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The impacts of species portfolios and democratic rulemaking on fisher support for addressing ecosystem trade-offs in fisheries: Lessons from Northern Peninsula, Newfoundland

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Abstract

This paper examines the politics of trade-offs in fisheries management to consider factors that might facilitate the inclusion of ecosystem considerations in fisheries management plans. Fisheries can have significant impacts on the structure and function of marine ecosystems, including impacts on habitats and non-target species. As a result management agencies face growing calls to develop and implement policies to account for the ecosystem impacts of fishing, but often face resistance from stakeholders with vested interests in the status quo. We assessed the impacts of two specific factors; namely the species portfolios of fishers and democratic rulemaking on the attitudes and well-being of shrimp fishers towards a selective fisheries closure to protect crab fishing grounds in Newfoundland, Canada. We found that shrimp fishers were more likely to support this closure if they also fished for crab, and felt they had an influence on the management of the fishery. Furthermore species diversification was associated with higher levels of subjective economic well-being. This study contributes to an emerging discourse on the human dimensions of ecosystem-based fisheries management, highlighting opportunities to pursue the social and environmental goals of ecosystem-based fisheries management through species diversification and potentially democratization of fisheries management.

1. Introduction

Marine fisheries face a number of threats with profound implications for marine ecosystems and society. Whereas problems associated with overfishing (Pauly et al. 1998, Myers and Worm 2003) and shifts in the relative abundance and distribution of species remain (Sumaila et al. 2011, Cheung et al. 2013, Mullowney et al. 2014), there is a growing concern about the broader impacts of fishing activities on the structure and function of marine ecosystems (Crowder et al. 2008, Cury et al. 2011, Smith et al. 2011, Eero et al. 2012, Eddy et al. 2016). As a result, scholars and fisheries managers are increasingly calling for the development and implementation of strategies to manage the ecosystem impacts of fishing. These include controls on the exploitation of forage species to account for the needs of dependent predators, (Rice and Duplisea 2014, Eddy et al. 2016, WWF 2016), rules to limit non-target mortality and bycatch (Pikitch et al. 2004, Phillips et al. 2010), and protect critical habitats (Kaiser et al. 2002, Link et al. 2011). Progress towards these objectives has been slow (Pitcher et al. 2009). However, as broad support for the general notion of ecosystem-based management (Biedron and Knuth 2016, Long et al. 2016) masks opposition to specific policies such as marine protected areas, fisheries closures, and reductions in catch limits that directly affect the interests of fishers, or segments thereof (Browman et al. 2005, Bennett and Dearden 2014, Cavanagh et al. 2016). Therefore, this paper examines how policies might be designed to build stakeholder support for the inclusion of ecosystem considerations in fisheries by considering the impacts of species portfolios and stakeholder participation on the political attitudes of shrimp fishers in Newfoundland, Canada.

The sustainability of resources has long been understood to depend upon the ability of groups to develop strategies to address social dilemmas (Gordon 1954, Hardin 1968). Common-pool

resources, such as fish, present challenges for human society because of a mismatch between public and private interests, generating incentives that promote excessive short-term exploitation at the expense of resource conditions and the long-term interests of fishers and society. These problems can be addressed by assigning secure and enforceable harvesting rights to individuals or groups, providing incentives for sustainable use and conservation of resources (Ostrom 1990, Pomeroy et al. 2001, Hilborn et al. 2005, Grafton et al. 2006, Costello et al. 2008, Branch 2009, Gutierrez et al. 2011, Pons et al. 2016). However, unlike the single resource context where actors primarily face trade-offs between short and long-term gains, ecosystem considerations tend to give rise to trade-offs among different the interests of different actors, activities and objectives (Leslie and McLeod 2007, Cheung and Sumaila 2008).

Protected areas, for instance, appear to prioritize conservation interests at the expense of fishers (McShane et al. 2011), while selective fisheries closures and conservation of lower trophic level species (i.e. forage fish) deliver benefits to sub-groups of fishers at the potential expense of other sub-groups (Mullowney et al. 2012, Rice and Duplisea 2014). Consequently, policies designed to address the ecosystem impacts of fishing tend to result in political trade-offs and conflicts, potentially undermining their adoption as key stakeholders organize to resist them. Indeed, the politics of fisheries management is often highlighted as a key barrier for achieving sustainability in fisheries as fishers and the politicians seeking their votes exploit scientific uncertainties in pursuit of short-term economic and electoral returns (Botsford et al. 1997, Daw and Gray 2005). Absent the political will to impose policies to address the ecosystem impacts of fishing, there is a need to better understand how stakeholders might come to support, or perhaps even demand the adoption of such policies themselves. Therefore in what follows we provide a brief

introduction to one such conflict among northern shrimp (*Pandalus borealis*) and crab (*Chionoecetes opilio*) fishers in Newfoundland and Labrador, Canada before turning to theory to consider factors that might facilitate the management of ecosystem trade-offs in fisheries.

