Marine Policy 37 (2013) 132–140

Contents lists available at SciVerse ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Conservation incentives and collective choices in cooperative fisheries

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ARTICLE INFO

Article history:
Received 11 January 2012
Received in revised form
22 March 2012
Accepted 26 March 2012
Available online 17 May 2012

Keywords:
Fisheries management
Cooperatives
Conservation
Catch shares
Marine protected areas
Common pool resources

ABSTRACT

Cooperatives are increasingly proposed as solutions for sustainable fisheries management. While individual case studies and economic theory suggest that cooperatives may manage fisheries effectively under some conditions, there is little empirical evidence comparing the actions of cooperative fisheries across a diverse set of environments. This study applies a standardized survey method to collect data from a set of cooperatively managed fisheries from around the globe, documenting their social, economic, and ecological settings as well as the cooperative behaviors in which they engage and the role they play in conservation. The resulting database covers 67 cooperatives from the major oceanic regions of the world, providing a unique overview of the global diversity of fishery cooperatives. It enables empirical analysis of the links between the characteristics and contexts of fisheries, such as the development status of the host nation, fisheries management practices, and species characteristics, and the collective actions taken by fishery cooperatives. The evidence shows that cooperatives form in a variety of development and governance contexts, and in diverse kinds of fisheries. Fishery cooperatives often take actions directed toward coordinating harvest activities, adopting and enforcing restrictions on fishing methods and effort, and taking direct conservation actions such as establishment of private marine protected areas.

1. Introduction

While many of the world's fisheries are poorly managed and at risk of or already in a state of collapse [1,2], it is also clear that many successful fisheries exist [3–8]. A large and growing literature focuses on tools such as marine protected areas (MPAs) and property rights-based fishery management instruments, and their ability to improve the state of fish populations and provide economic and ecological benefits [9–12]. But, conservation tools such as MPAs and economic instruments such as catch-shares are often presented as separate or alternative solutions [11]. This paper addresses a third approach that has received less attention but is broadly used around the world; fishery cooperatives. The evidence provided here indicates that cooperative fishery management has the potential to cross the gap between MPAs and rights-based approaches.

Fishery cooperatives may be able to resolve a wide range of fishery management problems and simultaneously achieve conservation benefits [10,13–16]. Cooperatives have the potential both to improve economic conditions and to mitigate the environmental impacts that have decimated many fisheries around the world. However their actual and potential role in fishery management is not well understood. In light of the diversity in purpose, setting, structure, and management of the world's fisheries, no one strategy can be expected to succeed in all cases. There is a need, therefore, to better understand what results can be achieved through cooperative management, and the conditions and attributes that contribute to their effectiveness relative to other management strategies. It is particularly important to understand how cooperatives can contribute both to economic efficiency and to conservation. This paper addresses this knowledge gap by presenting a database of information on fishery

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http://dx.doi.org/10.1016/j.marpol.2012.03.012

cooperatives and reporting on the roles these cooperatives play in fisheries management, conservation, and the creation of MPAs across a diversity of fishery types and settings.

While fishery cooperatives vary considerably in structure and function, the working definition adopted for this study is an institution in which groups of fishers or other interested parties act collectively to manage some aspect of a fishery. As solutions to common-pool resource dilemmas, cooperatives have been studied extensively. Perhaps the most notable contribution is Ostrom's [17] delineation of the general conditions enabling successful management of the commons through cooperative action. Other works have provided detailed analysis of their economic performance [10,18–21], ecological effects [22,23], social implications [14,24,25], and general structural characteristics and practices [26–28]. These studies describe a broad array of potential benefits from cooperative management, such as reducing or eliminating the race for fish, improving economic efficiency and market value, improving enforcement and compliance, and promoting conservation and environmental stewardship.

The literature on cooperative management of common pool resources is vast, but there is little comparative analysis of the benefits from cooperation. Most studies either provide high level theoretical treatments of cooperation or provide detailed, descriptive information for a select region or type of fishery. This division in the literature and the scarcity of comparative empirical analysis are understandable. Detailed data on the actions and structures of cooperative fisheries are difficult to obtain, limiting thorough analyses of the conditions that give rise to successful cooperative management [29]. Taken individually, the results of specific case studies often cannot be applied to wider sets of fisheries, while broad theoretical treatments on the underpinnings of cooperation lack the specificity and empirical support needed to guide management.

Gutiérrez et al. [13] provides a notable exception, analyzing the role of co-management attributes in the sustainability of a sample of global fisheries, many of which included cooperatives. However significant gaps remain. First, it is important to understand not only whether cooperatives are successful, but also how they achieve success. A first step toward this understanding is to document the specific actions cooperatives take to achieve both economic and ecological goals. Second, given the poor state of many marine ecosystems, stakeholders need to better understand the incentives that drive cooperatives to undertake conservation actions; at present knowledge on this issue is rudimentary at best. For the analysis to be broadly applicable, information should be drawn from cooperatives ranging across the entire spectrum of geographic, social, environmental, and economic settings in which these institutions are found.

