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Original Article

Incorporating the spatial access priorities of fishers into strategic conservation planning and marine protected area design: reducing cost and increasing transparency

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Marine protected areas (MPAs) are increasingly used to address multiple marine management needs, and the incorporation of stakeholders into the MPA planning and designation processes is considered vital for success. Commercial fishers are often the stakeholder group most directly affected by spatial restrictions associated with MPAs, and the success of MPAs often depends, at least in part, on the behaviours and attitudes of fishers. MPA planning processes that incorporate fishers, and minimize the negative impact of MPA designation on the fishing community, should therefore have a greater chance of success. Here, the incorporation of both quantitative and qualitative fisher-derived data in MPA planning is investigated using strategic conservation planning software and multi-scenario analysis. We demonstrate the use of spatial access priority data as a cost layer, and suggest a process for incorporating fishers' MPA suggestions into planning scenarios in a transparent, but flexible, way. Results show that incorporating fisher-derived data, both quantitative and qualitative, can significantly reduce the cost of MPA planning solutions: enabling the development of MPA network designs that meet conservation targets with less detrimental impact to fishing community. Incorporating fishers and fisher-derived data in MPA planning processes can improve both the efficiency and defensibility of planning outcomes, as well as contribute to reducing potential conflicts between biodiversity conservation and the fishing industry.

Keywords: biodiversity conservation, fisheries management, marine spatial planning, MPAs, participatory planning, spatial access priority mapping, stakeholders.

Introduction

Marine protected areas (MPAs) are playing an increasingly prominent role in marine biodiversity conservation strategies (OSPAR, 1998; EC, 2007, 2008; DEFRA, 2011), and the global number of MPAs has increased rapidly over the last 20 years (Pita *et al.*, 2011). MPAs can provide many conservation benefits, including: increased biodiversity (Halpern, 2003); increased number and size of previously exploited species (Alcala and Russ, 1990; Bennett and Attwood, 1991; Francour, 1994; Halpern, 2003); increased productivity (Alcala and Russ, 1990); protection for rare or threatened species (Roberts *et al.*, 2005); protection for critical life stages, i.e. spawning and nursery grounds (Gell and Roberts, 2003); and increased ecosystem resilience (Hughes *et al.*, 2005; Micheli *et al.*, 2012; Bates *et al.*, 2013). They have also been shown to provide social and economic benefits (Agardy, 1993; Farrow, 1996) and evidence of the potential of MPAs to support and enhance sustainable fisheries, through spillover of both larvae and adults, is increasing (Beukers-Stewart *et al.*, 2005; Halpern *et al.*, 2010; Russ and Alcala, 2011; Harrison *et al.*, 2012).

There are costs associated with MPAs, however, and their establishment is often still viewed as a conflict between biodiversity conservation and fisheries interests. Commercial fishers are often the most directly affected, socially and economically, by the spatial restrictions associated with MPAs (Jones, 2008). Despite this, many fishers feel they are given insufficient opportunity to participate in decision-making processes, and that their concerns are not taken into account (Himes, 2003; Pita *et al.*, 2010; Shaw and Johnson, 2011; Yates, 2014). The success of MPAs depends at least in part on the behaviours and perceptions of fishers, and inadequate involvement of fishers in the planning process can leave them feeling resentful and suspicious of planning outcomes, which can act as a barrier to buy-in and hinder compliance (Suuronen *et al.*, 2010; Pita *et al.*, 2011). Recognition of the need to incorporate fishers into marine management is growing (Johannes *et al.*, 2000; Rossiter and Stead, 2003; Helvey, 2004; Salas and Gaertner, 2004), and fisher involvement has been shown to lead to better environmental decisions and more sustainable fisheries (Kuperan and Abdullah, 1994; Brody, 2003; Pitcher *et al.*, 2009; White and Courtney, 2010).

One of the ways that fishers can contribute to improved environmental decision-making is through the generation of additional data. Fishers can provide local ecological knowledge that can feed into conservation planning (Silvano and Valbo-Jørgensen, 2008; Thornton and Scheer, 2012), they can suggest potential MPA sites (des Clers *et al.*, 2008; Wheeler *et al.*, 2008; Yates, 2014), and they can improve conservation planners' understanding of the impacts of potential plans on the fishing community. These data can enable planners to more accurately take the fishing community into account when developing MPA networks, and incorporating fisher-derived data into the planning process can help encourage fishers to have a sense of ownership over planning outcomes.

