MPAS AS A TOOL FOR ADDRESSING THE COLLATERAL IMPACTS OF FISHING GEARS

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SUMMARY
An often overlooked aspect of fisheries management is the collateral impact of fishing- bycatch and habitat damage. Discussions concerning the role of marine protected areas (MPAs) and fisheries management have focused on recovering depleted fish stocks through adult immigration or larval dispersal, but relatively little discussion has focused on the use of closed areas to address collateral impacts. Zoning MPAs for specific fishing gears can be an important option for protecting seafloor habitats or areas where vulnerable species are at risk. Here we present the results of a process to address and rank the collateral impacts of fishing based on the “damage schedule approach”. Our approach integrates scientific and fishers’ knowledge in ranking gear impacts. Based on a review of literature and their own experiences, a panel of fishers, managers, and scientists reviewed impacts of ten commercial fishing gears in the US. These results were summarized and incorporated into a survey that was distributed to managers, fishers, scientists, and conservationists. These professionals were asked to consider the suite of collateral impacts of various gears in paired comparisons, each time choosing which set of impacts they considered ecologically most severe. Contrary to general expectations, the results of this survey show remarkable consensus among the different groups, which consistently ranked impacts associated with bottom trawls, gillnets and dredges as the most severe. We use this gear ranking to propose a MPA zoning scheme to address the collateral impacts of fishing gears.

1. INTRODUCTION

Traditionally, fisheries managers have focused on maintaining catch levels for the commercially valuable species. Incidental impacts such as bycatch and habitat damage are not of primary concern unless they impact other commercial species. Alternatively, managers of marine parks and recreational areas, on the basis of their different and broader responsibilities and mandates, are focused on maintaining a more holistic approach, looking to manage for ecosystem integrity and protection and to provide services mainly to recreational users. As a consequence of differing mandates for fisheries managers and park managers, conflicts may arise in discussions over common jurisdictions and species. Here we place fishing gears in an ecological context for park managers with the goal of greater cohesiveness of management discussion between park and fishery managers in future discussions of multiple use zoning and marine protected areas.

Marine protected areas are proposed as a management tool to limit adverse impacts of human activities. Proposals range from fully-protected, no-take reserves, (no extractive or harmful human activities permitted including oil and gas development, fishing and its collateral impacts, bycatch and habitat damage, dredge disposal, pollution, etc.), to MPAs that only regulate very specific activities sometimes for very short periods of times (e.g., seasonal closures for one fishery). The range of activities that are restricted in MPAs is quite large, and quite maddening to those attempting to classify different types of MPAs.

Fishing continues to be a human activity that has a great influence on marine ecosystems (1,2,3) and one that can be successfully managed through spatial closures (4,5). Conventional fisheries management addresses a range of issues including setting catch limits, maintaining or rebuilding stock levels, limiting overfishing, avoiding gear sector conflicts, and allocating catch. Today, however, they are also charged with protecting endangered species, reducing bycatch, and limiting habitat damage, all components of ecosystem based management. This change comes with the understanding that altering food webs by removing keystone predators or crucial forage species, or affecting fish habitat by removing structure-forming, suspension feeding species on the seafloor, can result in unwelcome changes in marine ecosystems (6). These are outcomes of fishing that stock assessment-based fishery management cannot possibly predict because it deals with fish populations one-by-one, as if each fish population and fishery exists in isolation, but scientists have known the flaws inherent in this approach for decades (7,8).

Despite existing calls for a management shift (e.g., 9,10,11), we are calling for a management shift, refocusing on protecting and rebuilding ecosystems, including species and habitats, rather than the traditional focus of rebuilding fish stocks one-by-one. As yet ecosystem-based management has not been implemented to any meaningful degree. Part of this is the insufficient recognition that the gears we use to fish affects a wide range of species—not only those species we target, but also the young of targeted species, other species that are also commercially fished, and many other ecosystem components such as ecosystem engineers (e.g., tilefish, 12) —as well as the geological and biological components of the seafloor that comprise the habitat for most commercially fished species. Therefore, a central consideration in marine ecosystem management is not just how many fish we catch, but how we fish. Managing the collateral effects of gears is part of why a broad range of MPA approaches is necessary to developing an effective framework for sustainable resource management, safeguarding ecosystem function, protecting biodiversity and alleviating multiple uses of resources and space while minimizing conflict. This is one aspect of ecosystem management that must be addressed.

