions pose difficulties in achieving goals and objectives when area-based management interventions disproportionately impact one state or fleet. The participant also noted the importance of coordination across jurisdictions when spatial property rights have been allocated either at the EEZ level or at some smaller level. Hilborn agreed that coordination is key and noted that the Western Pacific fisheries are subjected to similar management issues through PNA countries within the WCPFC. Spatial property rights have been a hot topic in fisheries management, especially in the WCPFC.

Small Group Sessions

Rapporteurs reported on discussions of breakout sessions and on progress of text for an emerging document.

Breakout Group: Developing Science-Policy Forum

This section will integrate insights from Chapter 6 of preparatory paper and develop a short standalone document. This should highlight successful application of spatial management beyond “blunt” tool of MPAs. Policy Forum should be short version of main paper (2,000 words maximum; https://www.sciencemag.org/authors/science-information-authors).

Elevator Pitch

Issue: Biodiversity management beyond EEZs is a substantial problem to address. Spatial measures to protect biodiversity and spatial measures to regulate ocean uses must be harmonized for either to succeed. Here we examine the extent to which specific types of measures can deliver biodiversity outcomes and fishery (or other) outcomes to minimize conflicts with objectives of other legitimate authorities and interests.

Problem: The BBNJ is a policy process/context that requires scientific input on ABNJ.

To apply spatial tools to achieve both fishery and biodiversity outcomes, fishery and biodiversity (and deep-sea mining and shipping) databases will need to be federated so that other things (i.e., biodiversity or uses) that might be affected by a spatial measure applied by any single agency can be evaluated before the measure is finalized.

Solutions:

- BBNJ is unlikely to yield a new treaty focused specifically on biodiversity. Thus, biodiversity management will need to be addressed by disparate governing bodies.
- There are very strong win-win scenarios for achieving multiple goals (e.g., fisheries and biodiversity). Agostini asked what the policy contexts are that can make use of these data?
- The range of ABNJ options have relevance across these different governance contexts (e.g., deep sea mining, wind energy etc.) that traditionally do not manage biodiversity.
- The framing for the resultant paper is a table with biodiversity in the context of a range of different mandates/priorities.

Benefits: “Translating” this range of ABNJ options into relevant governance contexts provides a mechanism for effective management of biodiversity (in lieu of any new international treaty).

Summary**:** The policy angle is likely to be focused on the BBNJ, addressing the policy question of how area-based tools help can “unstick” sticking points in questions associated with biodiversity and conservation beyond national jurisdictions. In the absence of a new BBNJ-type treaty, there should be a push for new innovations in policies and technologies. For example, RFMOs and mining groups could reach a shared policy agenda to achieve a given set of objectives. The target audience is convincing BBNJ-style members that managers can think outside of the MPA and still (or perhaps better) achieve biodiversity outcomes, in addition to a treatment of ABMT and how they can contribute to biodiversity objectives. Spatial management tools have the ability to harmonize different objectives for sustainable use and conservation of biodiversity. There are tools that can do multiple things. One way to conceptualize this is to present different governance contexts that may have jurisdiction of biodiversity outside of EEZs (e.g., deep sea mining, energy, RFMO) and discuss how area based methods can harmonize these groups.

There is no legal framework to manage BBNJ. United Nations Convention on the Law of the Sea (UNCLOS) gives overarching concepts, and there are various treaties (e.g., seabed, transport, straddling fish stocks). Access to genetic resources was a big sticking point in BBNJ negotiations. Negotiations are to determine if tools to conserve biodiversity are to be implemented effectively by relevant legal instruments (i.e., RFMOs or International Seabed Authority, etc.) as part of the treaty or if it is the case that there needs to be another group that would use MPAs as the main tool. The treaty will not specify the answer to this. There are debates ongoing as to whether goals of managing biodiversity can be in line with fisheries.