This study presents empirical information on the role cooperatives can play in fisheries' management and conservation, building upon the existing literature in two important ways. First, data are compiled from a large set of case studies of cooperatives and organized into a detailed database of the ecological, economic, institutional, and social structure of the fisheries involved, together with the collective actions fishery cooperatives undertake. Second, these data are used to test hypotheses on how ecological, economic, social and governance circumstances are linked to the collective choices made by cooperatives. Specifically, this analysis focuses on the role cooperatives can play in conservation through the creation of private marine protected areas (PMPAs).

The conservation role cooperatives can play is particularly relevant given the poor ecological performance of many of the world's fisheries and the debate between MPAs and catch shares as answers to these problems. This study hypothesizes that cooperatives, because they hold rights and make management decisions collectively, are potentially well-structured to take conservation actions that benefit all users simultaneously.

Cooperative management can also help solve another class of important collective action problems: providing basic management functions such as controlling catches, setting size limits, imposing penalties for rule violations and carrying out enforcement. When governments function effectively and adopt policies that serve the public interest, these collective action tasks can safely be assigned to government regulators. When top down governance is an ineffective or inefficient tool, fishery cooperatives may take collective actions to fill the void. This study tests these hypotheses by examining the actions of cooperatives between developed and developing nations, and by empirically analyzing the factors influencing the creation of PMPAs.

2. Methods

A database was compiled from published case studies by designing and implementing a survey instrument to enable standardized collection of information. Ecological and microeconomic theory was informally used to guide the selection of survey questions. As a general framework, the choice to engage in a cooperative behavior is postulated to depend on the expected costs and benefits of that behavior. The variables chosen for collection were, therefore, justified on this basis. For example, in considering the ecology of the fishery, some of the variables selected indicate the ability of fishers to capture the benefits of management actions; these variables include species' growth rates, home ranges, aggregation behaviors, and breeding habits. Social and governance indicators include the strength of contract enforcement and degree of corruption. These variables indicate how secure any rights assigned to a coop are likely to be in practice; they also may indicate whether or not government can be relied upon to carry out basic fishery management functions. Economic factors such as the value of the target species and predictability of the catch can influence the benefits that cooperative management can bring relative to open access. Finally, existing government policy toward fisheries, such as total allowable catch regulations and fishery subsidies, can affect choices to either collectively assume management duties or leave them to government.

Using this selection process, six categories of questions were applied to surveyed fisheries: ecology, institutions, economics, government policy, coop structure, and cooperative actions. Per the preceding explanation, the first four of these categories are factors hypothesized to influence coop formation and the actions cooperatives take. The fifth category, coop structure, is descriptive. The sixth, cooperative actions, is the main focus of attention. The survey instrument was designed to collect quantitative measures such as landings volumes, binary options such as the presence or absence of a given trait, or discrete choices such as selection from a pre-defined and carefully described list of options. This approach allows data to be compared across sample cooperatives, while limiting the extent of surveyor choice that could introduce subjectivity.

Ecological variables focus on the life history traits of the species targeted by the fishery, such as growth rates, movement patterns, and habitat preference. For multi-species fisheries, separate entries were recorded for the most commonly caught species. Institutional variables reflect the national context of the fishery, such as the population growth rate, the per capita GDP, the human development index (HDI), and indices of corruption and contract enforcement (see Table S.1). Economic variables are fishery-specific rather than national, and capture information on species' value, market destination, and reliability of catch. Policy variables measure the role of government in the management of the fishery. They include total allowable catch or size limits, legal

Table 1
Description of cooperative behavior categories.

Cooperative behavior	Description
Marketing	Cooperation to collectively market or brand catch
Proceed sharing	Pooling system to distribute proceeds from fishing among fishery members
Coordinated harvesting	Coordination of fishing strategy among fishery members
Catch limits	Implementation of self-imposed catch limits above and beyond any similar governmental restrictions
Gear restrictions	Implementation of gear restrictions, e.g. the prohibition of dynamite, beyond any similar governmental regulations
Size limit	Implementation of self-imposed size limits above and beyond any similar governmental regulations
Gear sharing	Collective ownership or use of fishing gear, such as boats, nets, or landing facilities
Direct enforcement	Collective action to physically enforce fishery regulations, for example organization of patrols
Codified penalties	Collectively determined set of defined penalties for infractions of fishery regulations
Temporal restrictions	Voluntary cessation or restriction of fishing activities for the fishery as a whole, or for a defined spatial region, for a given period of time
Spatial marine protected areas	Voluntary closure or restriction of spatially defined portions of the fishery
Restocking	Collective action to restock the fishery, for example through the seeding of juveniles
Habitat restoration	Voluntary efforts to restore fishery habitat, for example planting of mangroves
Gear shift	Collective choice to switch to more environmentally friendly gear types
By-catch avoidance	Cooperative actions to reduce by-catch above and beyond any government stipulations
Research support	Cooperative support of fishery research activities, such as data collection or science funding

support for a cooperatives authority, and the extent of government subsidies for fishing. Structural variables describe the attributes of cooperatives, for example the number of vessels, formation date and annual landings. Finally, cooperative action variables identify the specific collective activities each cooperative undertakes (Table 1).

