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Trawl fisheries, catch shares and the protection of benthic marine ecosystems: Has ownership generated incentives for seafloor stewardship?

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ABSTRACT

Proponents of catch share-based fisheries have claimed ecological stewardship can result from the assignment of individual catch quotas. This claim is examined by analyzing the distribution of benthic habitat protection measures adopted by quota-owning industry sectors within the exclusive economic zones (EEZs) of the U.S. (Alaska), New Zealand, and high seas seamounts within the Southern Indian Ocean Deepsea Fishers Association (SIODFA) competence area. Results suggest the protection of both benthic ecosystems and essential fish habitat (EFH) are marginal at best when quota owners have primacy in determining the boundaries of bottom trawl closures. The majority of the areas in these three regions that are closed to trawling are too deep to fish, may not contain vulnerable marine ecosystems, and do not have high abundances of commercially important species. "Freezing the footprint" of bottom trawling is not the best method for benthic habitat protection in areas where the fishing industry is actively fishing vulnerable habitats. Analytical methods should be applied to help determine boundaries of future bottom trawl closures rather than allowing the fishing industry to place benthic protection areas (BPAs) in areas where they are not interested in fishing.

1. Introduction

Market-based instruments are controversial means of managing natural resources, especially in the oceans. Because marine resources are owned by the public under most legal systems, the notion of giving any industry exclusive and perpetual rights to them is anathema, whether the resources are non-living and non-renewable, such as oil and natural gas, or living and renewable, such as fisheries. After the United Nations Law of the Sea Convention endorsed the extension of exclusive economic zones to 200 miles offshore, many industrial fishing fleets were over-capitalized and fish stocks overfished. This was largely due to government subsidies, economic globalization, and the continued free nature of the resource base. Because overcapitalization persists, some policy analysts have advocated fisheries rationalization, the widespread adoption of market-based instruments such as individual transferable quotas (ITQs), the distribution of which can reduce fleets to a more efficient size [1,2]. But others have questioned the wisdom of such measures given their permanence, the expense of their administration, and the social and economic changes that can result [3,4]. In the era of ecosystem-based marine governance, one impact of particular concern is the enhanced ability of quota-owning fishing interests to determine the spatial extent of their fisheries and override the interests of non-owner stakeholders [5].

In some countries, frustration with the fishing industry's resistance to implementing sustainable fishing methods and catch rates and the lack of political will to establish meaningful caps on fishing has led some former catch-share skeptics to endorse qualified versions of exclusive fishing rights. In the United States, for example, a congressional moratorium on individual fishing quotas (IFQs) was replaced by legislation authorizing individual quotas and a federal policy of encouraging regional "catch share" programs [6,7]. Some environmental advocacy groups claim catch shares benefit fisheries rationalization by restoring overfished fish stocks and revitalizing fishing communities [8].

Oversized fishing fleets have been a strong driver behind overfishing, but they also cause additional problems for marine ecosystems. Ecosystem-based objectives have now become as important as rebuilding fish stocks. Industrial-scale fishing methods and oversized and heavy fishing gear can result in high levels of mortality to pelagic marine life caught in or encountering the fishing gear as well as extensive damage to the seafloor environment. Market-based instruments such as catch share arrangements are not designed to address these ecological costs of intensive fishing and third-party certification bodies have been

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slow to incorporate benthic impacts into their certification criteria. Ecological losses due to fishing are not diminished unless additional regulations are imposed upon the owners of the fishing quotas [9]. Whether fishers accept these restrictions depends on the extent and likelihood of enforcement and sanctions or their perceived vulnerability to negative publicity. Measures adopted voluntarily are likely to reflect only the economic incentives that catch share programs convey: to minimize costs and to preserve maximum flexibility in case of stock declines or environmental changes.

Mortality and injury of seabirds, cetaceans, and sea turtles can be highly visible costs of fishing and therefore regulations to reduce such mortality are not uncommon. The fishing industry needs consumers for its products; killing iconic species of marine wildlife is not a good way to satisfy consumer demand, so the industry has incentives to accept these regulations and adopt fishing methods that meet them. But other ecological impacts of fishing are not as visible. Fishing fleets, therefore, are less inclined to accept regulations aimed at reducing those impacts. Catch shares and IFQs do not create incentives to reduce these ecological impacts because fishermen, for the most part, are unwilling to accept the fact that habitat plays a role in the productivity of their fisheries, arguing instead that their activities do not influence environmental productivity or that trawling enhances bottom communities. The maximum sustainable yield (MSY) paradigm adhered to by most fisheries is based on the premise that sustainable catches are strictly a function of fishing mortality and reproduction rates and do not take into account the importance of intact seafloor environments for long-term fisheries sustainability.

Bottom fishing is responsible for considerable amounts of invisible mortality and unseen ecological damage [6,10]. The gear is dragged across the seafloor leaving behind the broken colonies of sessile animals and habitats turned upside down. Many of the animals killed slide through the net or are pulverized into small fragments that appear only as rubble when brought to the surface. It is difficult to devise regulations to protect these organisms and ecosystems because it requires knowing where these organisms live and then protecting them with site-specific closures that are difficult to regulate. Fishers naturally see these as restricting their access to current or future fishing grounds and as costs that are not compensated for by higher prices. The fishing industry has an incentive to prevent managers from adopting spatial closures or to ensure they put them where they impose the least costs to industry. Yet, the point continues to be made that private fishing quotas help to align the incentives of the fishing industry with the greater public interest [11].