1.1. Background on the Northern Shrimp Fishery

Northern shrimp and crab fisheries became increasingly important to the resource based economy of rural Newfoundland with the collapse of more traditional groundfish stocks which was accompanied by rapid increase in the abundance of invertebrate fisheries. As a result of this increased abundance, the Department of Fisheries and Oceans determined that shrimp were underexploited by the existing offshore shrimp fleet and initiated a process by which inshore operators affected by the groundfish closure could obtain a license for shrimp if they geared up (i.e. acquired suitable vessels and gear) to participate in this fishery. However, as the inshore shrimp fishery expanded they increasingly came into conflicts with crab fishers who argued that shrimp trawling was having a variety of negative impacts on crab, including damage to habitats, leg loss, damaged carapaces and mortality. As a result the crab fishers successfully lobbied for a selective fisheries closure in the Hawke Channel, which prohibited trawling in a 1,370 km² area of shrimp fishing area (SFA). This was later expanded to approximately 8800 km² in 2004 and was joined by the approximately 7300 km² Funk Island Deep closure, in 2005 both of which are shown in Figure 1 below. It is worth noting that these closures came about within the first ten years of the inshore shrimp fishery, and at a time when stocks and quotas (Figure 2) appeared to be on the rise; both of which potentially facilitated adoption and implementation.

The case of the shrimp fisheries closures provides a clear example that it is possible for stakeholders and governments to develop policies to address the ecosystem impacts of fishing

(Kincaid and Rose 2014). However, 74% of shrimp fishers interviewed for this research would like to see these areas opened to commercial shrimp fishing (Figure 3). At a minimum, these closures impose opportunity costs on shrimp fishers by displacing them from potential fishing grounds, and may increase operational costs if fishing pressure and/or environmental factors affect the relative abundance of shrimp within and outside of the closed area. These issues have been further exacerbated in recent years as both crab and shrimp stocks have declined significantly as part of a more general shift in the species composition of the North Atlantic ecosystem (Cheung et al. 2013, Mullowney et al. 2014). Nonetheless, a non-trivial fraction of shrimp fishers (~19%) were opposed to opening closed areas, providing a valuable opportunity to consider factors that might facilitate the management of ecosystem trade-offs in fisheries.