Here, we investigate the use of fisher-derived data in MPA planning. Using strategic conservation planning software, we compare planning scenarios that incorporate fishers' spatial access priority (SAP) data (Yates and Schoeman, 2013a, b) as a cost layer with those that use area as a cost layer. We also examine the impact of incorporating fishers' MPA suggestions into planning scenarios. We show how both quantitative and qualitative fisher-derived data can be used to reduce the detrimental impacts of MPAs on the fishing community, while still producing MPA network designs that meet conservation targets.

Study area

Our study area consisted of Northern territorial waters, up to 12 nautical miles offshore, which covers an area of roughly 4600 km^2. Northern Ireland is a devolved administration of the UK. As a result, marine management in Northern Ireland is governed by a complex hierarchy of legislation and policy, including: International conventions, European directives, National UK legislation, and local Northern Ireland specific legislation (Yates *et al.*, 2013). Recent legislative and policy developments, at all levels, have place an increased emphasis on MPAs and spatial management, and the Northern Ireland Assembly is committed to expanding the existing suite of MPAs to develop a more coherent, representative network (Yates *et al.*, 2013). The newly passed Northern Ireland Marine Act has provided the Assembly with the necessary powers to both expand the existing MPA network and develop a comprehensive Marine Spatial Plan (The Northern Ireland Assembly, 2013). To date, the vast majority of stakeholder engagement in the Northern Irish MPA and Marine Spatial Planning processes have been through a series of large meetings, to which fishers find attendance problematic, or through representatives, whom fishers do not always feel adequately represent them (Yates, 2014). While stakeholders' views are certainly sort and considered, there are currently no defined mechanisms in place for the transparent incorporation of stakeholders' priorities.

There are four main fisheries in Northern Ireland, white fish, *Nephrops*, pot fishing, and scallops, and fishing vessels are based mainly at three fishing ports, Kilkeel, Portavogie, and Ardglass. There are also and over 20 smaller ports where small numbers of pot fishing vessels are based (Figure 1). There are a total of 367 commercial fishing vessels registered in the Northern Ireland fleet, 224 of which are officially recorded as active (DARD, pers. comm.). Historically, white fish (cod, pollock, haddock, whiting) was the largest fishery, supporting over 100 vessels, but a drastic decline in stocks, and thus quota, has meant it is now the smallest. The largest fishery is now the *Nephrops* trawl fishery, which supports over half of the commercial fishers in Northern Ireland. The second largest fishery is the pot fishery, which targets mainly lobster and brown crab, with some velvet crab, whelks, and larger pot-caught *Nephrops*. The scallop fishery is a dredge fishery, which catches a mix of queen and king scallops.

Methods

We investigated the impact of incorporating fisher-derived data into MPA planning processes by incorporating various levels of fisher-derived data (none, qualitative, quantitative) into a series of planning scenarios. We then developed multiple MPA planning solutions, all of which meet a set of conservation targets, and compared both their cost and spatial configuration.

Data

A total of 60 biodiversity conservation features were incorporated into all scenarios. These included: 45 habitats, 2 foundation species, 2 spawning areas, 5 nursery grounds, and 6 depth zones (see Supplementary data S1 for details). Data were provided by the Northern Ireland Department of the Environment (DOE) and the UK Joint Nature Conservation Committee (JNCC). Locations of existing aquaculture sites were also provided by DOE. Aquaculture sites were designated unsuitable for incorporation into MPAs and were therefore locked out of planning solutions.

Fisher-derived data were obtained from interviews with 106 Northern Irish fishers, conducted between 2011 and 2012 (Yates

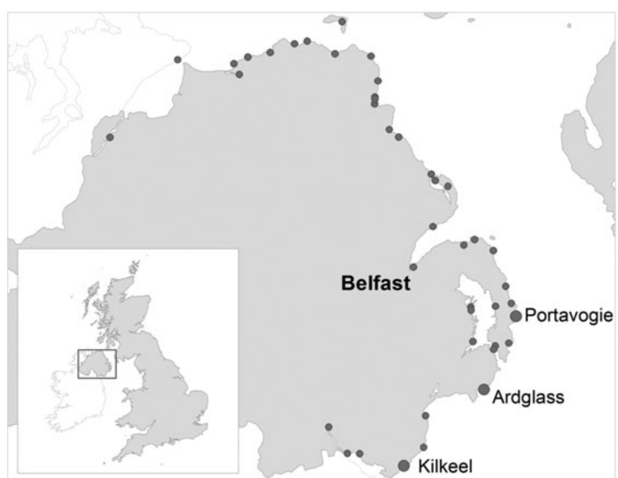


Figure 1. Map of Northern Irish fishing ports, with inset showing Northern Irelands location within the UK.

and Schoeman, 2013a; Yates, 2014). Respondents took part in a semi-structured interview and a mapping exercise, the results from which were used to generate the qualitative [fisher-preferred sites (FPSs)] and quantitative (SAP) data used in this study.