An exhaustive set of possible cooperative actions was identified from instances of clear voluntary cooperation behaviors in the literature; examples include cooperative marketing, enforcement, research support, and conservation actions (Table 1). Fisheries were included in the database if they engaged in one or more of these cooperative activities; they were then scored according to the number of cooperative behaviors undertaken. This selection method eliminated the need for subjective decisions on whether a particular fishery qualifies as a cooperative, while also providing a quantitative measure of the degree of cooperation.

Ideally, fisheries would have been selected randomly from the world's population of fisheries, and all those with cooperatives noted for analysis. This would have allowed analysis of factors contributing to coop formation and provided a random sample of cooperatively managed fisheries. This is impractical, however, given the vast number of global fisheries and because only a small portion of the world's fishery cooperatives have been described in the literature. Instead, cooperatives were selected from the existing literature for inclusion in this database, recognizing that the fisheries that have received attention in the published literature presumably are not a random sample of the population. Nevertheless, the fisheries included do represent a very broad range of diversity of geographic, environmental, and institutional settings. Cooperatives from developed nations may be over-represented, as they may be disproportionately covered in the literature. To shed light on potential bias from this source, mean values for three national level indicators, per capita GDP, HDI, and Polity, were compared for fisheries in the cooperative database and for the world and *t*-tests were computed to determine significance. Per capita GDP indicates relative wealth among nations. The HDI, reported by the United Nations Development Program, is a composite index of health, educational opportunity, and living standards with higher values indicating better outcomes. The Polity score indicates the democratic ($+10$) versus autocratic (-10) nature of a country's governance institutions (Table S.1).

Complete linkage cluster analysis was used to identify relationships among cooperative actions to provide insight into choices made by cooperatives. While this provides a way to visualize associations, it cannot identify significant differences among groups [30]. Complete linkage cluster analysis forms groups among the data by measuring the maximum distance between paired observations of variables. For example, consider the clustering between marketing and proceed sharing. For these two variables, each cooperative can be plotted as a point on a plane, where the *x*-coordinate is the presence or absence of marketing, and the *y*-coordinate is the presence or absence of proceed sharing. The dissimilarity score is then calculated using the largest differences in distance between the points among the individual cooperatives. The result is a measure of "dissimilarity", where higher scores indicate less similar groups. Clustering among fisheries in their choices of cooperative behaviors is shown as a dendrogram. For each cooperative behavior, missing data points were assumed to equal the average value of that behavior across all fisheries.

The actions cooperatives take were compared between developing and developed country fisheries, with development status indicated by Organization for Economic Cooperation and Development (OECD) membership as of 2010. Significant differences were identified by computing *t*-tests for differences in the mean frequency of each cooperative behavior in the two groups of countries.

Lastly, logit regression analysis for clustered survey data (in order to account for multiple entries for different species targeted by the same cooperative) was used to examine factors contributing to the probability of the formation of PMPAs. PMPAs may be temporal, such as a prohibition on fishing during part of the season; spatial, such as the prohibition of fishing in specific areas; or both, such as rotating closures of specific areas. Seven institutional and ecological factors were chosen as potential determinants (Table 4). The institutional variables indicate the host nation's wealth, the extent and nature of national government fisheries policy, and relevant ecological indicators of the cooperative's target species. These variables were regressed against two separate dependent variables; the presence of any PMPA (spatial, temporal, or a combination of both), and the specific case of the spatial PMPAs. The rationale for these choices and hypotheses on the roles these determinants play are explained in the discussion of results.

3. Results

3.1. Attributes of cooperatives

The global cooperative database includes 67 cooperative fisheries spanning the major oceanic regions of the globe (Table S.2; Fig. 1). The database shows that cooperatives exist across an extremely diverse set of fisheries and span a wide range of operating environments and internal structures. Membership size

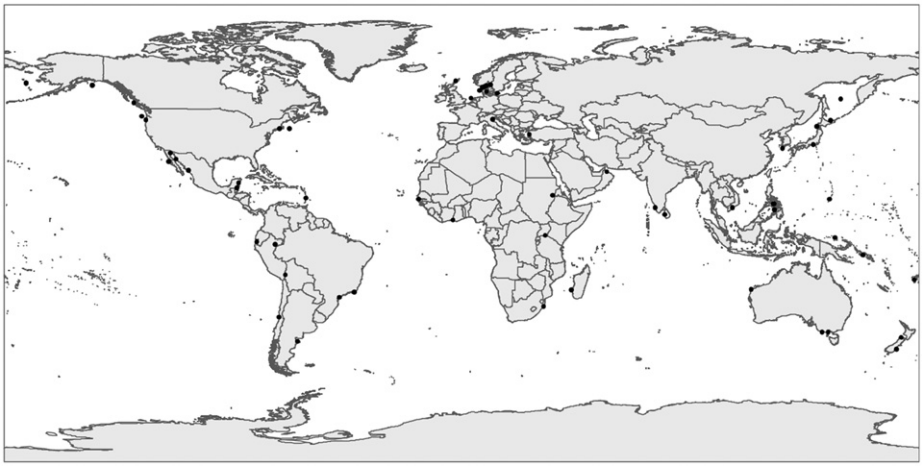

Fig. 1. Map of surveyed cooperative locations.