In this paper, we consider the quality of the seafloor stewardship exhibited by the owners of exclusive fishing rights in two cases where the owners cooperated with government managers to create bottom trawling closures. Our purpose is to assess the evidence used to support the assertion that private quota ownership aligns a fisherman's incentives with the ecosystem. The two cases are the recent adoption of closed areas in the U.S. EEZ for fisheries around the Aleutian Islands in the Northeast Pacific and the network of Benthic Protection Areas (BPAs) adopted for the New Zealand EEZ. The cases are presented after a brief introduction to the legal frameworks in the U.S. and New Zealand that mandate protection of benthic marine environments.

2. Seafloor habitat and stewardship

Decades after adopting two-hundred mile EEZs, the U.S. and New Zealand amended their national fisheries legislation to address habitat. These amendments acknowledged the dependence of marine fishes on habitat and that habitat can be adversely affected by industrial-scale fishing. In the U.S., the 1996 amendments to the Magnuson–Stevens Fishery Conservation and Management Act require the Secretary of Commerce to identify "essential fish habitat" for all managed fish stocks. In addition, if federal managers determine that fishing activities adversely affected habitat they must mitigate or prevent these adverse effects by adopting regulations such as gear restrictions or area closures [12]. In New Zealand, the Fisheries Act of 1996 obliges the Minister of Fisheries to ensure sustainability in the utilization of fishery resources. To meet this goal, the Minister must avoid, remedy or mitigate any adverse effects on the aquatic environment [11]. The U.S. Magnuson–Stevens Act requires a public process to amend fishery management plans to identify essential fish habitat and any adverse effects based upon the "best scientific information available". The New Zealand Fisheries Act requires the Minister to seek the advice of officials and to consult the public in interpreting the Act's threshold terms including "adverse effects" [11].

In addition to its sustainable fisheries law, New Zealand adopted a biodiversity strategy to protect ten percent of its marine environment by 2010 by adopting a marine protected areas policy. The United States has no explicit marine biodiversity policy. However, President George W. Bush used the U.S. Antiquities Act of 1906 in 2006 and 2009 to declare several marine national monuments encompassing marine habitats in the Pacific that may harbor unique and rare marine life forms. In 2010, President Barack Obama signed an executive order establishing a national policy to protect, maintain, and restore the health of the oceans through regional, coastal, and marine spatial planning and improved coordination of government decision making [13].

Since the 1980s, New Zealand has converted all its commercial fisheries to a quota-owning system by conveying to fishing companies property rights in percentage shares of the annual catch quotas, set separately for individual fish stocks [14]. As mentioned above, the U.S. has only recently begun pursuing catch shares as official policy. Prior to the congressional moratorium in 1996, the only major IFQ program in the U.S. North Pacific was for the halibut and sablefish fisheries in Alaska [15]. However, during the congressional moratorium on ITQs from 1996 to 2002, large fishing interests lobbied Congress to enact the American Fisheries Act of 1998 to allow private harvesting cooperatives to receive sectorial quotas for the catching and processing sectors of the Alaskan pollock fishery [16]. Then, following the expiration of the moratorium in 2002, other share-based management programs were adopted, including programs for the lucrative crab fisheries in the Bering Sea and Aleutian Islands. Thus, most, if not all fisheries in the U.S. EEZ off Alaska are under some form of catch share ownership.

2.1. Aleutian Islands habitat conservation area

After habitat protection provisions were added to the U.S. Magnuson–Stevens Act, the North Pacific Fishery Management Council identified coral and sponge beds in the EEZ around Alaska as essential fish habitat and "habitat areas of particular concern" (HAPCs). The Aleutian Ridge contains some of the world's most diverse and complex deep-sea coral and sponge ecosystems [17,18] in waters that are heavily fished. U.S. federal fishery observers recorded over two million kilograms of coral and sponge by-catch from the waters around the Aleutians from 1990 to 2002 [19]. NMFS estimates 82 t of coral is removed from the seafloor in the US EEZ off Alaska each year by commercial groundfish fishing [20]. Numerous commercial species use these ecosystems as nursery areas and they are known to be highly vulnerable to fishing impacts [20,21]. Stone [20] reported 85% of commercially fished species in the Aleutians are associated with emergent epifauna at some point in their life

cycle. The council did not adopt any measures to protect these areas from the adverse effects of bottom contact fishing gear, including pelagic trawls, bottom trawls, pots, and longlines used in the waters around the Aleutian Islands prior to 2007 [19].

Voting members of the North Pacific Fishery Management Council are state-nominated and federally appointed, and are almost entirely representatives of commercial and recreational fishing interests who adopt fishery management plans for the fisheries off Alaska. All regions of the U.S. EEZ have regional fishery councils with these responsibilities. The Secretary of Commerce implements these plans if they meet the requirements of the Magnuson–Stevens Act to prevent overfishing, rebuild depleted fish stocks, and protect essential fish habitat based upon the "best available scientific information." Given the fact that many of Alaska's largest and most lucrative fisheries are in some form of catch share management program and are represented on the council, ownership of catch shares should provide incentives for ecosystem stewardship, and the council process would be the opportunity to manifest this stewardship.