All respondents were vessel skippers and/or owners, 103 were currently active in the industry and 3 were retired. The vast majority of fishers interviewed (>90%) were approached directly at ports; the rest responded to flyers that had been distributed by mail. Before each interview, information sheets detailing the research were provided to fishers and discussed; verbal consent was then obtained from those who chose to participate.

During the mapping exercise, fishers were provided with both paper admiralty charts and digital admiralty charts within a GIS. Fishers were asked if there were any areas they thought should be protected, and those that did were asked to indicate the locations directly onto the digital charts. Over half of the 106 fishers suggested at least one MPA site, with some suggesting multiple sites (Yates, 2014). Fishers' MPA suggestions were overlaid within a GIS and any areas that were suggested by at least five different fishers were classed as FPSs.

Quantitative SAP data were obtained from the 103 active fishers. The active fishers mapped their priority area(s) and assigned relative importance to each area. The total importance value for each respondent was 100. The SAP (km^{-2}) for each area was then calculated by multiplying the number of full-time crew on the associated vessel by the importance value for that area, then dividing by the number of square kilometres the area covered. Results from individual respondents were scaled up using vessel characteristics (home port, fishery, length) to produce SAP maps representative of the whole fleet (Yates and Schoeman, 2013a).

SAP provides quantitative measure of fishers' perceived value of the ocean. As such, it can be used as a surrogate cost layer in planning scenarios, with SAP being fishing value, and the displacement of SAP, due to restricted access, being the cost of that restriction to the fishery(ies). One of the main advantages of SAP data is they can be generated without the need for often unobtainable revenue or landings data because the method uses crew numbers to weight responses (Yates and Schoeman, 2013a).

Planning scenarios

Three primary planning scenarios were developed. Scenario 1 incorporated no fisher-derived data and used area as a surrogate cost layer, the premise being that, in the absence of other data, planning solutions that have a smaller total area will have lower negative impact. Scenario 2 still used area as the surrogate cost layer, but this time included a target for the incorporation of FPSs. FPSs were not locked into Scenario 2 because in combination they constituted 670 km^2 (14.7%) of the study area, thus locking them in might lead to planning solutions that were far greater in area than was required to meet conservation targets. Instead, FPSs were included as a feature in Scenario 2, with an initial target of 50%. Scenario 3 used SAP data as the surrogate cost layer. Each primary scenario was run with and without existing protected areas locked in, and at five different conservation target levels: 10, 15, 20, 25, and 30% of each biodiversity conservation feature.

The cost and spatial configuration of planning solutions for the different scenarios were compared. The cost of planning solutions was defined as the total amount of perceived value that fishers would lose access to, i.e. cost was the total SAP value of all areas included in the MPA planning solutions.

Additional Scenario 2 analyses were then conducted to explore the impact of FPS target level on the cost difference between Scenarios 1 and 2. Ten different FPS targets were used, in scenarios both with and without existing MPAs locked in.

Marxan

Marxan was selected for this analysis because it is the most widely used conservation planning software in the world (Watts *et al.*, 2009). It uses a simulated annealing algorithm to solve a minimum set problem, namely how to incorporate a given target for each of the conservation features into protected areas at the (near) minimum cost.

In this study, MPA site selection analysis was conducted using Marxan version 1.8.10 (Game and Grantham, 2008). The study area was divided up into 5169 planning units. The vast majority of planning units were 1 km^2, with a minority around the coast and on the edge of the study area being smaller. The cost of each planning unit, both in terms of area and SAP, and the amount of each conservation feature contained within it were calculated. Then optimized protected area planning solutions were developed for each of the various planning scenarios. All targets were met in all scenarios. Compactness of solutions was not considered in the analysis (i.e. boundary length modification was zero for all scenarios).

In total, 120 different scenarios were run, each at 200 repetitions. Full details of all scenarios can be found in the Supplementary data S2.

Results

Analysis showed that planning scenarios that incorporated fishers' data consistently had lower cost (SAP) than those that excluded fishers' data (Table 1). The reduction in cost was greatest with the incorporation of quantitative data, Scenario 3, where up to a 66% reduction in SAP displacement was obtained (Figure 2). Solutions from Scenario 3 had consistently lower costs than both Scenarios 1 and 2, across conservation target levels and with and without existing MPAs locked in.