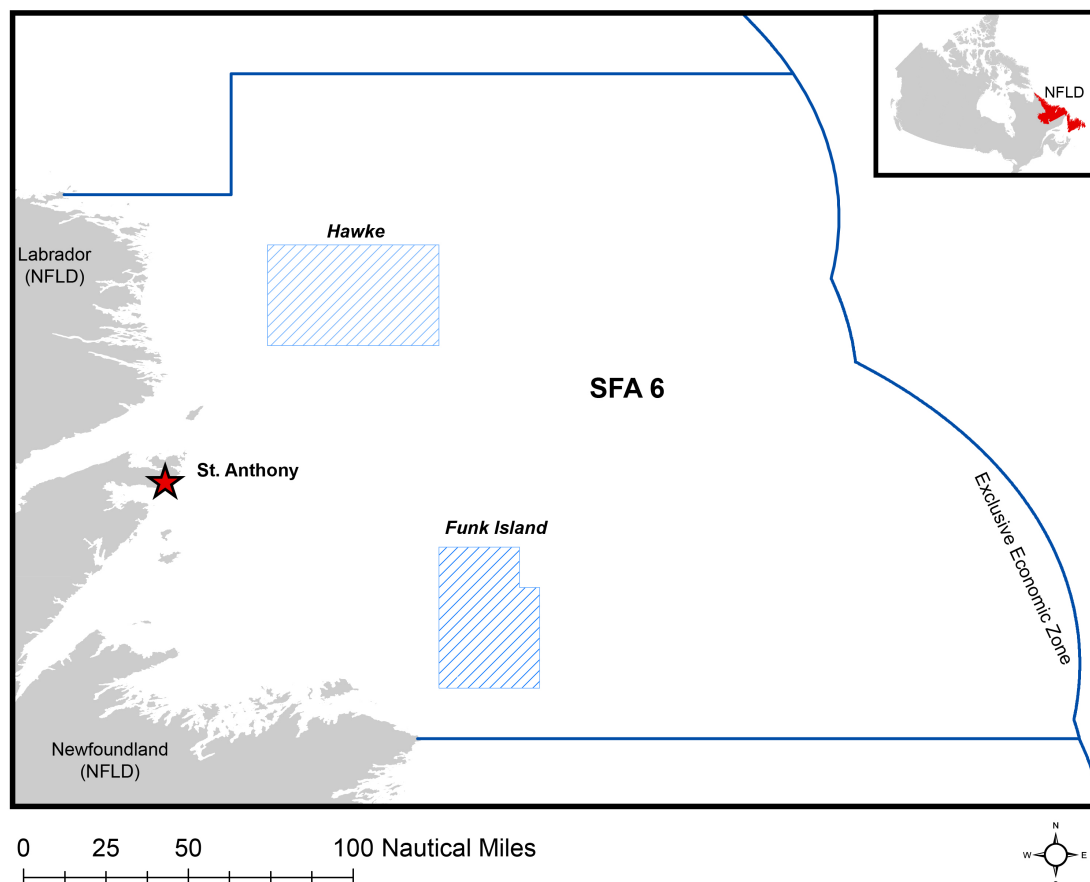


Figure 1: Map of closed areas and shrimp fishing area (SFA) 6

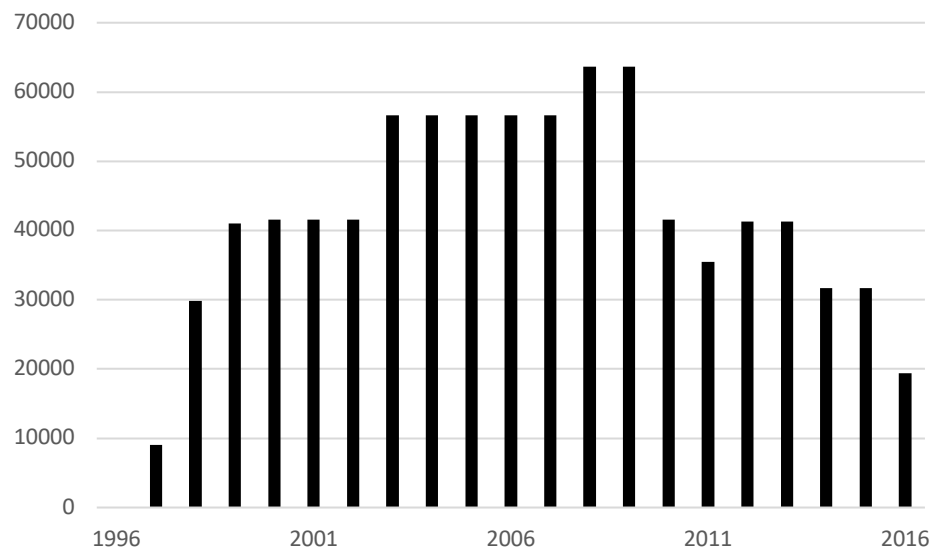


Figure 2: Inshore shrimp quotas in shrimp fishing area (SFA) 6

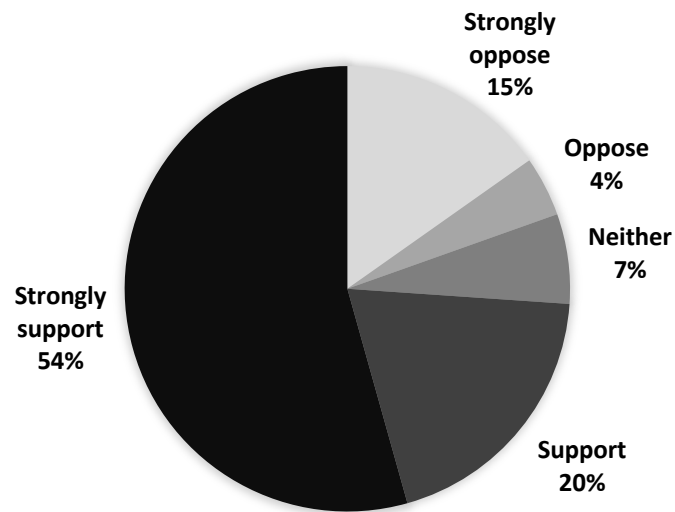


Figure 3: Political attitudes of shrimp fishers towards the opening of closed areas surveyed in St. Anthony, Newfoundland (n=46).

1.2.Managing the ecosystem impacts of fisheries

The ecosystem impacts of fishing are a classic example of an externality, wherein a mismatch between public and private interests result in costly impacts and outcomes for society (Buchanan and Stubblebine 1962, Martinet and Blanchard 2009). Externalities underlie a wide range of environmental problems including overexploitation of fisheries and other common-pool resources, pollution and climate change, and the broader impacts of human activities on natural ecosystems. Private actors are compelled to contribute to these problems because they face only a fraction of the total costs of their actions. Thus in the absence of additional incentives they are typically better off ignoring them to pursue their own individual self-interest. A considerable body of research has therefore developed to better understand the ways in which incentives might be provided to align private interests with those of society (Gordon 1954, Hardin 1968, Ostrom 1990, Grafton et al. 2006). While the specific source of these incentives can vary immensely, recent research highlights two general classes of incentives; namely internalization of economic costs through rights-based or price-based policies, and intrinsic motivation through meaningful participation in rulemaking processes.

Rights-based approaches in fisheries generally include strategies such as individual transferable quotas (ITQ's) and territorial use rights for fishing (TURF's) that provide long-term rights for some fishers to use resources, while excluding others. This in turn provides incentives for fishers to invest in the long-term sustainability of resource use (Grafton et al. 2006, Costello et al. 2008), provided of course that systems are in place to exclude outsiders and prevent overfishing by free-riders (Basurto and Ostrom 2009). Rights-based approaches have, however, also been criticized by some for providing incentives for the conservation of certain species or areas, while neglecting impacts on the broader ecosystem (Smith et al. 2009, Gibbs 2010).

Recent insights from research applying a network approach has proposed a conceptually simple solution to this problem by arguing that groups are more likely to sustainably exploit two or more interconnected resources when actors use and are involved in the management of each (Bodin et al. 2014). More specifically when actors derive benefits from two or more resources, the use of one or both of which has an impact on the other, then they have at least some economic incentive to invest in strategies to reduce the indirect impacts of resource use. For instance, a shrimp fisher that also fishes for crab might be opposed to opening closed areas because they enjoy some of the economic benefits of that closure while fishing for crab. They may also have a more holistic understanding of the relationship between shrimp trawling and impacts on the crab fishery based on personal experience. Furthermore, because of the natural variability of fish stocks it has been suggested that species diversification may also enhance the well-being of fishers by increasing their resilience to social and environmental change (Kasperski and Holland 2013, Cline et al. 2017).