In October 2003, the North Pacific Council invited nominations from outside groups for the designation of "habitat areas of particular concern." The nominated areas, however, had to be located in one of two priority regions and meet specific criteria. These regions were (1) seamounts in the EEZ "that provide important habitat for managed species", and (2) "largely undisturbed, high-relief, long-lived hard coral beds" particularly those in the Aleutian Islands that provide "habitat for life stages of rockfish or other important managed species" [22].

In addition, the council limited the HAPC nominations to sites that contained species of rockfish that were managed by an existing fishery management plan and that were largely undisturbed and occurred outside core fishing areas [22]. From the submitted proposals the council fashioned a complex array of alternatives identifying areas and management measures, and then reviewed all for their enforcement, management, and economic implications. A proposal to protect deep-sea coral and sponge ecosystems in the Aleutians by the environmental advocacy group, Oceana, was analyzed in the environmental impact statement. Designed to freeze the "footprint" of trawl effort, their proposal specified an "open area" spatial management strategy using observed coral and sponge bycatch rates and groundfish catches. All the remaining areas would be closed to future bottom trawling. Additional measures included coral and sponge bycatch limits within the "open to trawling" areas and a plan for seafloor research, mapping, and monitoring [19].

After concluding the analysis on a tight schedule to meet the court order in *American Oceans Campaign v. Daley*, the legal challenge to the council's essential fish habitat amendments, the council selected an alternative that was based on a modified version of the Oceana plan. The existing footprint (42,609 km^2) was frozen through the designation of "open areas," with the remaining 960,000 km^2 of seafloor closed to bottom trawling (Fig.1; Table 1). Virtually all areas that had recorded fishing activity during the years 2001–2003 are contained within the boundaries of the areas where fishing will be allowed. However, only 105,243 km^2, or about 10% of the bottom in the closed area was considered fishable. The remaining 90% is mostly too deep (>1000 m) to be fishable, may be too rough to fish easily, or may not have any resources worth going after. Oceana lauded the large size of the entire closure (nearly 1 million km^2) but little attention was drawn to the fact that a majority of the theoretically fishable bottom (59.5% of the 105,243 km^2) became closed to mobile bottom gear [23] (the % area closed to bottom fishing shrinks to 47% when the depth range most commonly fished, i.e., <200 m is considered [20]). An additional six areas totaling 380 km^2 (0.04% of the total protected area, 0.4% of the fishable bottom) labeled as coral gardens, are off limits to any type of bottom gear, including pots and long lines.

Cold water corals and sponges are an important part of the bycatch of bottom fisheries in the Aleutians Islands [17]. When the distribution of corals, known from various data sources, are mapped onto the areas of fishing effort (Fig. 2), it is easy to see that most of the coral was recorded from the areas where fishing will still be allowed (with the exception of the small areas set aside as coral gardens). As a consequence, while large areas of the bottom are now off-limits to mobile bottom gear some of the most important coral and sponge habitat areas identified to date are not protected. Since the closure went into effect an additional 25 coral and sponge garden sites have been identified in the central Aleutians [21]; 19 of the 25 sites (76%) are located in areas that remain open to trawling. From a fisheries perspective, this will have important consequences since Stone [20] reported that juvenile and adult rockfish and some commercially important crabs are intimately associated with corals and sponges in this region.

Throughout the decision-making process for the North Pacific essential fish habitat, NOAA Fisheries maintained there was no credible evidence that any long-term damage to the productivity of managed species resulted from benthic habitat features damaged by fishing activities [23]. NOAA concluded that no fishing activities under the council's jurisdiction, if continued at the current rate and intensity, would have more than minimal and temporary adverse effects on essential fish habitat. The designation of open areas was practicable and taken as precautionary to provide additional protection for habitat [23].

2.2. New Zealand's Benthic Protection Areas

New Zealand is a small island nation with a very large territorial sea and EEZ, which together cover more than 4 million km^2. The seafood industry reported landings of about 452,000 t of wild fisheries in 2008, about 30% (140,000 t) of which were from 31 demersal deep-water FAO taxonomic categories. These deep-water species are managed using a Quota Management System, which includes ITQs. According to Helson et al. [11], a significant result of this system has been "to improve the alignment of many of the private interests held by quota owners with the interests of the public" (p. 558). One of the less well-aligned interests had to do with the environmental effects of fishing. While it was widely recognized that bottom trawling did extensive damage to seafloor habitats, e.g., [24], no action had been taken prior to 2005 to eliminate or mitigate those impacts. However, since the rights of the deep-water fishing industry were moderately well-defined, at the suggestion of the then Minister of Fisheries [11] the industry followed the example from Alaska and proposed, in 2006, a set of Benthic Protection Areas that would be off-limits to fishing by any kind of bottom mobile gear.

In 2005, three companies came together to form the Deep-water Group Ltd (DWG), combining their interests into a single management company. The number of shareholders has now risen to 14 (DWG web site: www.deepwater.co.nz/dw-about). Each shareholder owns quota in the deep-water fisheries, which are primarily for hoki (blue grenadier), squid, and orange roughy, but a total of 31 demersal deep-sea FAO taxonomic categories were landed and reported to FAO in 2008. The DWG currently represents about 95% of the quota for New Zealand's deep-water and middle depth fisheries [11].