Breakout Group: Objectives and Performance Metrics

Purpose

Discussion from this group reviewed the range of objectives and performance metrics that have been proposed for the conservation and management of pelagic ecosystems. Ideally (and rarely), national or international policies would explicitly specify the objectives of the policy or the problem it addresses and (even more rarely) what attributes could be measured to evaluate the success at achieving the objectives. Participants reviewed a range of published papers and documents associated with pelagic ecosystems and area-based management to summarize what objectives and performance metrics have been proposed. There are many threats to the ocean that include climate change, ocean acidification, plastic, oil spills, other pollutants, deep sea mining, coastal runoff, and unsustainable fishing. For the purpose of this review, participants focused specifically on objectives related to the impact of fishing, its impact on the pelagic ecosystems, and the interaction between fishing induced changes and ecosystem status and function.

Objectives

Spatial management of pelagic ecosystems can be used to achieve a wide range of objectives including biological, social, and economic. Objectives are often based on the desire to counter perceived threats to the marine system including seafloor mining, fishing, climate change, ocean acidification, micro plastics, seismic surveys, shipping, and geosequestration (CEA Consulting (editor) 2019). The breakout group’s review of objectives found that they can range from broad, such as to protect biodiversity, to specific, such as to increase the abundance of a specific stock. There are a number of traditional objectives of single species fisheries management, including providing sustainable catch, maximization of yield, maintaining size of fish, food security, or employment for specific communities, and profitability. These are the primary objectives of a large amount of existing area based management.

Gilman et al. (2019a) evaluated five specific objectives of Area-Based Fisheries Management MPAs:

1) Reduce or eliminate bycatch fishing mortality of pelagic species of conservation concern;
2) Reduce or eliminate fishing mortality at habitats that are important for critical life history stages of pelagic species;
3) Reduce the fishing mortality of target stocks to contribute to sustaining desired production levels (i.e., stay near target thresholds) and avoiding conditions where protracted or irreparable harm to the stock occurs (i.e., stay above limit thresholds);
4) Reduce fishing mortality of prey species of pelagic target stocks and species of conservation concern in order to stay near targets and above limits (i.e., Biodiversity Impact Mitigation Hierarchy); and

5) Reduce trait-based selective fishing mortality and fisheries-induced evolution (FIE).

Lester et al. (2009) in a large-scale meta-analysis of MPAs list objectives in reasonably vague terms such as "restoring and sustaining marine ecosystems within their boundaries. Lubchenco and Grorud-Colvert (2015) suggest objectives including "more species in greater numbers and larger sizes, a control to evaluate the impact of fishing." Partnership for Interdisciplinary Studies of Coastal Oceans (2002) in their brochure and video entitled "The Science of Marine Reserves" said "major purpose for establishing marine reserves is to protect the habitats and to restore animals and plants in particular sites." They further stated, "objectives of marine reserves are to restore and protect biodiversity and to enhance sustainable fisheries."

Some other area based management systems can be analyzed for their stated objectives. The North Pacific Fisheries Convention states "the objective of the Convention is to ensure the long-term conservation and sustainable use of the fisheries resources in the Convention Area while protecting the marine ecosystems of the North Pacific" (FAO 2019). FAO's web site on "sustainable fisheries management and biodiversity conservation of deep-sea living marine resources and ecosystems in the ABNJ" (FAO 2020) cites an objective of "reducing adverse impacts on VMEs [vulnerable marine ecosystems] and enhanced conservation and management components of EBSA [ecologically or biologically significant areas]."

This range of objectives can be summarized in the following categories:

1) Sustainable food production. This is the traditional goal of fisheries management and many area based approaches have been developed to achieve this through regulating catch and effort and protecting critical habitat. In the management of pelagic fisheries, there is often a major distinction between food production for local communities and export production. Additionally, zoning helps with allocation and conflict reduction.
2) Employment, both local and global. Pelagic fisheries provide employment, both small scale in coastal states and in the industrial fisheries.
3) Profit. Profit potentially accrues to the vessel operators and, in some cases, to coastal states who charge for access fees.
4) Communities and culture.
5) Reducing bycatch and non-target catches. Reducing impacts of pelagic fisheries on marine mammals, turtles, marine birds, and non-target species, such as sharks, is a major priority for pelagic fisheries management.
6) Protecting critical habitats. This is generally of low importance for pelagic fisheries with the exception of seamounts.
7) Maintain ecosystem structure and function. Pelagic fisheries dominantly affect high trophic level species such as tunas, billfish, and sharks. The overall trophic structure of pelagic ecosystems is largely unchanged except at trophic level 4 and above (Essington 2006). The Biodiversity Impact Mitigation Hierarchy is to avoid, reduce, mitigate, or compensate.
8) Resilience to climate change.
9) Perceived ease of enforcement.