Incorporating qualitative fisher data, Scenario 2, also reduced the detrimental impact on the fishing community, with a reduction of

Table 1. Cost of MPA planning scenarios.

		Target (%)				
Existing MPAs	**Scenario**	**10**	**15**	**20**	**25**	**30**
No	1	7 486.2	11 195.6	15 179.9	18 744.9	22 372.7
	2	6 827.0	10 398.8	13 913.1	17 707.4	21 374.9
	3	2 528.2	4 537.9	6 773.8	9 176.6	11 715.0
Yes	1	9 191.0	11 252.2	14 317.8	17 520.9	20 992.7
	2	8 866.0	10 530.6	13 288.2	16 418.0	19 750.9
	3	8 261.7	9 148.2	10 597.6	12 524.8	14 819.9

The cost of three primary planning scenarios across different conservation targets, with or without existing MPAs locked into the planning solutions. Cost is mean fisher SAP included in the MPA planning solutions, across 200 repetitions of each scenario combination.

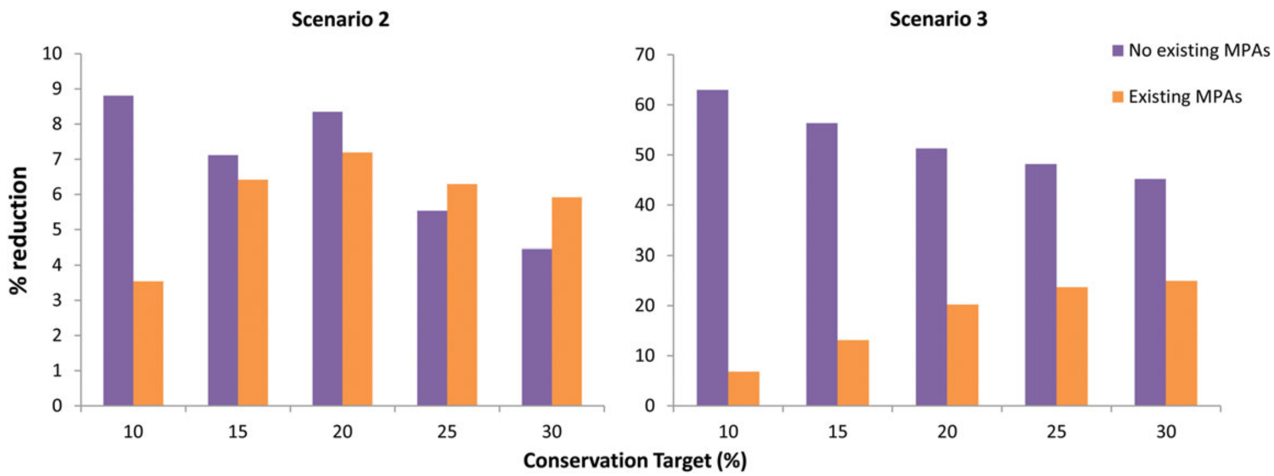


Figure 2. Percentage reduction in cost. The percentage reduction in the cost of MPA planning Scenarios 2 (qualitative fisher data) and 3 (quantitative fisher data) compared with Scenario 1 (no fisher data). Cost is mean fisher SAP included in the MPA planning solutions, across 200 repetitions of each scenario.

up to 9% of the total cost of the planning solutions (Figure 2). Again the reduced cost, compared with Scenario 1, was consistent across conservation target levels and both with and without existing MPAs locked in (Table 1).

A three-factor analysis of variance (ANOVA) showed significant difference in cost between the scenarios ($p < 0.001$, $F = 248\,253$, d.f. $= 2$), but it also showed significant interaction between the other factors (Figure 3). The difference in cost between scenarios varied depending on both the conservation target and on whether the existing MPAs were locked into the solution, or not. Existing MPAs cover 10% of the study area (520 km^2) and locking existing MPAs into planning solutions generally increased the solution cost, particularly at the lower conservation target levels (Table 1). As the conservation target increased, and a greater total number of planning units were incorporated into the solutions, the effect of locking in existing MPAs reduced. At the higher conservation targets in both Scenarios 1 and 2, locking in existing MPAs generated slightly lower cost solutions (Table 1), suggesting that existing MPAs were designated with at least some consideration to the impacts on the fishing community.