There is also abundant empirical evidence suggesting that participatory rulemaking can facilitate the management of social dilemmas, contributing to higher levels of cooperation, compliance, and in many cases more sustainable management of resources (Ostrom 1990, Cox et al. 2010, Baggio et al. 2016, Epstein 2017). Although there is some debate about the specific mechanisms linking participation to cooperation (see Abatayo and Lynham 2016), self-determination and crowding theory argue that meaningful participation in decision-making processes provides intrinsic motivation for cooperation by satisfying innate psychological needs for self-determination (Deci and Ryan 2000, Frey and Jegen 2001). As a result actors choose to pursue

socially beneficial actions and outcomes not because of the potential for economic returns, but rather because they come to personally endorse and value actions prescribed through participatory decision-making processes (DeCaro and Stokes 2008). Moreover, because participation helps to satisfy innate psychological needs it has also been suggested that participation may be associated with increased well-being (Ryan and Deci 2000). Indeed, an empirical study of Swiss residents found that citizens with voting rights reported higher levels of subjective well-being than foreign residents, while those living in jurisdictions with extended participation rights (i.e. ballot initiatives, public referenda) reported higher levels of well-being than those that lacked such rights (Stutzer and Frey 2006).

2. Data and Methods

Data was collected using a dockside survey of shrimp fishers in St. Anthony, Newfoundland between August 8-19, 2016. A total of 52 fishers responded to the survey, 46 of which are included in the analysis as a result of listwise deletion of observations due to missing data on one or more variable. The final sample includes 13 license holders and 33 crew members. A typical shrimp vessel employs three to four crew members and thus, the sample is slightly biased towards the views and perspectives of licence holders. Finally, the shrimp fishery in SFA 6 is a particularly important source of income for the fishers, more than two thirds of whom more than 60% of their total fishing income in this fishery.

Summary statistics are reported in Table 1. Three dependent variables were used in this study:

(i) ‘oppose’, records whether a fisher is strongly or somewhat opposed to opening closed areas to shrimp fishing (1) or not (0), as well as index measures of (ii) the social, and (iii) economic well-being of fishers. The concept of well-being has been the subject of considerable theoretical

debate in recent years, as scholars highlight of the opportunity to improve our understanding of material or income-based measures, by emphasizing a more holistic approach that includes relational and subjective well-being (Coulthard et al. 2011, Daw et al. 2011, Hamann et al. 2016). This particular study adopts a subjective approach by asking respondents to indicate their level of satisfaction with several life domains using a five point Likert scale, and then aggregating these measures using a principal component analysis of the polychoric correlation matrix. The economic well-being index is comprised of three items that record levels of satisfaction with one's income, savings, and debt, and explains approximately 71% of the total variance of the three items (Table S1). The social well-being index, meanwhile, is comprised of five items that record levels of satisfaction with one's personal health, stress, free time and leisure, relationships with family and friends, and employment, explaining over 82% of the total variance (Table S2).

A logistic regression is used to estimate the impacts of species portfolios and democratic rulemaking on the likelihood that a shrimp fisher opposes opening closed areas to shrimp fishing. Crab income records whether a fisher earned any part of their fishing income in the past year from crab, reflecting the hypothesis that fishing portfolios that include affected species will affect attitudes towards policies designed to address the ecosystem impacts of fishing. The democratic rulemaking hypothesis, meanwhile, is operationalized using two separate measures. Participation indicates whether a fisher attended consultations in the past year, while political efficacy is a composite measure of three items related to the perceived influence of "people like them", the large offshore fishing fleet, and government scientists on rulemaking in the shrimp fishery. This index explains approximately 63% of the total variance of the three items (Table

S3), and has been used in similar studies seeking to explain collective action and compliance (i.e. Scholz and Lubell 1998). Lower values correspond to a perception that rulemaking in the shrimp fishery is heavily influenced by the perspectives of others; while larger values indicate that “people like them” exert more influence than others. Several additional variables are included to account for potentially intervening factors. For instance, livelihood diversification might influence decisions to pursue additional fishing opportunities, while also reducing the impacts of closures on individual fishers (Allison and Ellis 2001).

Finally, linear regressions are used to estimate the impacts of species portfolio diversification and democratic rulemaking on the social and economic well-being of fishers. Because ecosystem considerations often involve reductions in catches or increases in costs for individual fisheries (for some exceptions see Rice and Duplisea (2014)), it is important to consider the impacts of strategies on the welfare of fishers. Ideally, strategies designed to address the ecosystem impacts of fishing would also contribute to the social and economic well-being of individual fishers. Variables included in these models are identical to the attitudes model as we would generally expect a close relationship between well-being and political attitudes towards the closures. The only exception is that species diversification, which measures the number of species from which a fisher has earned income in the past year, replaces crab income.

Table 1: Descriptive statistics (n = 46)

Variable	Description	Mean	Std. Dev.	Min	Max
Dependent variables					
Oppose	Binary. Respondent is opposed to opening closed areas to commercial shrimp fishing.	0.196	0.401	0	1
Economic well-being	Continuous. Index of respondent's level of satisfaction with income, savings and debt.	0.000	0.953	-2.362	2.087
Social well-being	Continuous. Index of respondent's level of satisfaction with stress, personal health, relationships, leisure and employment	0.000	0.975	-2.315	1.180
Independent variables					
Crab Fisher	Binary. Respondent earned income from crab in the past year	0.304	0.465	0	1
Species diversification	Ordinal. Number of species from which fisher earned income in the past year	1.543	0.862	1	5
Participation	Binary. Respondent participated in consultations in the past year	0.152	0.363	0	1
Political efficacy index	Continuous. Index of respondents perceived influence on management process	0.000	0.921	-0.476	4.859
Dependence	Ordinal. Fraction of income derived from shrimp fishing in Area 6.	2.957	0.842	1	4
License holder	Binary. Respondent owns license for shrimp fishing in Area 6	0.283	0.455	0	1
Livelihood diversification	Binary. Respondent earns income from sources other than commercial fishing.	0.173	0.382	0	1
Married	Binary.	0.783	0.417	0	1
Age	Continuous. Age of fisher	45.630	12.776	18	68

3. Results

The results are presented in two sections below. The first section addresses questions concerning the impacts of crab fishing, participation, and political efficacy on the political attitudes of shrimp fishers towards closed areas. These results may be used to inform the development of strategies, such as the promotion of greater participation, devolution of authority, or species portfolio diversification to manage ecosystem trade-offs in fisheries. The second section continues by considering the potential impacts of species diversification, participation and political efficacy on the subjective social and economic well-being of fishers.