The DWG initially proposed to protect 14 Benthic Protection Areas (BPAs) within New Zealand's EEZ, encompassing about 31% of the EEZ area. This initiative was proffered in order to set aside a "broadly representative sample of benthic habitats, in essentially pristine condition, to avoid any future adverse effects of fishing on

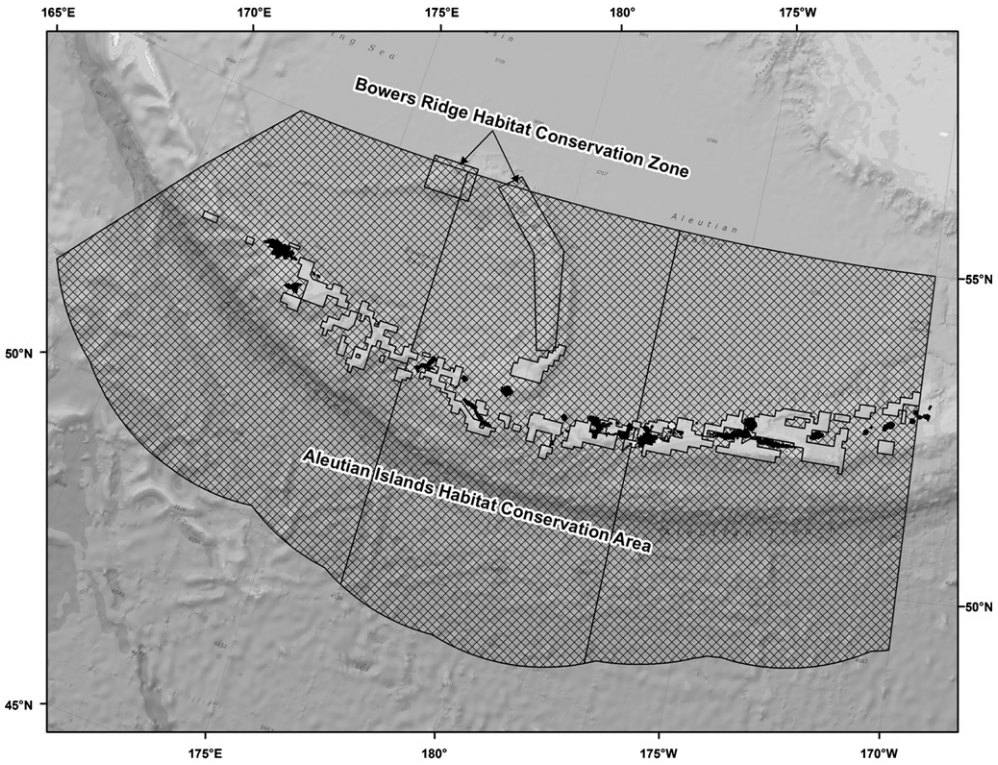

Fig. 1. Map of Aleutian Islands showing areas closed to bottom trawling (light grey) and "open" areas, where fishing is allowed (dark gray). Two other areas on Bower's Ridge, set aside as Habitat Conservation Zones, are also shown in intermediate gray color.

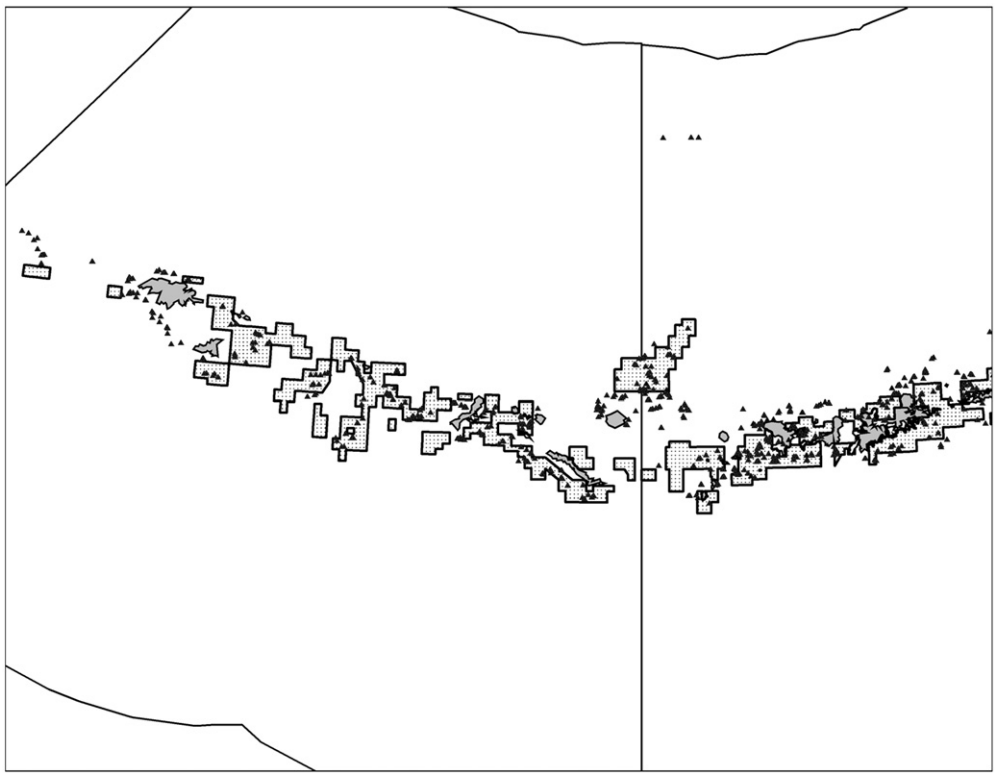

Fig. 2. Detail of central Aleutian Islands showing areas "open" to trawling (stippled). Small triangles are coral records from various sources.