1.1 Collateral Impacts of Fishing

A key stumbling block for assessing collateral damage is the absence of ways to compare fisheries. It is not difficult to measure fisheries in tons or dollars. But what would a thoughtful fishery manager consider more harmful: a gear class that kills large numbers of juvenile fishes before they are marketable, that kills many uncommon seabirds, that uproots whole forests of corals, or that disturbs large areas of crucial nursery habitat for post-settlement fishes? Finding a way to compare the various bycatch and habitat effects of different gears is difficult. But such comparisons are crucial because different gears are often used to catch the same target species in the same place, and fishery managers need ways to decide which gears have acceptable or unacceptable impacts.

Because understanding and limiting this collateral damage is essential to any kind of marine protected area management, this report addresses ecological impacts of different types of fishing gear that are used in US commercial fisheries. While many studies have addressed some aspect of bycatch or habitat impact, and a small number of reports have looked broadly at either one or the other, this report is the first to consider these impacts together across all major kinds of commercial fishing gear types used in the US.

1.2 Bycatch and Habitat Damage

Bycatch and habitat damage reduce the value of marine ecosystems through direct economic losses to fisheries, and harm to ecosystem integrity. The extent of these losses can be determined in different ways: by quantification of lost monetary value due to changes in productivity or removal of species with monetary value, or by non-monetary measures of social well-being related to the resource (e.g., enjoyment of the act of fishing). Because we are still in our scientific infancy in determining the effects of fishing on ecosystems (13) and it is exceedingly difficult—if not impossible—to place a monetary value on marine ecosystems (although marine biodiversity collectively is extremely valuable to humankind, accounting for over 60% of the economic value of the biosphere, 14). This report uses a non-monetary valuation approach, the "damage schedule," to assess the consequences of fishing in terms of bycatch and habitat damage (15,16).

Every year US fisheries discard vast numbers of fishes, 1,360,777 MT (150,000 tons) discarded by one estimate (17), marine mammals, seabirds, sea turtles and invertebrates that were caught unintentionally during the pursuit of desired (marketable) species. Bycatch is defined as the portion of retained catch that is discarded at sea dead (or injured to an extent that death is the most likely outcome) because it has little or no economic value or because retention is prohibited by law (18). Target bycatch refers to the individual organisms that belong to the target species of the fishery, but are unmarketable because of their size, condition, sex, age or any other reason. Non-target bycatch refers to all other species that do not belong to the targeted fishery. Additional sources of bycatch mortality are collateral mortality (i.e., fish killed by the gear but not caught in the gear) and lost-gear mortality (i.e., mortality caused by gear lost in the sea, also known as ghost fishing), effects that are even more difficult to access. Many factors can influence the severity of bycatch, such as whether the species is geographically concentrated or diffuse, seasonally or continuously found on fishing grounds, has a predictable distribution and behavior, is rare or abundant, or is associated with the target species or not as well as the behavior of the fisher (18).

Commercial fishing gears also have impacts on benthic (seafloor) habitats, resulting in changes to the physical structure and species composition of the ecosystem (19,20,21,22,23). Fishing gears that contact the seafloor disturb geologic and biological structures. On soft areas of the ocean bottom, these gears plane off structures, and can upset the nutrient content and organisms in sediments, especially in areas that are rarely disturbed naturally. In more complex habitats, the gears can destroy organisms like sponges and corals, displace boulders, and harm bottom-dwelling organisms by crushing them, burying them, or exposing them to predators. The benthic animals most sensitive to fishing gears are those that are erect and fragile, long-lived and slow-growing, or living in waters where severe natural disturbances are less common, particularly below a depth of 350 feet (100 meters). The habitat damage caused by a particular gear also depends on its footprint—that is, whether the gear is towed across the bottom and causes linear disturbances or contacts the bottom only at restricted points. Type of habitat, duration of contact, and type, width, weight, and number of units employed all determine the extent of adverse effects.