3.1. Political attitudes

Table 2 reports coefficients, standard errors, and confidence intervals, in addition to several scalar model statistics. Model fit was assessed using several measures including a chi-square test, count R^2 , and by visually analyzing model residuals (Figure S1). Count R^2 reports the fraction of observations correctly assigned by the model, showing that the model is successful in classifying over ninety percent of the observations.

Table 2: Logistic Regression Results

	Coefficient	Std. Err.	p-value	95% Confidence Interval	
Crab income	7.040	1.555	0.000	3.992	10.088
Participation	-2.494	1.131	0.027	-4.710	-0.278
Political efficacy	1.370	0.370	0.000	0.646	2.094
Livelihood diversification	0.381	1.385	0.783	-2.334	3.096
Dependence	0.994	0.830	0.231	-0.634	2.622
License	1.535	1.594	0.335	-1.588	4.659
Married	-0.097	1.131	0.932	-2.314	2.120
Age	0.056	0.070	0.427	-0.082	0.194
Constant	-12.194	5.731	0.033	-23.427	-0.961
N	46				
Count R ²	0.913				
Chi-square	134.92				
p-value	0.000				
Mean VIF	1.42				
Max VIF	1.79				

The results suggest that both crab fishing income and political efficacy have a positive and statistically significant impact on the likelihood that a shrimp fisher is opposed to opening closed areas to shrimp fishing. However, participation is associated with a lower likelihood of opposition. Additional models presented in the appendix omit participation (Table S4) and political efficacy (Table S5) because of a general theoretical expectation that they would be closely related (DeCaro and Stokes 2013). However, neither of these changes has an impact on the sign or significance of crab income, participation, or political efficacy coefficients, and in fact there appears to be a limited relationship between participation and the political efficacy of shrimp fishers ($p = 0.090$, $p > 0.10$).

Figure 2A plots the probability that a fisher with and without crab fishing income would oppose opening closed areas, and reveals substantial differences between the two groups. Whereas the likelihood of opposing the opening of closed areas is approximately 59% among crab fishers, it is barely above zero for non-crab fishers. Figure 2B plots the probability that a fisher would

oppose opening closed areas as political efficacy varies from its minimum to maximum value. It shows that fishers with higher levels of political efficacy are more likely to oppose opening closed areas to shrimp fishing, although confidence intervals include zero throughout much of its range. None of the remaining factors have a statistically significant impact on the political attitudes of shrimp fishers.