Table 2
Comparison of national level statistics, per capita GDP (in 2009 US dollars), Human Development Index, and Polity, between the cooperative sample and world. Significantly greater results are marked by *** for significance at 5%, * for 10%.

Variable	Sample mean	Global mean	$P > \|t\|$
Per capita GDP (2009)	$17,000	$14,232	0.23
Human development index	0.69*	0.630	0.06
Polity index	5.84***	3.76	0.04

varies greatly, from as few as a handful of individuals up to several thousand participants, with a median value of 150 members among the sample cooperatives. Comparison of national characteristics between the sample fisheries and the world as a whole show some differences, with significantly different means for HDI and the Polity index, but not for GDP (Table 2). On the whole, the sample is composed of more developed and democratic, but not necessarily wealthier, nations.

The fishery cooperatives in the sample are found in relatively democratic and developed countries, as evidenced by the frequency of high Polity and HDI scores (Fig. 2A–B). There is a broad range of the HDI scores in this sample, however, indicating that cooperatives are found in wide variety of development contexts. Many of the surveyed cooperatives have some form of government imposed management structure in place, such as a total allowable catch (TAC), an individual transferable quota (ITQ) system, or a formal cooperative fishery program (Fig. 2C). Approximately 45% of surveyed cooperatives occur in conjunction with a TURF system, despite the relative scarcity of TURF systems across all global fisheries. Approximately 25% of surveyed fisheries operate in open access conditions, however, indicating no government imposed restrictions on fishing; clearly, cooperatives are not solely products of highly managed fisheries.

The species types caught by cooperatives in the dataset are highly diverse, with mollusks being the most commonly caught taxa, followed by benthic finfish (Fig. 3A). The distribution of targeted species differs between developed and developing nations; cooperatives in OECD member countries tend to target benthic finfish, while non-OECD nation cooperatives focus on reef associated finfish (Fig. 4A). Artisanal gear such as spears and hand-lines are the most common gear types used by the fisheries in the dataset; relatively capital-intensive methods such as dredges and long lining are the least common (Fig. 3B). Fishing methods with complex gear requirements such as trawling are more common in developed nations, while simpler methods such as hook-and-line and beach seines are more predominant in developing countries (Fig. 3B). The majority of surveyed cooperatives sells to both local and export markets; cooperatives that specialize in one market focus more often on export than on local market sales (Fig. 3C). Most of the solely export oriented cooperatives are located in OECD member nations.

3.2. Cooperative behaviors

Each fishery in the database engages in at least one cooperative behavior; the average number of such behaviors is five. Cooperative behaviors were grouped into four categories, based on the motive for a particular activity: non-management actions; catch and effort management; coordination and policing; and stewardship actions (Table 3). These categories are only approximate, however, as a given action may serve more than one purpose.

The most common cooperative action observed in the overall sample is coordination of effort and harvest activities. Gear sharing, another form of coordination among individual fishers, is also common. The catch and effort management category, which includes actions often considered the exclusive province of government agencies, is represented in both development categories of host countries but with different frequencies. Restrictions on fishing gear and fishing seasons are more common in developing country than in developed country cooperatives. Two policing activities, imposition of codified penalties for rule violations and enforcement of rules, are also common in both sets of countries. These are also actions many consider to be the sole responsibility of government regulators.

Activities included under the heading of stewardship, or conservation, are less common than other categories, but still significant (Table 3). Aside from research support, the most common stewardship actions are imposition of spatial restrictions, mandated changes in gear and bycatch avoidance measures. Further, catch and effort management actions such as size limits, gear restrictions and season closures may be motivated by an interest in conservation. Overall, complex conservation actions occur with relatively high frequency.

The data in Table 3 also reveal differences in behaviors and attributes between cooperatives found in developed versus developing countries. In OECD nations, activities such as by-catch avoidance and research support are significantly more common, while non-OECD nation cooperatives have higher frequencies of proceed sharing, gear restrictions and direct enforcement (Table 3). Two non-management actions, marketing and proceed-sharing, are common in both developed and developing country coops. Of course, a single variable such as OECD