Seafloor communities support an extraordinary diversity of life and much of the sea's productivity. Of the more than 235,000 animal species known to live in the ocean, more than 98 percent are found in or on the ocean floor during at least one life-history stage (24). Many major marine species groups are exclusively or almost exclusively benthic as adults. These include sponges, corals, annelid worms, clams, oysters, sea slugs, shrimps, lobsters, crabs, sea stars, rockfishes, and other perch-like fishes.

Another factor that can amplify habitat damage, bycatch, or both is the loss of fishing gear, which can lead to ghost-fishing. This occurs when lost gear continues to disturb the seafloor or catch organisms even though fishers are no longer able to recover the catch. Because lost pelagic and midwater gear gradually gets heavier from encrusting organisms and dying animals, it eventually sinks, and can damage the seafloor. Lost gear adds to the collateral impacts caused when it was in use.

Fishing is not one discrete activity. Different gears result in very different levels of ecological impacts, thus it makes good sense that MPAs that are looking to meet different management and use objectives look at the impacts of different fishing methods. Difficulty arises because there is no consistent means for quantifying gear impacts. Not all management goals can be obtained by simply restricting fishing, and realities suggest that large closures to fishing maybe politically unrealistic even when goals suggest that restricting a certain type of gear might lead to successful management outcomes. But understanding the relative severity of the damage caused by different gear types can help in creating MPAs by zoning multiple use areas to achieve both fishery and conservation goals. Here we apply the results of a recent study (25) that examined the ecological impacts of fishing, in order to delineate options for managers that address the issue of zoning fishing activities in an ecologically consistent manner.

We describe the process employed to assess and compare impacts of ten selected commercial fishing gear classes commonly used in the USA, i.e., dredges, bottom gillnets, midwater gillnets, hook and line, bottom longlines, pelagic longlines, pots and traps, purse seines, bottom trawls and midwater trawls. We conclude with the severity ranking of these gears that resulted from the study and suggest a set of appropriate policy responses in relationship to multiple use MPA zoning.

2. METHODOLOGY

We first conducted a comprehensive literature review to obtain information about bycatch and habitat damage associated with ten fishing gears. This information was used at an expert workshop to determine what is currently known about bycatch and habitat damage associated with different fishing gears. The workshop participants rated the effects of the ten gear classes on five categories of bycatch: (1) shellfish and crabs, (2) finfish, (3) sharks, (4) marine mammals, (5) seabirds and sea turtles; and two categories of habitat damage (6) physical structure and (7) seafloor organisms. These impact ratings were then used to generate 'impact scenarios' presented as a paired comparison questionnaire to a group of respondents, also comprising fishers, managers, scientists and other marine professionals.

The method of paired comparisons is an appropriate tool to elicit individual's judgments about complex issues by simplifying them as binary choices. Several applications of the methods suggest its applicability in decision-makings related to various settings, such as in the selection of potential sites for noxious facilities (26); in the comparison of values of public and private goods (27); in the preference for fisheries ecosystems (28); and in the importance of marine reserves (29). Using the results from this workshop and following the 'damage schedule' approach developed by Chuenpagdee et al. (15,16), we used a paired comparison survey method to elicit the knowledge and judgments of additional experts in these groups regarding the severity of ecologic impacts.

We use the method of paired comparisons because it elicits individual's judgments about complex issues by presenting them as binary choices. Such presentation simplifies and follows closely natural thought processes people use to make decisions on a daily basis (26). The basic model for the paired comparison method involves all possible pair combinations for the objects, with total number of pairs (N) equals n (n-1) / 2, where n is the number of objects (30). When pairs are presented to a sample of respondents, it is assumed that each object has the same possibility of being selected because all are paired an equal number of times. For example, when paired comparison involves four objects (n), the total number of pairs for comparison (N) equals 6, and each object is paired three times.