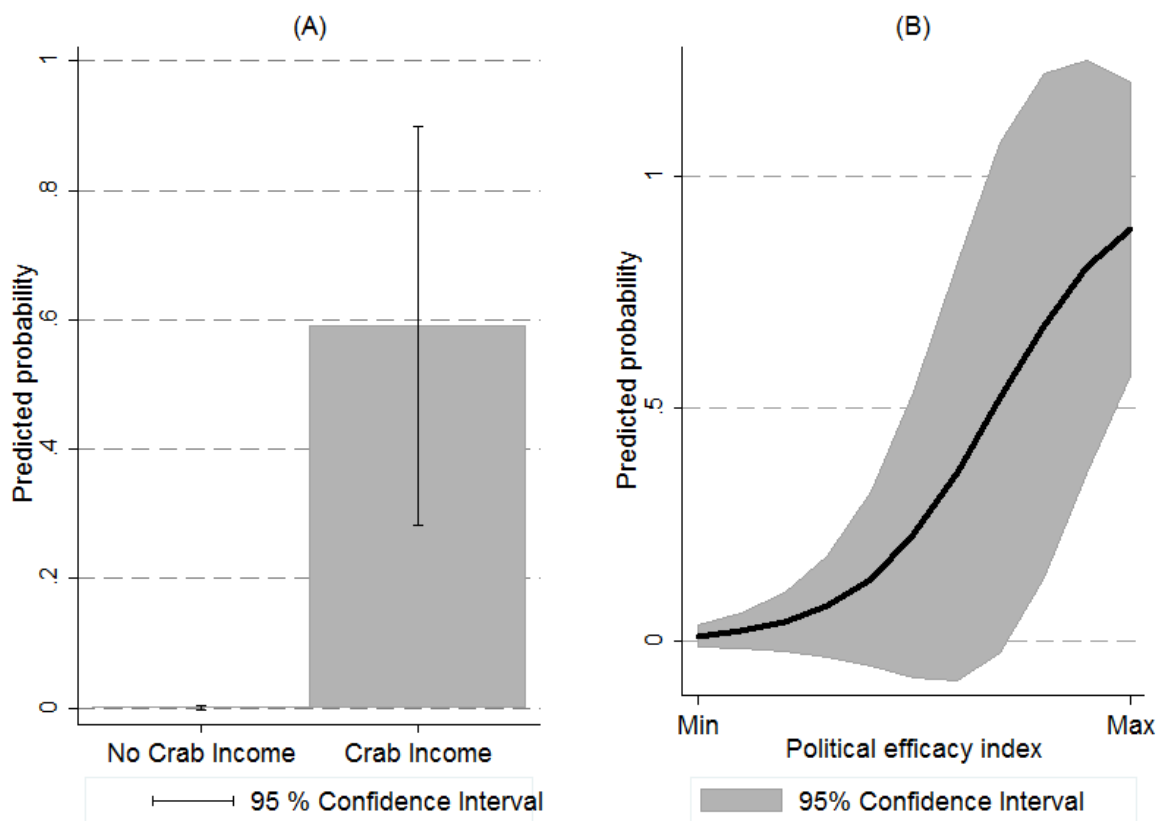


Figure 3: Predicted probability of opposing the opening of closed areas as a function of (A) crab income, and (B) levels of political efficacy. All other values are held at their respective sample means.

3.2. Well-being

Table 3 and 4 summarize the results of two linear regressions estimating the impact of species diversification, livelihood diversification, and democratic rulemaking on the economic and social well-being of fishers, while controlling for several additional factors. Before turning to the

individual hypotheses, it is worth noting that the model performs better in explaining the variation of the economic well-being index. The results suggest that neither participation nor political efficacy have an impact on either outcome. However, fishers that earned income from a more diverse portfolio of species tended to enjoy higher levels of economic well-being ($p < 0.01$), while livelihood diversification was associated with higher levels of social-well-being ($p < 0.10$). Several fishers expressed personal difficulties with short fishing seasons, which are influenced by several factors including the size of quotas and efficiency of fishing technologies. Thus, diversification outside of fisheries may provide important intangible benefits to fishers, contributing to higher levels of social well-being.

Table 3: Economic well-being

	Coefficient	Std. Err.	p-value	95% Confidence Interval	
Species diversification	0.512	0.161	0.007	0.168	0.857
Livelihood diversification	-0.109	0.421	0.799	-1.013	0.794
Participation	0.205	0.342	0.558	-0.528	0.938
Political efficacy	0.070	0.100	0.497	-0.145	0.285
Dependence	-0.327	0.128	0.023	-0.601	-0.053
License	-0.178	0.292	0.552	-0.805	0.449
Married	-1.057	0.369	0.013	-1.850	-0.265
Age	0.011	0.013	0.422	-0.018	0.040
Constant	0.525	0.533	0.341	-0.618	1.668
N	45				
R ²	0.427				
Adjusted R ²	0.300				
F	14.00				
p-value	0.000				
Mean VIF	1.41				
Max VIF	1.81				

Note: Standard errors are clustered by the town in which the fisher lives

Table 4: Social well-being

	Coefficient	Std. Err.	p-value	95% Confidence Interval	
Species diversification	0.286	0.273	0.313	-0.299	0.871
Livelihood diversification	0.570	0.316	0.093	-0.107	1.248
Participation	-0.072	0.194	0.716	-0.488	0.344
Political efficacy	-0.169	0.261	0.528	-0.728	0.390
Dependence	-0.172	0.248	0.499	-0.704	0.360
License	-0.378	0.194	0.072	-0.794	0.038
Married	-0.777	0.228	0.004	-1.267	-0.288
Age	0.009	0.010	0.384	-0.013	0.031
Constant	0.311	0.425	0.477	-0.601	1.223
N	44				
R ²	0.205				
Adjusted R ²	0.023				
F	21.78				
p-value	0.000				
Mean VIF	1.41				
Max VIF	1.80				

Note: Standard errors are clustered by the town in which the fisher lives

4. Discussion and Conclusion

The ecological basis for developing and implementing policies to address the ecosystem effects of fishing is clear (Pikitch et al. 2014, Rice and Duplisea 2014). Although important questions remain concerning the science of marine ecosystems, including debates concerning our capacity to reliably predict and manage the ecosystem impacts of fishing (Hilborn 2011); perhaps the most significant challenge (and therefore promise) rests in the development of strategies to address trade-offs (Kellner et al. 2011). More specifically there is abundant empirical evidence to suggest that even well-intentioned and often urgently needed environmental policies are prone to failure if they neglect the human dimensions of resource use (Liu et al. 2007, Charles and Wilson 2008, Bennett and Dearden 2014). Thus, this research which highlights two potential pathways, namely species portfolio diversification and democratic rulemaking to manage trade-

offs may inform further developments in the theory and practice of ecosystem-based management, contributing to more sustainable use of marine resources.

Before turning to the implications of this research it is important to make note of its limitations.

First and foremost, the sample which includes 46 individuals does not necessarily reflect the population of 1200 to 1300 affected shrimp fishers. Fishers were selected based upon their presence at the most important landing site for shrimp by weight during the time of research, excluding fishers from other locations and those that had already captured their quota.

Furthermore this sample compares favourably to recent published research involving shrimp fishers in Newfoundland which were able to collect samples of 19 (Kincaid and Rose 2014), and 54 (Foley and Mather 2016), respectively. Second, although crab fishers clearly believe they have benefited from these closures (Kincaid and Rose 2014) debates remain as to their actual impact on the health and abundance of crab. More specifically, several studies have questioned the magnitude and extent of impacts of shrimp trawling on crab (Dawe et al. 2007, Mullowney et al. 2014, Nguyen et al. 2014), while others have found that any of the potential benefits for recruitment have been negated by the intensity of crab fishing in these closures (Mullowney et al. 2012). Third and finally, this research which took place during a period of rapid declines in resource conditions may have influenced the perspectives of fishers, contributing to high levels of support for opening closures. In fact it is possible that the closures themselves were facilitated by the relative abundance of shrimp at the time. Nonetheless, evidence of some, albeit limited ongoing support for closures, and the relationships observed in this study demonstrate that stakeholders may be willing to support policies designed to address ecosystem trade-offs even in a context of crisis and resource decline.