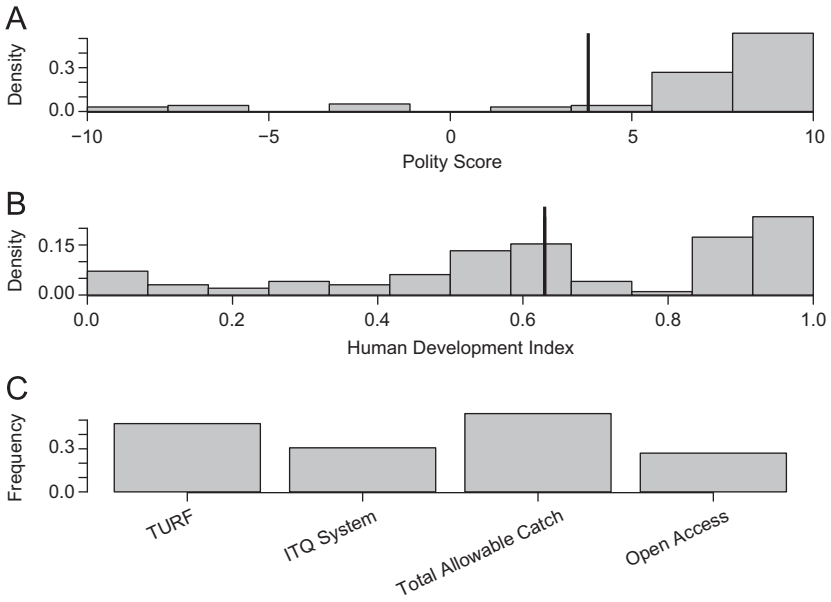

Fig. 2. Summary of national level statistics: (A) shows the distribution of Polity scores, the black line indicates the global mean Polity score, (B) shows the distribution of the HDI index within the database, the black line indicates the global mean HDI score and (C) shows the proportion of the species targeted by the database cooperatives that have territorial user rights (TURF), individual transferable quota (ITQ), total allowable catch (TAC), or open access systems in place for their management.

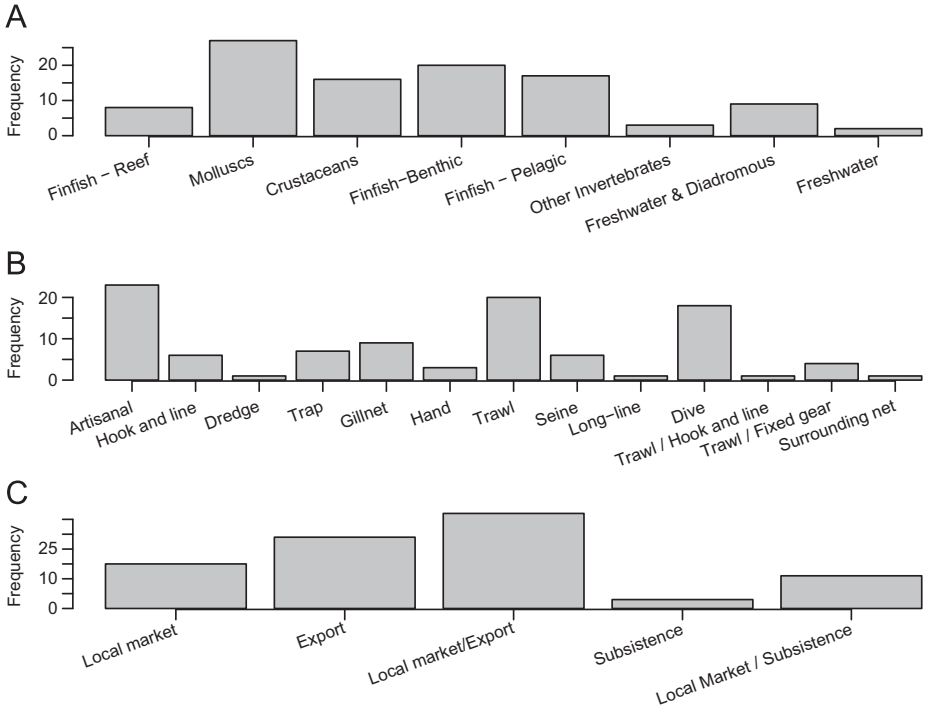

Fig. 3. Summary of fishery level data: (A) shows species caught by cooperative fisheries, (B) shows gear types used for fishing and (C) indicates how the catch is used; subsistence corresponds to catch being used almost exclusively for personal consumption for survival, local market represents sale to nearby or national markets, and export represents catch sold or sent to foreign countries.

membership is unlikely to decisively explain the choice of collective action given that individual acts of cooperation presumably result from complex chains of variables [29].

Examining the clustering of cooperative behaviors based on co-occurrence within a cooperative reveals several groupings of cooperative activities (Fig. 5). Marketing and proceed sharing are closely linked, but relatively dissociated with other activities. Activities representing data and effort-intensive fishery management such as the use of TACs, size limits, restocking and habitat restoration are closely grouped. In contrast, cooperative harvesting does not exhibit a clear relationship with any of the other cooperative activities, suggesting that collective harvesting occurs independently of other cooperative actions.