the seabed" [[11]: 560]. In return, the DWG wanted the government to agree that establishing the BPAs would relieve the DWG of any further responsibility to "avoid, remedy, or mitigate any adverse effects of fishing on the benthic environment" [11:560]. As part of the BPA proposal, the industry initially requested that some of the seamount closures already in place, and not falling within the BPAs, be abolished. Ultimately, the initial proposal was not accepted, and further negotiation between the government

and the DWG, followed by some public input, resulted in a series of 19 BPAs, including all existing seamount closures, spread around the New Zealand EEZ [11]. These 19 BPAs cover 1.2 million km^2, or 31% of the EEZ (Table 2, Fig. 3). Further, maps of trawling effort (Fig. 3; see also [25]) were used to "help design a network of closures that had minimal impact on current fishing activities" [11: 561].

The final BPAs that were adopted met the following four criteria: (1) they were large; (2) they were relatively unfished; (3) they had simple boundaries; and (4) they included representative portions of the main environmental classification areas identified in the simplified marine environment classification (MEC) of 2005 [26].

The New Zealand deepwater fishing industry, and the research body, the National Institute for Water and Atmosphere (NIWA), consider depths greater than 1500 m to be essentially unfishable. About 65% of New Zealand's EEZ is in water more than 1500 m deep and 40% of those deep waters are within the BPAs. Looked at another way, 82.3% of the 1.1 million km^2 of deep-sea bottom set aside as BPAs are in water that is too deep to fish (Table 1), therefore, the criterion of protecting areas that have been relatively unfished has easily been met by mainly closing large areas in very deep water.

Other criteria, such as representativeness of the various individual classes identified in the marine classification cannot be so easily met if 82% of the BPAs are in water greater than 1500 m water depth. Of the three MECs with mean depths less than 1500 m, i.e., classes 55, 63, and 178 [26], only 3%, 11%, and 15%, respectively, are within the BPAs. Those classes that are at abyssal depths, i.e., 1 (mean depth 3000 m), 9 (5345 m), and 127 (4799 m), are 79%, 86%, and 25% within the BPAs. Thus, while one can argue that all MECs are "represented" [11] there is great disparity in the proportional coverage. Especially egregious are classes 63 and 178 (mean depth 750 and 754 m, respectively). They are both relatively large in overall area (400,000 km^2 to 500,000 km^2), but only 11% and 15% of those areas, respectively, are in the BPAs. It is clear that much of these two areas, being predominantly at fishable depths on the heavily fished Chatham Rise and Campbell Plateau (Fig. 3), are valuable to the DWG for southern hake and other species.

Leathwick et al. [27,28] tested a series of alternative closure scenarios, including the industry proposed BPAs, to see which would give the best protection to all species of demersal fish, and by extension, to New Zealand's range of marine biodiversity. They modeled the distribution of 122 species of demersal fish (as a proxy for marine benthic biodiversity) taken in more than 21,000 research trawls from depths shallower than 1950 m within the New Zealand EEZ. The model looked for grid cells of highest diversity, surrounding grid cells were then removed in a manner resulting in the least loss of biodiversity. The result would be areas with the highest diversity of fish. These areas were subsequently constrained in a number of ways: (1) by using a weighting scheme for individual fish species; (2) examining connectivity issues and protecting isolated areas or compensating for highly mobile species; (3) reducing the value of some grid cells that were known to be heavily trawled; and (4) constraining the analysis in various ways to account for marine protected areas or benthic protected areas already in place or proposed. They concluded that the current system of marine protected areas were not very representative, thus not providing protection for a large number of fish species, and that the BPAs, as currently configured, provided a much lower level of protection for demersal fish than did any other scenario examined. In fact, Leathwick et al. [27] noted that the BPAs, at these fishable depths, were predominantly located in areas of low value both for the fishing industry as well as for protection of biodiversity and that closures of significantly greater protection value could be achieved with very little additional 'cost' (in terms of fishing area) to industry.

Though many of the BPAs are too deep to fish and/or do not contain high levels of biodiversity, the BPAs encompassing the Kermadec Islands and portions of the Chatham Rise (one of the most productive regions in all of New Zealand's waters) are known to harbor vulnerable marine ecosystems. Kudrass and von Rad [29] reported the occurrence of dense patches of branching corals (e.g., *Goniocorella dumosa*) and gorgonian corals on the Chatham Rise, particularly in areas where large phosphorite nodules cover the seafloor. Nevertheless, New Zealand's Ministry of Economic Development has issued permits for mineral extraction in both areas irrespective of the BPAs established by the Ministry of Fisheries and the 2010 amendment to the Wildlife Act that seeks to protect deep-sea corals (Fig. 4). New Zealand passed the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act in October 2012, but the associated regulations are currently being written. However, the Act explicitly excludes bottom fishing from these regulations and may or may not contain limitations on mining in the BPAs [30].