Further investigation of Scenario 2 showed that at almost any FPS target level, incorporation of fishers' MPA suggestions reduced the cost of the planning solutions compared with Scenario 1 (Figure 4). Only at the lowest conservation feature target (10%), with MPAs locked in and an FPS target of over 70% did the planning solution cost of Scenario 2 exceed that of Scenario 1 (resulting in a positive cost difference). Existing MPAs cover 10% of the study site and FPSs cover almost 15%. It is no surprise that at a conservation feature target of just 10%, forcing the specific inclusion of almost 25% of the study area leads to higher cost solutions. The fact that the cost of Scenario 2 exceeded that for Scenario 1 only when an area (>20% of study site) more than double the conservation target (10%) was effectively locked in demonstrates how much more efficient MPA planning can be, when it incorporates fisher data.

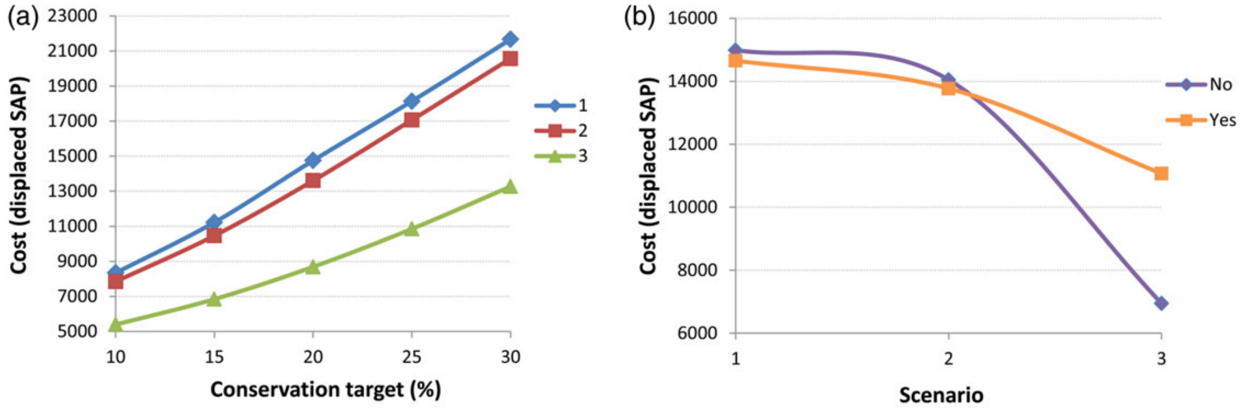
As well as having different associated costs, the three planning scenarios also generated different spatial solutions (Figure 5). Selection frequency (SF) diagrams indicate how many times a given planning unit is incorporated into one of the planning solutions. Adding fisher data influences the spatial pattern of SF. Comparing the SF diagrams of Scenarios 1 and 2, for example, shows how the adding of a target for FPS has increased the SF of planning units in the northeast of the study site. The SF diagrams also show that incorporating fishers' data impacts the numerical spread of the SFs (Figure 5). As the incorporation of fisher data increased (from none in Scenario 1 to qualitative in Scenario 2, to quantitative in Scenario 3), the specificity of solutions increases, with an increasing number of planning units never incorporated into solutions and a subset of planning units incorporated with increasing frequency.

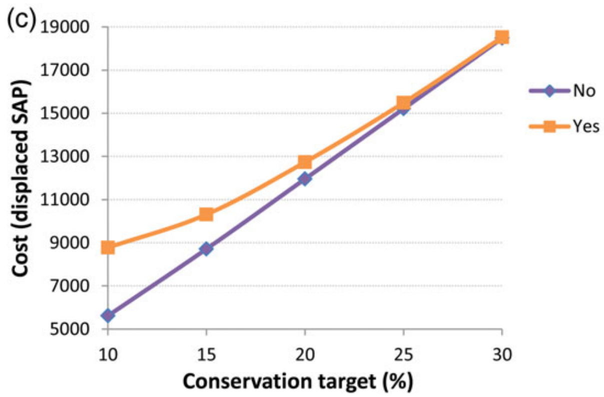
Discussion

Stakeholder participation is widely regarded as a vital component of environmental decision-making processes and stakeholder involvement, particularly in respect of resource-based industry groups, has been shown to lead to better environmental outcomes (Brody, 2003; Pitcher *et al.*, 2009). This study has demonstrated that stakeholder involvement can also lead to significant, and sometimes drastic, reductions in the cost of environmental planning solutions, without compromising on the level of biodiversity conservation.