This study suggests that the development and implementation of policies to address trade-offs in fisheries might be facilitated by expanding the species portfolios of fishers, with a particular emphasis on interrelated species. This coincides with theoretical predictions that the use of interlinked resources internalizes the costs and benefits of resource use, contributing to more sustainable use of each (Bodin et al. 2014) . It is also consistent with research suggesting that species portfolio diversification can enhance the well-being of fishers by increasing their resilience to social and environmental change (Kasperski and Holland 2013, Cline et al. 2017). Indeed, although the twentieth century corresponds to a period of increasingly specialized fisheries, there has been a growing chorus of scholars highlighting the broad benefits of diversification, including internalizing costs and benefits, increased resilience to changes in the abundance of resources, and a better understanding of the structure and function of an ecosystem (Bodin et al. 2014, Lindahl et al. 2015, Stoll et al. 2016). Nonetheless, questions about access to resources are often highly contentious (Charles 1992, Chuenpagdee and Jentoft 2009), particularly in Newfoundland where rapid shifts in the abundance of species have led to political battles over allocations to changing quotas (Sprout et al. 2016). Thus, the promotion of species diversification to help resolve conflicts between users of different resources may simply engender conflicts over the size and allocation of quotas for the same resource.

Further questions remain as to how economic incentives might be generated in situations where trade-offs arise between conservation goals and resource use, and whether these will have similar impacts on the attitudes and well-being of stakeholders. In this instance, economic incentives were provided by harvesting a resource with well-established markets. However, such markets

are typically lacking when it comes to protected areas, and the conservation of forage species for some types of dependent predators, such as seabirds (Cury et al. 2011). Payments for ecosystem services and eco-labelling programs may be relevant in this regard. However, despite their theoretical promise, many have failed to achieve their objectives (Wunder et al. 2008, Muradian et al. 2013). Pecuniary sanctions that punish actors for undesirable behaviour or outcomes, rather than rewarding them for desirable ones are another option that have proved successful in managing conservation trade-offs in some fisheries (Grafton et al. 2006). However, it is unlikely that sanctions would stimulate support from affected stakeholders unless paired with some type of positive economic rewards.

In addition to species portfolio diversification the results highlight the possibility of addressing trade-offs by delegating greater authority to stakeholders for rulemaking. This is consistent with several studies that have found relationships between democratic control and the willingness of actors to cooperate to address social dilemmas (Cox et al. 2010, Sutter et al. 2010). However, in this particular case it is unclear why some fishers feel they have a greater influence on rulemaking than others given the absence of an association between participation and political efficacy. Thus, although this research highlights a potentially useful relationship between political efficacy and support for addressing the ecosystem impacts of shrimp fishing, more research is needed to investigate why some fishers feel they have a greater influence than others.

The results of this analysis are useful for researchers and policymakers seeking to develop theoretically rigorous and practically useful knowledge to manage trade-offs associated with fisheries. There is an urgent need for such knowledge in the context of forage fisheries where

increasing dependence on lower trophic level species such as shrimp (Pauly et al. 1998, Foley et al. 2015) potentially threatens the health and abundance of dependent predators (Cury et al. 2011). Because many dependent predators are also exploited by commercial fisheries it may be possible to address this problem by promoting species diversification through licensing and other mechanisms, potentially enhancing the resilience of fishers to social and environmental change (Kasperski and Holland 2013, Cline et al. 2017). However, important questions remain regarding the design and potential impacts of programs for non-market ecosystem goods and services, and the ways in which authority might be delegated to stakeholders to achieve more desirable social and ecological outcomes.

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Appendix

Table S1. Economic Well-Being Index

	Eigenvalue	Difference	Proportion	Cumulative	Variable	Factor 1	Uniqueness	Scoring coefficients
Factor1	2.118	1.480	0.706	0.706	Income	0.775	0.399	0.366
Factor2	0.638	0.394	0.213	0.919	Savings	0.924	0.147	0.436
Factor3	0.244	.	0.081	1.000	Debt	0.815	0.336	0.385

Likelihood ratio test: independent vs. saturated: $\chi^2(3) = 47.94$; $p > \chi^2 = 0.000$

Table S2. Economic Well-Being Index

	Eigenvalue	Difference	Proportion	Cumulative	Variable	Factor 1	Uniqueness	Scoring coefficients
Factor1	4.116	3.633	0.823	0.823	Health	0.921	0.152	0.224
Factor2	0.483	0.254	0.097	0.920	Stress	0.876	0.232	0.213
Factor3	0.229	0.087	0.046	0.966	Leisure	0.877	0.230	0.213
Factor 4	0.142	0.112	0.028	0.994	Relationships	0.931	0.134	0.226
Factor 5	0.030	.	0.006	1.000	Employment	0.930	0.136	0.226

Likelihood ratio test: independent vs. saturated: $\chi^2(3) = 259.40$; $p > \chi^2 = 0.000$