Table 1
Summary statistics for Aleutian Islands closure area.

	km^2	(%)
Total area of closure	999,943	
Area open to bottom trawling	42,609	4.26
Total area at fishable depths (< 1000 m)	105,243	10.5
Area open to bottom trawling at fishable depths	42,609	40.5
Area most commonly fished (< 200 m)	29,200	2.9
Area < 200 m closed to bottom trawling	13,676	47

2.3. High seas RFMOs

The model of setting aside areas where fishing will not occur has been extended recently into the Indian Ocean, where fishing on the high seas has dropped from a high of 20 vessels to a current four. The regional fishery association, known as SIODFA

Table 2
Comparison of areas by depth interval within the New Zealand EEZ with areas in the established benthic protection areas (BPAs). Note for the last column the denominator is the total BPA area and these numbers show that most of the BPA area is in water > 1500 m deep. Data from [11].

Depth intervals (m)	New Zealand EEZ		Within BPAs		
	km^2	% EEZ (%)	km^2	% BPA in each EEZ depth interval (%)	% Depth interval in all BPAs (%)
< 200	120,168	3	4,087	3.4	0.4
200–750	538,311	14	57,437	10.7	5.0
750–1500 m	705,073	18	139,031	19.7	12.3
> 1500	2543,110	65	933,534	36.7	82.3
All depths	3906,662	100	1134,089	29	100

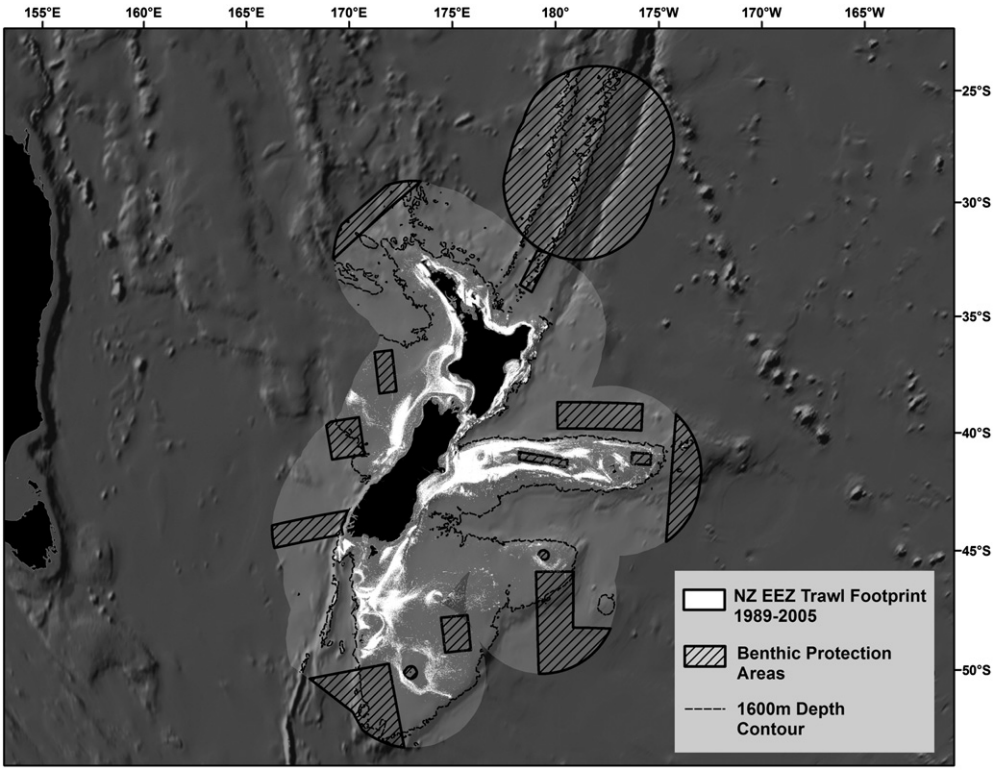

Fig. 3. Cumulative trawl effort data from the 1989–1990 to 2004–2005 fishing years within the New Zealand Exclusive Economic Zone. The 16-year dataset included about 1 million trawls on or near the seafloor (within 1 m) for fishable depths (<1600 m), less than half of which are illustrated here. Note, the majority of BPA closures are in waters too deep to fish (>1600 m). Data from NIWA, used with permission. See [26] for a comprehensive analysis of these trawl data.