Arguably quantitative data on the heterogeneity of cost of the planning area are the most useful for conservation planner, as they can enable quantitative comparisons of the impact of different planning options and trade-off analysis. Indeed, here the greatest cost savings were made using quantitative data: incorporation of fishers' Spatial Access Priorities as a surrogate cost layer allowed for the development of planning solutions that reduced the cost of meeting biodiversity conservation targets by up to 66%. However, if quantitative data are absent, this study has shown that incorporating qualitative stakeholder data, in this case, MPA suggestions, can also significantly, if not as greatly, reduce the cost of planning solutions.

It is unsurprising that having data on the spatial heterogeneity of cost allows for the production of lower-cost planning solutions, but the extent of the possible reduction emphasizes the importance of obtaining and incorporating robust, defensible cost data. Different methods for "estimating" (Ban *et al.*, 2009; Giakoumi *et al.*, 2013), "inferring" (Gonzalez-Mirelis *et al.*, 2013) and "documenting" (Klein *et al.*, 2010; Yates and Schoeman, 2013a) fisher cost and surrogate cost data have been developed. The main difference





	df	F	Sig.
Scenario	2	249235	.0005
Target	4	310766	.0005
Existing MPAs	1	26270	.0005
Scenario * Target	8	7354	.0005
Scenario * Existing MPAs	2	41680	.0005
Target * Existing MPAs	4	6080	.0005
Scenario*Target*Existing MPA	8	4904756	.0005

Figure 3. Results for a three-factor ANOVA on the cost of MPA planning solutions. Factors were: scenarios, conservation targets, and whether existing MPAs were locked into solutions or not. Graphs show the mean cost (over 200 repetitions) of: (a) conservation targets under three different planning scenarios, (b) three different planning scenarios with and without existing MPAs locked in, and (c) conservation targets with and without existing MPAs locked in. Standard error bars are included but are too small to be seen (std. error <15 always). Planning solutions were generated using Marxan.

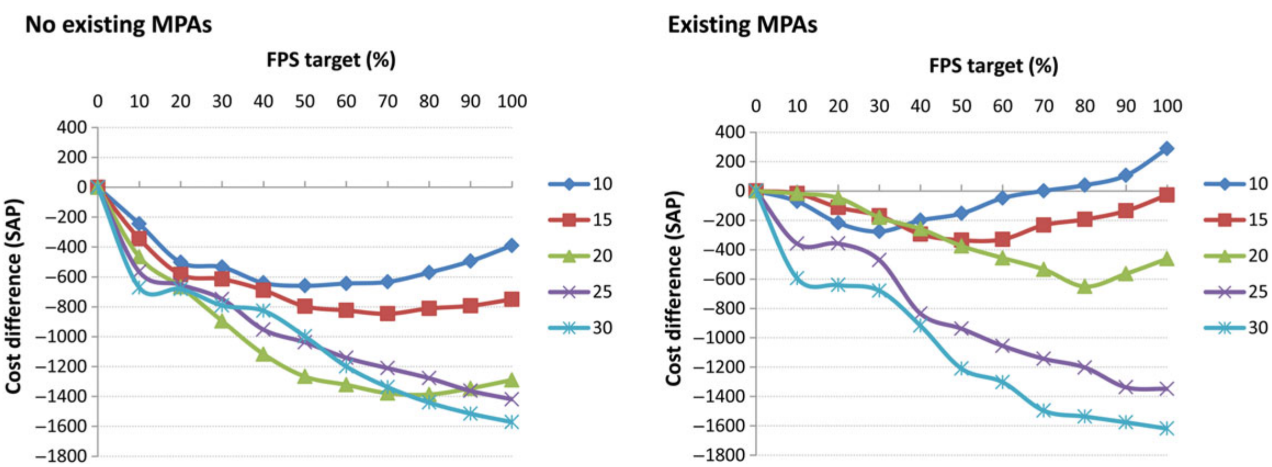


Figure 4. The impact of varying the FPS target on the cost difference between MPA planning solutions that incorporate FPSs (Scenario 2) and those that do not (Scenario 1) is shown at varying FPS incorporation targets. Results, across five different conservation target levels (10, 15, 20, 25, and 30% of each feature), are shown both for solutions that have existing MPA locked in and those that do not. A negative cost difference indicates Scenario 2 had lower SAP displacement than Scenario 1; a positive cost difference indicates Scenario 1 had lower displacement.

between methods is whether fishers are involved in the process, or not. In methods that document cost, it is fishers that identify fishing grounds and allocate relative importance. Estimating methods use surrogates such as distance from port, and inferring methods use remotely sensed data on fishing activity. Results here and elsewhere have shown that spatially explicit cost data can substantially change the planning outcomes (Ban *et al.*, 2009), so it is essential that the cost data developed with the aim of minimizing detrimental impacts on the fishing industry actually reflect fishers' spatial values. It seems likely that methods involving fishers will