3.3. Private marine protected areas

Many of the cooperatives in the sample voluntarily take conservation actions as part of their management strategy (Table 3). The incentives for cooperation in creating private marine protected areas (PMPAs) and taking other conservation

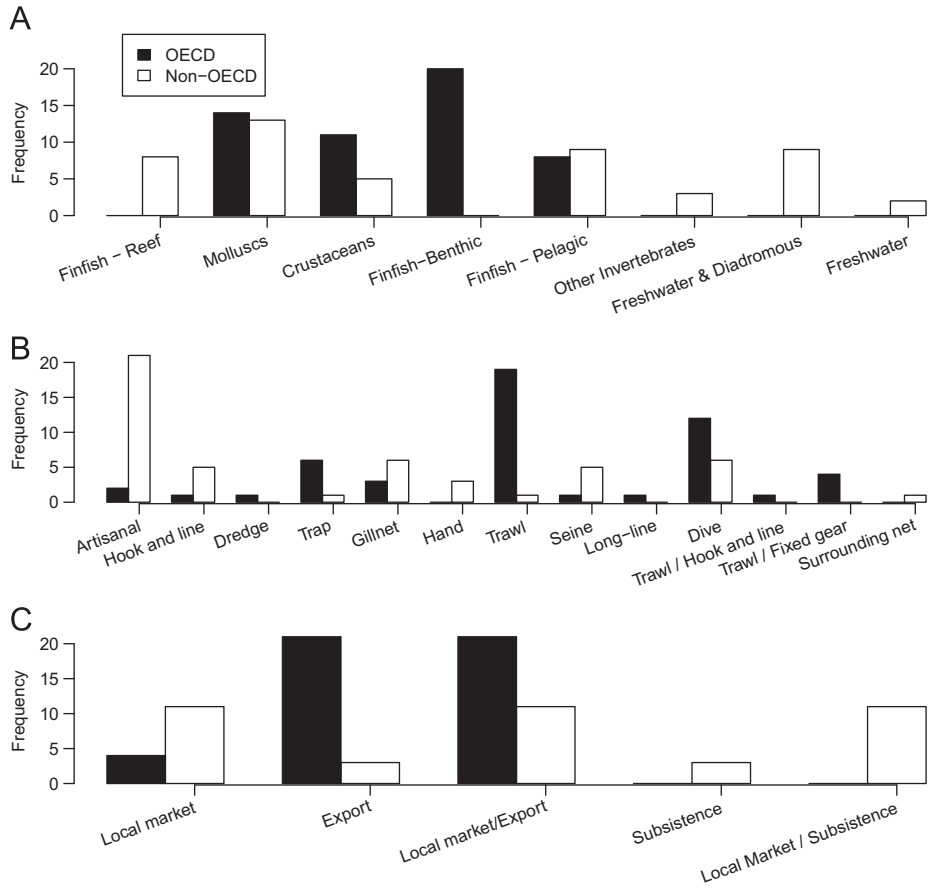

Fig. 4. Comparison of fisheries characteristics in OECD and Non-OECD member nations: (A) shows the species caught by cooperative fisheries, (B) shows the gear types used for fishing and (C) shows the how the catch is used, with subsistence corresponding to catch being used almost exclusively for personal consumption for survival. Local market represents sale to nearby or national markets, while export represents catch sold or sent to foreign countries.

Table 3
Percentage of surveyed fisheries engaging in each identified cooperative activity. Percentages are reported across all fisheries and among fisheries in OECD versus non-OECD nations. *P*-values report results of *t*-test for differences in means between the two groups. ** indicates that differences are significant at 5%.

Cooperative activity	All cooperatives	Developed countries (OECD)	Developing countries (non-OECD)
Non-management actions			
Marketing	39%	44%	33%
Proceed sharing	47%	37%**	59%**
Catch and effort management			
Catch limit	15%	22%	9%
Gear restrictions	45%	28%**	61%**
Size limit	11%	16%	7%
Temporal restrictions	35%	30%	40%
Coordination and policing			
Coordinating effort & harvest	65%	80%**	48%**
Gear sharing	30%	27%	36%
Enforcement	56%	42%**	70%**
codified penalties	36%	43%	30%
Stewardship actions			
Spatial MPA	31%	26%	36%
Restocking	11%	10%	13%
habitat restoration	3%	0%	8%
Change in gear	29%	24%	34%
By-catch avoidance	26%	48%**	2%**
Research support	47%	62%**	34%**
Sample size	67	38	29

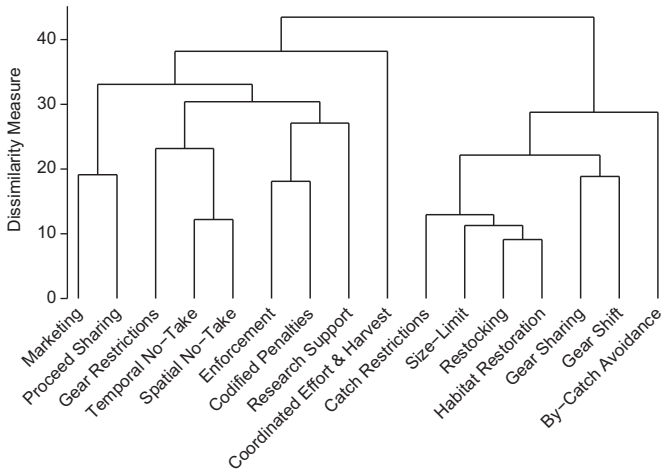

Fig. 5. Dendogram of cooperative behaviors. Nodes closer to 0 on the *Y*-axis (the degree of dissimilarity) represent activities that are more closely associated, while nodes at higher values of dissimilarity represent less associated activities.

actions are of particular interest, because coop activity in this realm is not widely appreciated. As a collectively organized management structure, cooperatives are well-configured (relative to other management regimes) to capture the benefits of collective action. Two cases in particular highlight the diversity of PMPAs that are formed by cooperatives. The fishing community of Ahus Island, Papua New Guinea has implemented forms of PMPAs within their lagoon for generations, prohibiting the use of nets

Table 4
Results of logistic regressions of predictor variables on the presence of any form of PMPA or on a spatial PMPA.