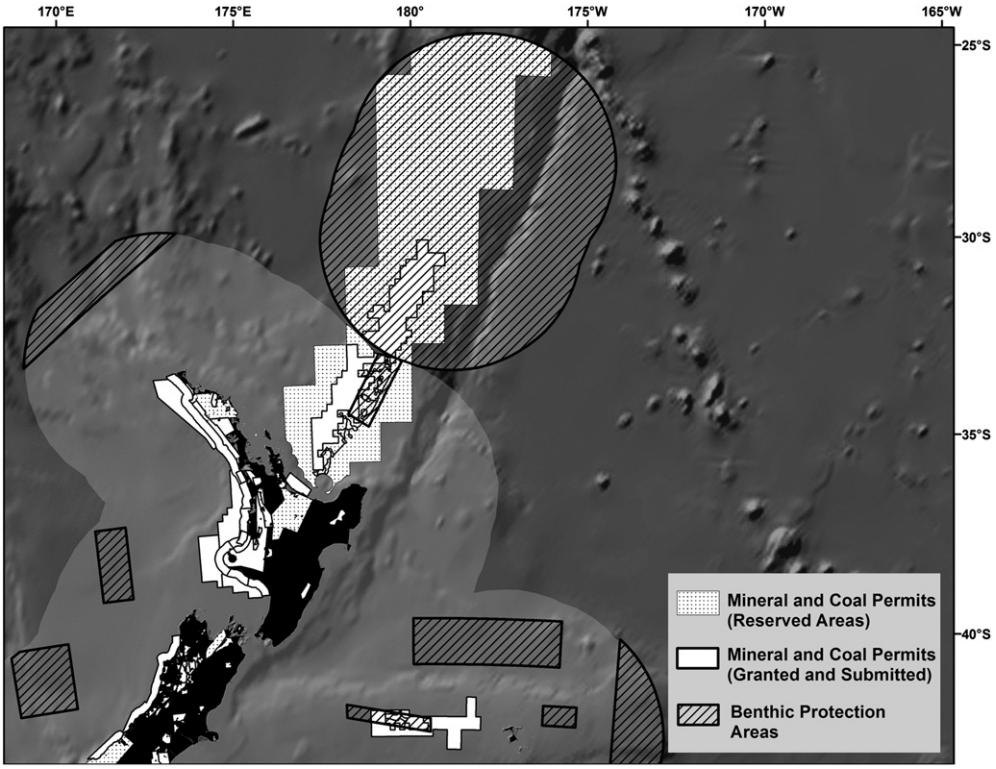

Fig. 4. Location of mineral prospecting and exploration permits (granted or submitted) within the Kermadec, Tectonic Reach, and mid-Chatham Rise BPAs. Data from www.nzpam.govt.nz/cms/minerals/permits/permit%20boundaries.

(Southern Indian Ocean Deepwater Fishers' Association) was established in 2006. The organization is currently made up of fishing companies from Australia, New Zealand, Namibia, and Mauritius [31] and they have voluntarily limited their fishing in the Indian Ocean in anticipation of the area coming under international fisheries management.

In 2006, SIODFA agreed to set aside 11 BPAs in the Indian Ocean area. They noted that adjacent areas of little or no potential interest to demersal fishing *should not be included* within proposed boundaries of the no take zones; rather their limits should be restricted to areas where there were (a) bottom features providing, or likely to provide, benthic habitat with particular vulnerability to bottom trawling, (b) fauna, such as stands of deepwater corals were known to exist, or (c) it was believed that the designated areas could be of particular scientific value. It was also recognized that there would be no benefit from asserting protection of biodiversity in areas beyond where their trawlers operate, e.g., by extending the boundaries of the no-trawling zones to large areas of adjacent abyssal areas simply to 'make the numbers look good' [31].

Under these constraints, a few of the BPAs are moderately large, but most are quite small (Fig. 5). To determine whether these BPAs offer much protection to important deep-sea habitat, we plotted the position and predicted summit depth of seamounts [32] in the SIODFA area in relation to the proposed BPAs. There are 254 seamounts in the SIODFA area whose summits are shallower than 1500 m, thus are capable of being fished with modern deep-sea trawl gear. Of these, only 14 (5.5%) are within the 11 proposed BPAs. The BPAs also cover small parts of large plateaus, or banks, which are mostly at fishable depths. Of the 205,127 km^2 of fishable bottom within the SIODFA area, only 13,762 km^2, about 7%, is encompassed within the BPAs.

3. Discussion

One of the major expressed or implied goals of catch-share management of fisheries is to improve ecological stewardship. For the most part stewardship in this context is interpreted in terms of restoration of fish stocks—to maintain them at sustainable levels over sufficiently long periods so that there is some consistency and predictability in production levels [33]. To the extent that catch share systems result in reduced vessel capacity and fishing effort, a number of catch share systems, through industry consolidation, have resulted in reduced TACs and restoration of target fish stocks. In this paper, we ask whether there is any evidence that catch share fisheries in deep water environments promote conservation of habitat and biodiversity.

In the two case studies outlined above, the areas closed to bottom trawling were developed through government and industry cooperation, with some input from non-governmental organizations, but very little participation from academic research scientists. In the SIODFA proposal, industry acted unilaterally to close areas to bottom trawling in the absence of any intergovernmental organization or other regulation. These efforts are a tacit admission by the fishing industry that bottom trawling is an environmentally destructive practice, but rather than trying to eliminate gear contact with the bottom where VMEs occur (although SIODFA is trying to minimize bottom contact [31]), or changing to less destructive fishing methods, the industry has chosen to try to isolate some areas where such gear will not be used. Unfortunately, the vast majority of the areas closed to bottom contact mobile fishing gear will never feel the effects of such gear because the protected bottom is too deep for the gear to reach or there are no resources worth exploiting.