Breakout Group: Design of Spatial Measures

The breakout group expressed that the new structure provided by Hilborn for this section in reviewing spatial management measures for pelagic blue-water fisheries is useful overall. The first three criteria (i.e., time/area closures, permanent closure, and real-time dynamic management) are broad spatial management approaches that can be either spatially static or mobile. However, the latter two categories (i.e., input/output controls and gear/method change) are a sample of common fisheries management measures and may not comprehensively cover all relevant management measures that enable spatial implementation.

Spatially-explicit thresholds (i.e., management “triggers”, such as a cap in the amount of fishery interactions with a species within a certain area) that require a change in gear or compensatory mitigation might be relevant to include. Thus, the group will conduct a systematic assessment of fisheries management measures to determine which categories should be included. There are certain examples that can fit within at least one the categories (e.g., ‘use strategic offal discards when seabirds are present’ fits in categories of temporally dynamic spatial management and gear/method change).

The topic of spatial access rights is a useful illustrative example of a spatial input control that should be “lumped” under this broader category, and not added as a new stand-alone, top-level category. The workshop participants intended to clarify the intent of spatial output controls. This could be interpreted as TACs for part of the distribution of a stock.

There are going to be many measures that have had no performance assessments, some of which lack explicit metrics for assessments of efficacy (e.g., most RFMO measures). This should be captured in the resultant table with the relative degree of evidence indicated.

A “low hanging fruit” research priority is to assess the degree of fishing-the-line in static MPAs and other static spatial management measures that restrict pelagic fishing as has been done for some very large MPAs (> 200,000 km^2) using automatic identification system (AIS) data.

Enforcement of spatial management measures can currently be achieved through various technologies, including vessel monitoring systems (VMS), AIS, electronic monitoring, and satellite buoys attached to FADs, etc. Compliance monitoring and surveillance is now much more readily feasible.

Some interesting examples of real time dynamic closures with promising results are voluntary industry self-policing/fleet communication.

The assessment of relative governance feasibility should be broken down by artisanal/small-scale vs. industrial, and rudimentary vs. robust fisheries management systems. All spatial management approaches are likely feasible now for governance with different or a subset of approaches feasible for small-scale fisheries and fisheries with weak management systems.

Increased transparency is a priority for effective fisheries management including through various spatial measures (e.g., for blue water fisheries). Pelagic longline fisheries in particular have extremely limited at-sea monitoring via conventional human observers and electronic monitoring.

It was noted that it is very important to retain a criterion for economic efficiency (i.e., profit/employment, etc.). This and other social and economic objectives need more attention.

There might be a way for spatial management measures to contribute to addressing human welfare issues in capture fisheries. Does fishing within national jurisdictional waters augment surveillance of human rights compliance vs. fishing in high seas? (see new FisheryProgress.org social policy for ideas).

Breakout Group: Evidence and Research

The breakout group was tasked to identify research and data needed to support empirical evidence and performance evaluation of area based fishery management measures (ABFMs) with respect to objectives, per the table below. +/- indicate the level of empirical evidence to support implementation of each measure.

	ABFM Measure				
Objective	Time-Area Closures	Adaptive Real-Time Closures	Permanent Closures	Input/Output Controls	Gear and fishing method changes
Sustainable food production, local and global	+		+ or -	+++	+
Employment, both local and global	perhaps remove as area based management is not key driver?				
Profit	perhaps remove as area based management is not key driver?				
Communities and Culture					
Reducing Bycatch and Non-Target Catches	++	+++	+	++	+++
Protecting Critical Habitats			+++	+	+++
Maintain Ecosystem Structure and Function			+	+	
Resilience to Climate Change			?	++	

The breakout group found it difficult to identify research specific to each cross-referenced area-based fishery management measure and objective. The group lacked expertise on social and economic topics to identify many of the non-biological data and research needs. Members were moved to other breakout groups but were asked to keep in mind research and data gaps that may coincide with discussions.