Table S3. Political Efficacy Index

	Eigenvalue	Difference	Proportion	Cumulative	Variable	Factor 1	Uniqueness	Scoring coefficients
Factor1	1.881	1.191	0.627	0.627	People like me	0.719	0.483	0.382
Factor2	0.690	0.261	0.230	0.857	Offshore fishers	0.796	0.367	0.423
Factor3	0.429	.	0.143	1.000	Scientists	0.855	0.269	0.454

Likelihood ratio test: independent vs. saturated: $\chi^2(3) = 25.88$; $p > \chi^2 = 0.000$

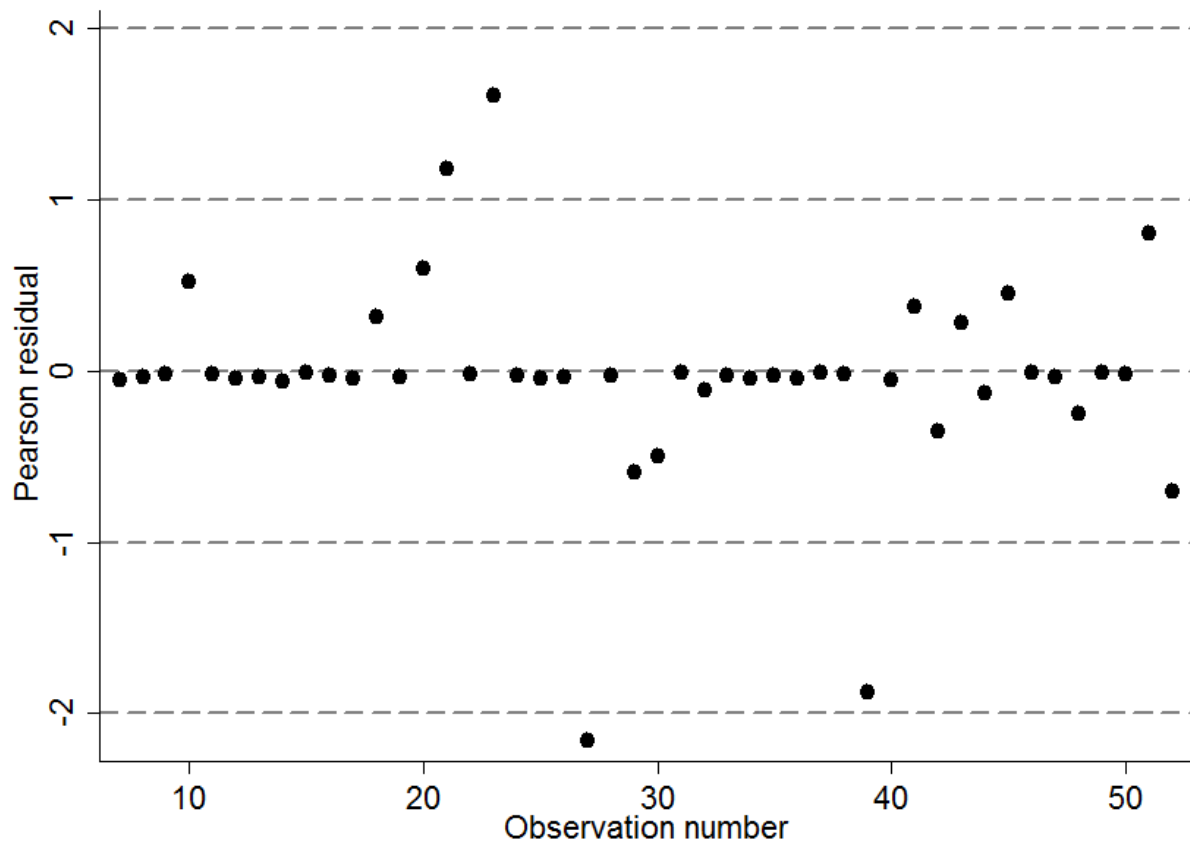


Figure S1: Residuals

Table S4: Logistic Regression Results, excluding participation

	Coefficient	Std. Err.	p-value	95% Confidence Interval	
Crab income	5.521	1.776	0.002	2.040	9.001
Political efficacy	1.226	0.380	0.001	0.482	1.970
Livelihood diversification	-0.645	1.097	0.557	-2.796	1.506
Dependence	1.212	0.861	0.159	-0.475	2.898
License	0.027	1.635	0.987	-3.178	3.232
Married	-0.101	1.224	0.934	-2.501	2.299
Age	0.079	0.078	0.313	-0.074	0.232
Constant	-12.608	6.248	0.044	-24.853	-0.363
N	46				
Count R ²	0.913				
Chi-square	28.32				
p-value	0.000				
Mean VIF	1.38				
Max VIF	1.72				

Note: Standard errors are clustered by the town in which the fisher lives

Table S5: Logistic Regression Results, excluding political efficacy

	Coefficient	Std. Err.	p-value	95% Confidence Interval	
Crab income	5.174	1.487	0.001	2.259	8.088
Participation	-2.055	1.223	0.093	-4.453	0.342
Livelihood diversification	2.068	1.423	0.146	-0.721	4.858
Dependence	1.309	1.068	0.221	-0.785	3.403
License	1.584	1.269	0.212	-0.903	4.071
Married	0.858	1.166	0.462	-1.427	3.143
Age	0.047	0.079	0.550	-0.107	0.201
Constant	-11.786	6.781	0.082	-25.075	1.504
N	46				
Count R ²	0.870				
Chi-square	35.63				
p-value	0.000				
Mean VIF	1.39				
Max VIF	1.77				

Note: Standard errors are clustered by the town in which the fisher lives