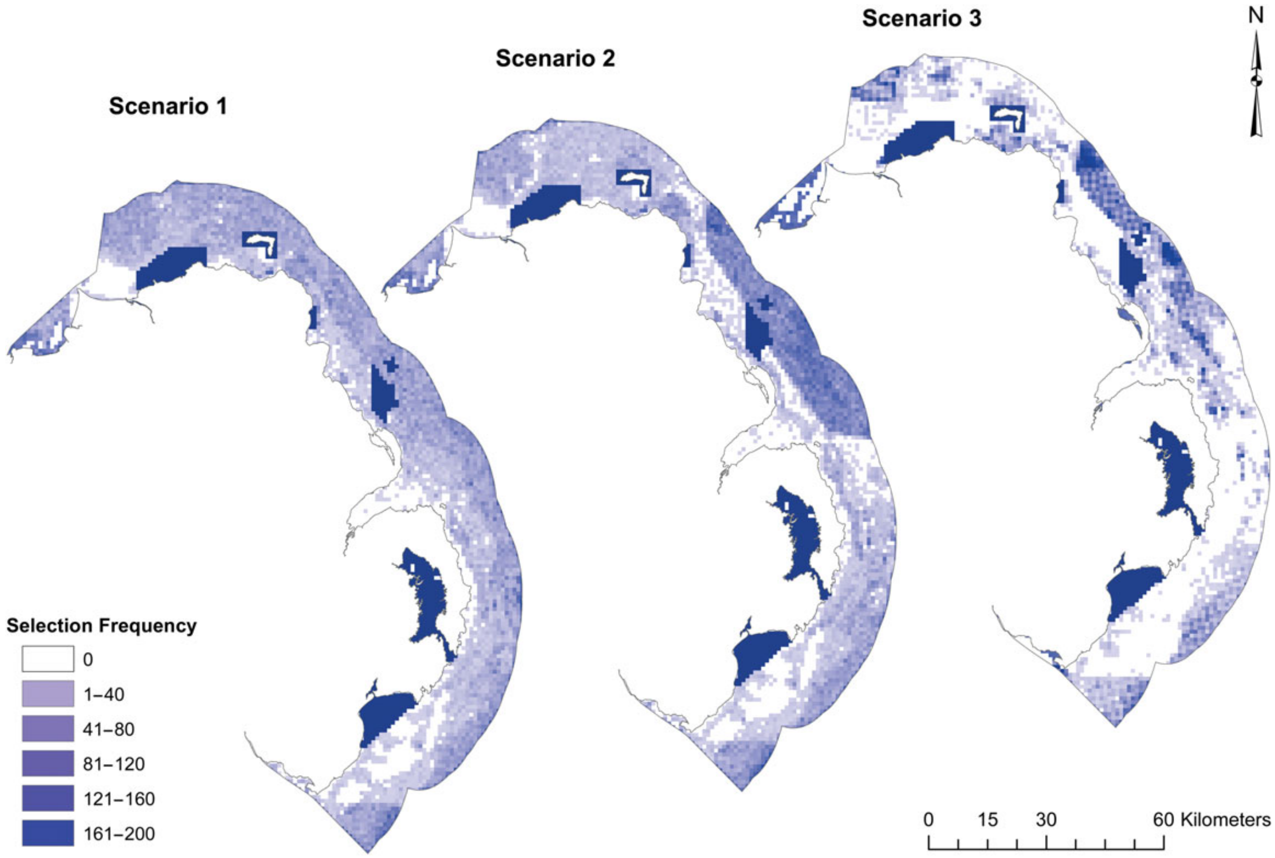


Figure 5. The selection frequencies of planning units differ under different planning scenarios. SF indicates the number of times, out of 200 repetitions, a given planning unit was incorporated into a planning solution. Differences in selection frequencies between scenarios indicate differences in the spatial distribution of planning solutions. Scenario 1 included no fisher-derived data, Scenario 2 included qualitative fisher data, and Scenario 3 included quantitative data. All scenarios had existing MPAs locked in and a conservation feature target of 20%. Scenario 2 had an FPS target of 50%. Planning solutions were generated using Marxan.

most accurately reflect their priorities, and directly involving fishers in the development of cost data in turn involves them in the MPA planning process, with all the associated potential benefits of improved trust, buy-in and compliance (Smith and Berkes, 1991; Duane, 1997; Reed, 2008). It is also, of course, harder for fishers to dispute data that they have been part of generating. Nevertheless, future research to determine how the different methods for generating cost data compare would be of great value.