Breakout Group: "Moving Forward" with ABMT

This section is independent from other components of an emerging document and is focused about drivers of the future. The goal of this section would be to try to get ahead of what may unfold with respect to ocean governance issues.

There is an increasing need for food production that will require a sliding scale when it comes to managing the oceans, which is role greater than MPAs and any conservation goals alone.

To what extent are MPAs a second best solution in the absence of better options? Proponents may propose MPAs because they do not trust the RFMOs can deliver on a management measure. Between the consumer and the technology angle, tools are available for the consumers. There are views that spatial management and input controls are imprecise measures that can be replaced by AIS and camera tracking. Therefore, how does the choice for an MPA change based on new technology or geopolitical issues?

Four drivers of change and their interactions were identified:

a) Environmental changes (e.g., shifting distributions, protected species interactions – winners and losers);
b) Shifting markets (e.g., consumer demand and trust, value chains making sourcing decisions, corporate stewardship, climate change financial disclosures – to be part of a stock market);
c) Changing actors (e.g., geopolitical strengthening or weakening); and
d) Improving technology (e.g., AIS and electronic monitoring to improve compliance)

There is a call for research needs to improve fishery management adaptive capacity to deal with the dynamic nature of blue water systems and consider area-based management in the context of a management that aims to keep the system in adaptive space and away from maladaptive space.

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DAY 3 PLENARY, JUNE 17, 2020

Review of Emerging Document from Workshop

Introduction

Lead: Mark Fitchett, 1,000 words.

Blue water fisheries are those that mostly take place beyond continental shelves and are dominated by fisheries for large pelagic fishes, primarily tuna and billfish, excluding benthic species. These occur both in national waters and those beyond.

Some examples of area-based management and current high level policy issues include those associated with ABNJ, CBD, and large ocean MPA activities. ABMTs can often be "insurance" against uncertainty in fisheries management.

This paper will focus on the following area-based management measures:

1) Space time closures of fishing, static and dynamic.
2) Allocation of quotas or fishing effort.
3) Spatial implementation of gear or fishing method modification.

The paper recognizes that there are multiple objectives in the management of fisheries and that there are trade-offs between these objectives. The group will review objectives and performance metrics, alternative approaches to spatial management, what is known and what is not known about the efficacy and impact of these measures on performance, the approaches and limitation for evaluation of impacts, and the research needs to better predict and evaluate the consequences of alternative approaches.

The aim is to provide both a summary of what is known and the gaps in knowledge to support planning of future area based management.

Support: Vera Agostini, Serge Garcia, Rishi Sharma, Tim Essington, Leah Gerber, Quentin Hanich.

Objectives and Performance Metrics for Area-Based Management in Blue Water Ecosystems

Lead: Ray Hilborn, 2,000 words.

a) Sustainable food production, local and global (clarify food security as an overarching goal and their implications in multiple objectives)
b) Employment, both local and global
c) Economic health and welfare
d) Communities and culture
e) Protect endangered, threatened, and protected species and reduce interaction with non-target species
f) Protecting specific habitats
g) Maintaining ecosystem structure and function
h) Resilience to climate change and other stressors

Support: Nathan Taylor, Hilario Murua, Don Kobayashi, Serge Garcia, Leah Gerber.

Spatial Management Measure for Blue Water Fisheries

Lead: Eric Gilman and Michel Kaiser, 2,000 words

Discussion was held on static vs. dynamic and temporal vs. permanent measures.

Measures such as:

a) Time-area closures;
b) Adaptive real-time closures, dynamic ocean management;
c) Permanent closures;
d) Input/output controls;
e) Gear and fishing method changes; and
f) Access and tenure rights.

Support: Victor Restrepo, Alistair Hobday, Quentin Hanich, Nathan Taylor, Sarah Lester, Graham Piling, Serge Garcia

Review of Evidence that Objectives Met by Spatial Management Measures/Needs

Lead: Eric Gilman, 3,000 words

In addition to what was provided in the preparatory paper and workshop discussion:

a) Knowledge gaps related to each crossroads of objective and measure;
b) Traditional knowledge, such as in national jurisdictions;
c) Research needs to generate empirical evidence for each application of ABMT for a given objective; and
d) Access rights and tenure.