The questionnaire contained a series of pairs of collateral impact scenarios. For each pair, we presented respondents with a series of these pairs, and for each pair, they were asked to choose the impact scenario that they considered ecologically more severe. Responses from the paired comparison survey were analyzed using Dunn-Rankin's variance stable rank sum method, where impact scores, indicated by selected choices, were calculated. These scores were then normalized to the scale of 0 (least severe) to 100 (most severe), yielding as a final result, an interval scale of relative severity of collateral impacts.

Three groups of respondents were selected for the study because of their knowledge about fisheries in the US. Surveys were mailed out to randomly selected potential participants chosen from three groups of people knowledgeable about fisheries, i.e., (1) voting members of the eight fishery management councils (FMC), (2) scientists and experts serving on the National Research Council's (NRC) Ocean Studies Board, and (3) fishery specialists of marine-related conservation organizations. In total, 70 people responded to the survey, including 22 respondents were from NRC Ocean Studies Board and 24 from the other two groups, for an overall response rate of 53 percent. The majority of the respondents (about 40%) identified themselves as biologists or scientists. Seventeen percent were fisheries managers, 16 percent were university professors, 13 percent were fishers and other people in fisheries-related activities, and the rest were people in other occupations (Table 1). Roughly 64 percent of the respondents had knowledge and expertise specific to a particular FMC region, while the rest were considered knowledgeable about the US fisheries and fishing gears in general. Of the total respondents, 58 percent indicated that they had experience onboard a commercial fishing vessel.

Table 1. Regional and occupational breakdown of respondents to ecological impact survey

	Occupation					
U.S. Region	Fisheries related	Fisheries managers	Professor	Biologist/Scientists	Others	Total
New England	1			1	3	5
Mid-Atlantic	1	2		1	2	6
South Atlantic	2			1	4	7
Caribbean	1			1		2
Gulf of Mexico	1			3	1	5
Western Pacific	3			2	3	8
Pacific		5		4		9
North Pacific			2	1		3
National			9	13	3	25
Total	9	7	11	27	16	70
% Total	13	10	16	39	23	100

3. RESULTS

Our analysis of the judgments of these three expert groups show that collateral impacts caused by gears such as bottom trawls, bottom gillnets, dredges, and midwater gillnets are considered high. These gears should therefore be managed using very stringent policies such as a complete prohibition of use in ecologically sensitive areas, and restriction to discretely defined areas. The level of bycatch and habitat impacts associated with pots and traps, pelagic and bottom longlines are moderate, suggesting policies that are rigorous, but less urgent than the previous set of gears. Management should include mandatory modifications of gears such as use of bird-scaring lines in longline fisheries. Finally, management of gears causing relatively low impacts, such as midwater trawls, purse seines and hook and line, requires relatively less stringent policies and would merit lower priority. Regardless of the gear, where impacts occur to threatened or endangered species or sensitive habitats, their management should be considered high priority. The severity ranking of fishing gears suggests policies that encourage shifting from high-impact gears to low-impact gears.

An analysis of the data using Dunn-Rankin's variance stable rank sum method was performed on the aggregated impact scores of individual respondents in each group. Numerical ranks were assigned to these scores such that '1' referred to most severe and '8' referred to least severe. Kendall's Tau rank correlation coefficient analysis was employed to test significant difference between rankings obtained from the three respondent groups. The results show strong agreement (at alpha level 0.01), in the ranking of collateral impacts by all respondents. Based on this analysis, we aggregated all impact scores onto one relative scale, which was then used to formulate three categories of multiple-use zoning in MPAs.