Dependent variable: presence of PMPA	Any PMPA		Spatial PMPA	
	Coefficient	$P>\|t\|$	Coefficient	$P>\|t\|$
Human development index	−5.00	0.19	−6.89***	0.01
Subsidy as fraction of landed value	−2.85***	0.00	−2.20*	0.01
TURF program	2.43***	0.04	2.01*	0.06
Nested fishery	−2.16***	0.03	−2.04***	0.03
Fishery spatially defined	−1.67*	0.09	−1.61*	0.09
Sedentary species	2.26***	0.02	0.59	0.55
Aggregating species	−0.43	0.71	−0.45	0.65
constant	5.40***	0.04	5.97***	0.01
Number of observations	73		66	
Prob > F	0.03		0.09	

and spears within established zones for extended periods of time [31]. On a completely contrasting scale, the highly commercialized Challenger Scallop Enhancement Company of New Zealand uses a system of rotating PMPAs in order to ensure the targeted scallop beds do not become depleted over time [32].

To further explore this phenomenon a logit regression model was specified that treats the presence of PMPAs as a function of the following seven regressors (Table 4): HDI, presence of fishing subsidies, TURFs, nested fisheries, sedentary species, and aggregating species. The results provide insight as to why cooperatives may choose to undertake conservation actions such as PMPA formation.

Consider first the significant results for creation of 'Any PMPA'. From an institutional perspective, subsidies are negatively related with the creation of PMPAs, meaning that the more a host nation's fisheries are supported by government subsidies, the less likely cooperatives in this survey were to enact PMPAs. Of particular interest given the theoretical debate on the relationship between catch shares and MPAs, the presence of a national TURF program, a type of catch share, is strongly positively related with the creation of PMPAs by cooperatives. The 'Nested Fisheries' coefficient indicates that cooperatives are less likely to establish PMPAs when non-cooperative fishers target the same stock as the cooperative. Cooperatives show a preference for enacting PMPAs in fisheries where the targeted species is sedentary, likely reflecting the challenge of realizing MPA benefits from more mobile species.

The specific case of spatial PMPAs was considered separately, as this form relates most closely to the traditional MPA concept. The presence of spatial PMPAs was predicted by the same variables as above (Table 4). The pattern of spatial PMPA determinants is similar to that for the any PMPA regression, with the addition of the HDI as a highly significant variable. The negative HDI coefficient indicates that spatial PMPAs are more commonly established by developing country cooperatives. Subsidies, TURFs, and the spatial definition of the fishery retained the same sign on their coefficients, although significance levels are lower (Table 4). Interestingly, the sedentary nature of the species no longer played a significant effect in this regression.

4. Discussion

This study documents the range of management activities fishery cooperatives undertake and the economic, social and ecological factors that influence their collective actions. Of particular importance, it demonstrates cooperatives often establish PMPAs and take other resource stewardship actions when institutional and ecological circumstances are appropriate. While the availability of case studies varies greatly across the globe, evidence of cooperative fishery management was found in every major fishing region. In addition, the range of species types, preferred fishing gear, membership size, landing volumes, and sales markets indicate that cooperative management is not solely associated with large, small, rich, or poor fisheries, but rather represents a broadly applied strategy for dealing with common-pool resources. Much of the literature on cooperatives has focused either on a high-value industrial set of cooperatives or on smaller market community institutions, giving the impression that the range of application is narrow. The evidence presented here demonstrates that cooperative fishery management can be applied in a broad spectrum of circumstances.

The finding that the sample contains a greater proportion of developed and democratic nations than the world as a whole indicates that it may not accurately represent the population of all the world's fishery cooperatives. Bias toward cooperatives in developed nations may arise from the greater availability of data and ease of fieldwork in these countries. Works such as Johannes [14] refer to a huge number of cooperatively managed fisheries throughout Oceania, but relatively few sources give empirical data on structure or performance. This suggests that greater representation of developed nations is due to data availability. One factor that may mitigate selection bias is the diversity of research questions that studies of cooperation have sought to address. Relatively few of the studies surveyed in this analysis were created as explicit case study descriptions of cooperatives. Most used cooperatives to study a specific research question, such as the effect of a cooperative on species composition [11] or a fishery's socioeconomic conditions [33]. Since the studies that populated the database addressed unique research questions, the probability that all were selected due to, for example, common economic or ecological characteristics is reduced. Nevertheless, the sample clearly is not representative of the entire population. It is, however, drawn from a broad range of geographic locations and data sources, and may therefore reasonably represent the diversity of cooperative fisheries.