Permanent closures tend to be much less expensive, except in protecting critical habitat since detailed mapping of the critical habitats is required. Adaptive management measures are difficult to implement but empirical evidence to date shows that they have good efficacy.

The bulk of this section (which is the longest in the paper) is a text summary of what methods have been shown to work to achieve various objectives, with one subsection for each objective. It will highlight research needs and costs and comment on successful implementation.

The centerpiece would be a table comparing the objectives and spatial management measures.

Support: Mark Fitchett, Amber Himes-Cornell, Dan Ovando, Craig Severance, Hilario Murua, David Itano, Graham Piling.

Objectives Emerging from Discussion

ABMT Type	Sustainable harvest	Employment	Profit	Communities, Culture, and Equity	Endangered, Threatened, and Protected Species	Protecting Habitats	Maintain Ecosystem Structure and Function	Resilience to Climate Change and other stressors
Time-Area Closures	+	+ or -			++			
Adaptive Real-Time Closures					+++			
Permanent Closures	+ or -	+ or -			+	+++	+	?
Input/Output Controls	+++	+ or -			++	+	+	++
Area Based Access and Tenure Rights								
Gear and fishing method changes	+	+ or -			+++	+++		

The "+" and "-" indicate the amount of empirical evidence to support evaluation of the respective ABMT. Red indicates the most difficult/costly to implement. Green indicates the easiest/inexpensive (in terms of management resources).

Review of Methods to Evaluate and Monitor Area-Based Management Measures

Lead: Milani Chaloupka, 2,000 words.

Generalize the following:

a) Cost-benefit analyses, comparative analyses;
b) Ranking on quality with respect to objectives;
c) Instrumental variables;
d) Interrupted time series;
e) Regression discontinuity;
f) Matching methods;
g) Difference in differences (e.g., BACI); and
h) Synthetic Controls.

Support: Alistair Hobday, Rishi Sharma, Mark Fitchett, Dan Ovando.

Moving Forward in Implementation of Area-Based Management Planning

Lead: Amber Himes-Cornell, 2,000 words.

Authors for other sections need to contribute directly on this, providing points on how to implement and move forward.

1. On the horizon: Refer to the Post 2020 Biodiversity Framework, the SDG 14, and the key conclusions of the FAO Symposium.
2. In pelagic ecosystem and fisheries:
    a. Strength: International agency and RFMOs data, research and management infrastructure. Increasing ocean data availability. Existing States commitments at FAO, CBD, United Nations.
    b. Weaknesses/challenges: incomplete mandates of RFMOs (on associated and dependent species and habitats); weak enforcement (Flag States duties); legal loopholes (cumbersome international legal systems). wide ocean. Species widely spread or highly migratory; difficult compliance. Costly research. International cooperation.
    c. Opportunities: big data (if databases federalized; inter-operable); scientific advances (end to end modelling, decision rules, MSE); satellite imagery; Vessel Monitoring Systems (Radar, AIS), artificial intelligence, deep learning (automatic surveillance).
    d. Threats: Increasing demand for food; Rush for the last ocean frontier. Competition for Space and resources. Climate change; Organized crime; Weak national governance systems.
3. The increased role of ABFMs: Complement other non-spatial management measures to (1) improve the protection of essential pelagic habitats; (2) reduce collateral impact on dependent and associated species.
4. The way forward on ABFMs (Action required):
    a. Strengthen the spatial foundations of fisheries management. Mapping of fishing activities, fishery resources, biodiversity hotspots, essential areas/habitats;
    b. Available information on EBSAs, Key biodiversity areas, etc.;
    c. Federate databases across RFMOs, at least at ocean level (needed?);

d. Systematically assess performance of existing ABFMs for fisheries sustainability and biodiversity conservation. Consider improving performance (e.g., look for other effective area-based conservation measures (OECMs)).