It is important to note that we examined only the collateral impacts of fishing gears. Virtually any gear can be used in ways that overfish target species. For example, Atlantic gray whales were eliminated by harpooning, a gear type that has virtually no collateral impacts. Precautionary measures and judicious restraint must therefore be practiced to avoid overexploitation even using "less-damaging" gears." Moreover, it is worth noting that the severity ranking developed in this study is based on current knowledge of habitat and bycatch impacts of fishing gears. As understanding of these gears and the effects of their operation increases we might recognize that some gears cause lower or higher impacts than originally considered. Further, our analysis did not account for the magnitude of operations by these gears in a particular fishery. For example, midwater trawl for Bering Sea pollock is one of the largest fisheries in the US and the world. While per-unit impacts of midwater trawls are low compared to other gears, with the magnitude of this fishery is a major cause of concern. Moreover, recent studies (31,32) suggests significant seafloor disturbance and bycatch of benthic species such as red king crabs and snow crabs result from so-called “midwater trawling” in the Bering Sea pollock trawl fishery. In the case of Bering sea pollock, mid-water trawl is a misnomer and this fishery should be managed as if it were a bottom trawl fishery. In this and other cases, management policies should err on the side of caution, putting healthy ocean ecosystems and resources first.

It is also important to note that local conflicts of fishing gears and species and habitats may at times override the more general ranking provided here. For instance, near sea turtle nesting beaches it may never be appropriate to use longline gear even though it may be appropriate in buffer areas where sea turtles are not common. For any region, a set of fishery-specific gears can be graded without a need to reconstruct a new scale. First, a small group of knowledgeable people can provide consensus ratings of collateral impacts associated with these gears, using a workshop setting as done in this study. The next step is to match these impact ratings of fishing gears with the ten gears provided in Figure 2. For example, if impact ratings of a certain gear in a particular fishery are medium (3) for physical and biological habitats, medium (3) for shellfish and crabs bycatch, high (4) for finfish bycatch, and low (2) for shark, marine mammal and seabird and sea turtle bycatch, their impact ratings will fall in the medium impact category, and thus should be managed with moderately stringent policies.

4. FISHING GEAR IMPACTS IN A MULTIPLE-USE MANAGEMENT CONTEXT

We apply the results of the relative ranking of ecological severity for different methods of fishing to the discussion of MPAs as a management tool. Note that while many papers discuss the larger societal aspects involved in MPA planning, this approach focuses solely on the ecological impacts of fishing and thus reflects a very restrictive scope with regard to the larger MPA management debate.

The results of the analysis resulted in three levels of fishing gear impact (Figure 1.) These impacts can be incorporated into multiple–use MPA planning and other established core-buffer planning strategies (e.g., Wildlands Strategy, Great Barrier Reef Marine Park Authority). In our proposal core areas would be fully protected from all fishing as well as other extractive activities. The first tier of buffers would allow fishing gears with the least severe environmental impacts – hook and line methods, and gears that do not contact the seafloor such as purse seines and midwater trawls. A second buffer tier would allow for moderately damaging gears such as pots and traps and longlines. Rather than propose a 3rd type of buffer for the other, most damaging, gears, we suggest that these not be used in MPAs. Where it is not feasible to ban these gears then their inclusion should be limited to areas that are best able to recover from impacts (shallow, soft bottom areas, 23). There should also be strictly defined use areas for these gears, such as trawl boxes.