In both Alaska and New Zealand, the industry was given the opportunity to demonstrate its willingness to protect habitat from the gear they prefer to use. In Alaska, as we have seen, the "frozen footprint" contains some of the most diverse and abundant coral and sponge areas identified, whereas corals are less common in the areas closed to trawling. In view of the relationship between these coral communities and commercially fished species [20], one might have expected an outcome that exhibited more habitat stewardship. In New Zealand, a similar approach has been taken in the industry proposals. The total area of the BPAs in New Zealand exceeds that of the Aleutian Islands closure (Table 2 in [11]). However, as in Alaska, most of the area protected will never be fished because it is too deep. About 90% of the Aleutian closure is in water deeper than 1000 m, as is 82% of the area of the New Zealand BPAs. Further, in New Zealand, two important

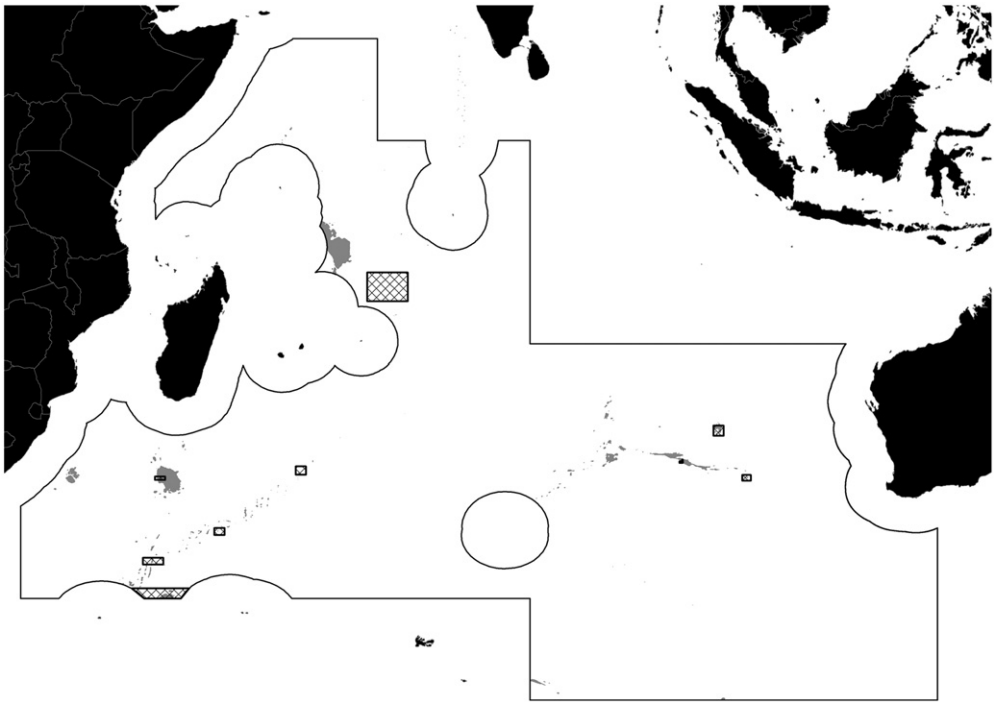

Fig. 5. Map showing SIODFA area in the Indian Ocean with bottom depths shallower than 1500 m shaded light gray. Proposed BPAs are marked as cross-hatched areas.

marine habitat classes that are within fishable depth are protected to only a very minor extent. Consequently, as in Alaska, there is the creation of a perception of habitat stewardship, but in reality, most of the bottom harboring high levels of biodiversity is still open to impacts from bottom trawl gear [27,28].

Predictive habitat modeling using fisheries-independent data can identify vulnerable and ecologically significant benthic ecosystems [34,35] without relying on industry's voluntary restraint from fishing in unfishable waters or ineffective move-on rules that assume bycatch indicates habitat. These models identify areas with the highest probability of harboring VMEs based on the environmental and physical characteristics of known VMEs in the region. Independent scientific advice based on these models is likely to produce closed areas that afford greater protection than voluntary spatial relinquishments such as "freezing the footprint" of existing deep-sea trawl fisheries, which have largely resulted in ongoing trawling in areas most likely to contain ecologically significant and vulnerable benthic ecosystems precluding their recovery from impacts of past trawling.

As the New Zealand example shows, there is also no evidence that areas set aside as no trawling zones will be protected from other bottom-impact extractive industries. In order for these areas to be fully protected, they will need to be designated as no-take marine protected areas.

4. Conclusion

Where the implementation of catch share arrangements has resulted in the fishing industry having privileged or priority access to decision making, whether because of the exclusivity of their quota-owned fishery (New Zealand) or the primacy of their recommendations in public processes for managing fisheries (U.S.), they have not adopted measures for protection of seafloor habitat that can be characterized as responsible stewardship. Proponents of catch shares should acknowledge that, while there may be target–resource conservation benefits from catch share programs like ITQs, broader environmental stewardship by the industry has not been achieved in these regions. Free-market ideology, economic efficiency, political considerations, or management fatigue may be valid reasons for welcoming the transition to catch shares, but environmentalists should be aware that their efforts on behalf of ecosystems will still be necessary, perhaps even more so, when catch shares are adopted. Those who choose to participate in the catch share transition in fisheries policy should seriously consider the development of management measures such as individual habitat quotas. Knowledge of seafloor habitat, based on fisheries-independent data and modeling, suggests this approach is feasible. [36]. Irrespective of the increased responsibility handed to industry to manage their own fisheries affairs it will always remain a key role of government to encourage, oversee, and if necessary, implement measures related to the broader public good aspects of environmental conservation.

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