Beyond a detailed descriptive picture of fisheries cooperatives, this study also provides empirical evidence for the collective actions cooperatives take and the correlates of these actions. While some well-known activities such as collective marketing are prevalent in the sample, lesser-known collective actions such as support for fishery research are also surprisingly widespread. The coordination of effort and harvesting stands out as a highly prevalent collective action, which agrees with evidence and economic reasoning that such actions can reduce costs by eliminating races that can arise under derby conditions [14]. Derby fishing can also have negative ecological consequences, as fishers use inefficient and environmentally harmful gear in an effort to race against competitors. The widespread use of coordinated fishing by cooperatives suggests that they can often provide economic and ecological benefits by the simple action of reducing the race for fish.

The exact bundle of activities cooperatives pursue varies depending on their context. Comparison of cooperative activities between developed and developing host nations shows differences in some collective action choices, such as by-catch avoidance and direct enforcement of fishery regulations (Table 3). The fact that by-catch avoidance is relatively common in OECD countries makes intuitive sense. Fishers in these nations tend to focus on a single or few species and may face by-catch restrictions or pressure from conservation NGOs, resulting in greater incentives to avoid by-catch. Conversely, many developing nation cooperatives target multiple species, reducing the number of non-target or "undesirable" species that might otherwise be considered bycatch. Even for species considered locally as by-catch, the non-OECD group is likely to have fewer regulations and watchdogs concerned with this issue, providing less reason to

actively avoid by-catch. Despite the vastly different circumstances facing fishers in developed versus developing countries, temporal and spatial PMPAs are fairly common in both settings. The somewhat higher frequency of PMPAs in developing country settings agrees with the hypotheses that cooperatives often fill gaps in collective actions that developing country governments fail to undertake. In any case, PMPAs clearly are not confined to a single region such as the Pacific Islands, but are far more widespread.

The finding that cooperatives frequently establish PMPAs, take other conservation actions and manage effort to reduce the race to fish demonstrates that cooperatives can play an important role in conservation. Eliminating the race to fish can reduce by-catch and habitat destruction. MPAs voluntarily established by fishing cooperatives contribute directly to marine conservation and demonstrate that fishers can support MPAs if appropriate incentives are in place. The factors correlated with PMPA establishment indicate that a key enabling condition is the ability to benefit collectively from stock enhancement. The presence of a non-cooperative fishing fleet competing directly with a cooperative (the 'Nested Fishery' variable) significantly reduces the probability of PMPA creation, as does a highly mobile target species. The negative influence of fishery subsidies on PMPA creation, as well as the positive influence of a national TURF program, may indicate that national level fishery policies can affect the incentives for conservation actions on a local scale. Government subsidies for fishing fleets are indicative of a national policy that favors increasing catches, with little concern for conservation. A national TURF policy, by contrast, indicates both a national level interest in fishery management and an acceptance of spatially delineated policy instruments. These results suggest that steps such as allocating TURFs to cooperatives may provide a useful tool in the creation of MPA networks.

5. Conclusions

The evidence presented here demonstrates that fishery cooperatives deal with common-pool resource problems in diverse ways and in diverse settings. Blanket descriptions of the actions, benefits or shortcomings of fishery cooperatives are therefore necessarily flawed. In considering cooperatives as tools for fishery management, it is appropriate to temper expectations of results with consideration of the actual incentives a fishery faces. The evidence reported here indicates that these incentives can be identified; with this knowledge, managers, scientists, fishers, and stakeholders can better understand what benefits cooperatives might provide. The database presented here provides a useful starting point for investigations of the role of cooperatives fishery in conservation, the influence of government regulations on collective action and other questions.

While the growing availability of case studies makes an analysis such as this possible, significant challenges remain in piecing together the disparate data sources on cooperative fisheries. Few case studies are created with an eye towards comparison to other fisheries. geared towards global comparison, inclusion of relatively simple data describing, for example, fishing grounds, membership size, gear types, or use of catch, can help put more specific results into context and allow for inclusion in broader studies.

With currently available data, cooperatives are shown to provide an extremely diverse portfolio of potential solutions to common-pool resource problems. A particularly notable finding is that cooperatives often support the creation of PMPAs, therefore providing both economic and environmental benefits. Through comparative analysis of wide groups of fisheries, it is possible to better understand what incentives drive the actions of cooperatives and in so doing, support the health of fisheries and the communities that depend on them.

Acknowledgments

We thank the Environmental Defense Fund and the Waitt Foundation for financial support and all participants at the workshop "When, why and how do fishing cooperatives form?" Dec 2010 Santa Barbara CA, including Steven Gaines, Rashid Sumaila, Joe Sullivan, Chuck Cook, Jake Kritzer, and Crow White, for their help and input on research applications for the database. We thank Frank Davis and Sarah Anderson for valuable technical advice. We also thank everyone who provided assistance with obtaining and verifying information collected for this study. Lastly, we are grateful to Heather Hodges, Kristin Van Abel, Micah Effron, Sarah Green, Kate Labrum, and Matthew Fulda for providing invaluable research support.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2012.03.012.

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