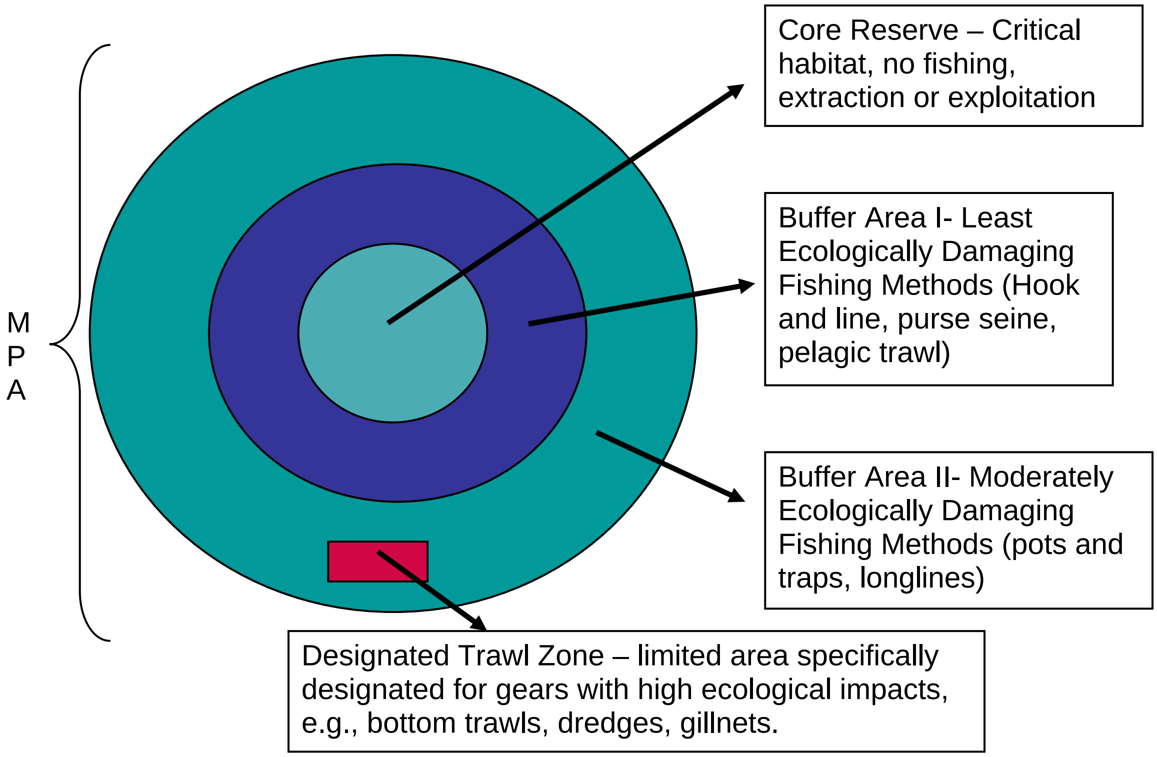
Figure 1. Ecological Ratings and Ranking of Commercial Fishing Gears and Proposed MPA Management Options

	HABITAT IMPACTS		BYCATCH					PROPOSED MANAGEMENT
GEAR CLASS	Physical	Biological	Shellfish & Crabs	Finfish	Sharks	Marine mammals	Seabirds & turtles	MPA Zoning Scheme (Policy responses)
Trawls – bottom	5	5	3	5	2	2	2	Highly Restricted (Very Stringent)
Gillnets – bottom	3	2	1	4	3	4	3	
Dredges	5	5	4	2	1	1	1	
Gillnets – midwater	1	1	1	4	4	5	5	
Pots and traps	3	2	4	2	1	3	1	Buffer II Restricted (Moderately Stringent)
Longlines – pelagic	1	1	1	3	4	3	5	
Longlines – bottom	2	2	1	4	3	1	2	
Trawls – midwater	1	1	1	3	2	2	2	Buffer I Restricted (Least Stringent)
Purse seines	1	1	1	2	2	3	2	
Hook and line	1	1	1	2	3	1	2	

Alternative scenarios could also be envisioned based on the gear ranking outlined here. For instance, all mobile benthic fishing gears could be excluded from certain areas. Buffer areas could allow for set gear, and mobile gears which do not contact the seafloor. This arrangement again should be implemented with a precautionary approach and gears only allowed where knowledge of the habitat impacts and species to be managed are well understood.

We propose multiple-use MPA zoning as one means by which to address the ecological impacts of commercial fishing. We have not included recreational fishing in this discussion, but limits on recreational fishing are necessary given the vast number of fishermen that visit coastal waters. MPA managers should welcome the broad-based agreement on fishing gear impacts discussed here, and work towards greater implication of gear restrictions in the context of site-specific MPA goals and objectives.

Fig 2. Conceptual MPA with Zoning Scheme for Fishing Gear Impacts



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