The discussion and conclusions would have paragraphs/sections on each of the following: a) Discussion of technical advances and the ability to monitor, enforce the Convention on the Conservation of Migratory Species, put in practice ABMT; b) Implications for ABNJ/BBNJ discussions (including issues of interference with competency of RFMOs), CBD OECMs, SDGs, and post 2020 goals; c) Consider ABFM including concept having coastal marine management dealing with stocks, not just entire regional management areas.

Support: Quentin Hanich, Serge Garcia, Nathan Taylor, Alistair Hobday.

Lessons Learned from Workshop

A summary of what we know about the use of ABMTs in blue water ecosystems and the next steps for the global community in use of ABMT in meeting management objectives is provided in a table below. These are emerging from the workshop's plenary and preparatory papers and to be incorporated in a manuscript to *Fish and Fisheries* (Hilborn et al., *in preparation*)

Fisheries Management Objective	**What we know**	**Next Steps in Management**
Maintain and enhance sustainable food production.	Area-based catch and effort restrictions have largely worked to maintain stocks in productive condition. Static pelagic closed area ABMTs would need to cover extremely large areas to significantly reduce the risk of capture of an individual pelagic fish throughout its lifetime (Botsford, 2003;Le Quesne, 2009 ;Gruss, 2011; Dueri, 2013) and spatial redistribution of fishing effort may negate perceived benefits (Martin et al., 2011; Kaplan et al., 2014). Theoretical analyses indicate that there will likely be no regional stock-level benefits for stocks that are not overexploited (Le Quesne, 2009), which is the case for most target pelagic species as well as for prey of pelagic predators (Olson, 2003; Le Borgne, 2011; ISSF, 2018).	• Catch reductions for species that are currently overfished. • Improve compliance and monitoring by management agencies, aided by emerging technologies • Elimination of IUU fishing • Monitoring impacts of selective exploitation throughout species' ranges.
Protection of non-target species (endangered, threatened or protected species (ETP))	The major successes have been accomplished by gear and fishing method modification. Where there are fixed breeding sites, seasonal closed areas may be most effective. Concentration around important feeding sites would likely be best managed through dynamic closures around temporary oceanic features. .	• Broad implementation of key technologies shown to reduce bycatch • Analysis of the potential of ABMT to contribute to bycatch reduction, particularly dynamic management options • Expedite regulatory response time to adaptive management

Fisheries Management Objective	What we know	Next Steps in Management
Protect critical habitats	This is generally not a significant issue with benthos in blue water systems. The benthic communities of concern are typically seamounts. Closure of sensitive bottom habitat to bottom contact gear has been shown to be effective.	• More mapping of benthic systems of concern in blue water ecosystems. • Closure of sensitive benthic habitats • Better understanding if there are critical pelagic habitats (e.g., pelagic spawning or feeding grounds) that could use some form of protection
Maintain ecosystem structure and function	Overall trophic structure of pelagic systems is largely intact and the main impact of fishing is on the highest trophic levels. There is no evidence that the structure and function of the blue water systems is significantly modified by fishing	• No clear ABMT action is thought to benefit maintaining ecosystem structure and function
Increase ecosystem resilience to climate change	Pelagic habitats such as feeding and spawning areas are shifting in space with climate change. It isn't clear how ABMT would contribute to this. .	• Where various forms of management are appropriate for specific habitats, those need to change adaptively
Provide employment (both local and global)	Mostly results from allocation of tenure and access rights and governance.	• Employment issues are very fishery and fleet specific and no general policy guidance can be given.

Fisheries Management Objective	What we know	Next Steps in Management
Facilitate economic benefits	Substantial economic benefits result from commercial tuna and tuna-like species fisheries in blue water ecosystems. Zone-based management of tuna fisheries (e.g., WCPFC vessel day schemes) are used to generate revenues for coastal states from distant water fishery access fees .	• If management agencies have specific objectives re where benefits occur management actions can be taken to direct those benefits • Ensure facilitation of economic benefits do not impede sustainability objectives
Support Communities and Culture	Fishing communities and cultures in many parts of the world depend on fisheries prosecuted in blue water ecosystems for food security, livelihoods, traditions and cultural activities. There is very little information on how management actions impact communities.	• Ensure reduction in defined disproportionate burden to coastal states

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