Generating cost data using documenting methods are relatively resource-intensive and, despite the advantages, they may be considered prohibitively expensive or otherwise unfeasible. The results here have shown the use of fisher-suggested MPA sites offers a possible alternative, which can reduce the cost of planning outcomes, while maintaining direct and transparent involvement of fishers in the planning process.

Fishers suggest potential MPAs for a variety of reasons, including: spawning and nursery grounds, high-productivity areas, high-biodiversity areas, areas of spatial conflict with other fishers or stakeholders, and areas where spatial restrictions would have low negative impact on them or the fishing industry in general. Indication of areas for any of these reasons can provided valuable input into MPA planning process. Individual fishers may, nevertheless, have priorities, and suggest MPAs, that do not align with the overall priorities of the fishing community. Overlaying individual MPA suggestions within a GIS and incorporating only areas that were suggested by multiple fishers (FPSs) should help alleviate this problem. Here, areas identified by at least five fishers were classed as FPSs, but in other situations, a different cut-off may be appropriate.

Including FPSs as a feature with a target, rather than locking those areas into planning solutions, helps to prevent the inclusion of unrequired areas, those that do not contribute to meeting conservation targets, and provides flexibility for the optimization algorithm. The targeted proportion of FPSs will be incorporated into planning solutions, but the specific areas included will depend on what conservation features they contain.

The most appropriate target for the incorporation of FPSs will depend on the planning problem, the total planning area, and the total area of all FPSs. Here, incorporation of FPSs at almost any target level reduced the cost of planning solutions, but that may not always be the case. Generalizations, in terms of the most effective ratio between planning area, FPS area, FPS targets, and conservation feature targets, may emerge if this method was applied in multiple other studies. In the meantime, if minimizing cost is the primary objective, it is possible to manually calibrate the FPS target to avoid the incorporation of extensive unrequired areas, by observing how the amount of conservation features included in planning outcomes compares with their target. If conservation features greatly exceed their targets, it may be that the FPS target is too high. If conservation feature targets are not exceeded, a higher FPS target might be appropriate. Through an iterative process, planners could optimize a problem-specific target for the incorporation of fishers' suggestions, and potential-associated cost reductions, without incorporating unrequired areas, and potential cost increases.

The importance of incorporating fishers (and other stakeholders) into marine management and marine spatial planning processes has led to stakeholder engagement being an increasingly legislated requirement for management agencies and governments (EC, 1998; The House of Commons, 2009). However, even when directly targeted as key stakeholders, fishers repeatedly report the perception that their needs and views are not adequately taken into account (Himes, 2003; Stump and Kriwoken, 2006; Nutters and Pinto da Silva, 2012). There is a need for improved engagement mechanisms and increased transparency, so that fishers can readily see how their input has been incorporated into decision-making processes. Here, we have demonstrated how fisher-derived data, both quantitative and qualitative, can be incorporated into strategic conservation planning in a transparent, easily communicated manner. Even if cost reductions from doing so were relatively small, incorporating fisher data in this way should offer many other benefits. The result of incorporating fisher data can be readily seen in the spatial configuration of planning solutions, providing planners with a simple and effective way of demonstrating to fishers how their information has been used and the influence it has had on potential planning solutions. This should improve the accountability of the planning process, which in turn should help increase trust and contribute to improved fisher buy-in to planning outcomes.

This study has shown that the incorporation of fisher-derived data, both qualitative and quantitative, can reduce the cost of MPA planning solutions. A similar process, possibly within the remit of multi-use ocean zoning, could be applied to spatial planning for other purposes, such as the rapidly expanding marine renewable energy industry. An underlying assumption in processes such as these, which reduce the cost of planning solutions, is that solutions that have a lower cost to the fishing community will be more palatable to fishers and thus will be associated with a reduced level of conflict. Testing this underlying assumption was beyond the scope of this study; it would however make a valuable avenue for future research.

Conclusion

The incorporation of fisher-derived data, both quantitative and qualitative, into MPA planning can significantly reduce the cost of MPA planning solutions to the fishing industry, which in turn should contribute to reduced conflict between biodiversity conservation and the fishing industry. Planning future MPAs through strategic, transparent processes that allows stakeholders to readily appreciate how their input has influenced outcomes should improve both stakeholder trust in the planning process and buy-in to planning outcomes.

Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

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