Marine Policy 76 (2017) 169–177

Contents lists available at ScienceDirect

Marine Policy

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

Recreational fishing in a time of rapid ocean change

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ABSTRACT

Fishing is an important recreational activity for many Australians, with one in every four people participating every year. There are however many different pressures exerted on Australian fish stocks, including climate-related changes that drive changes in local fish abundances. It is inevitable that recreational fishers will need to adapt to these changes. When resource abundance alters substantially, user adaptation to the new situation is required and policies and incentives may need to be developed to encourage behaviour change. It is important to correctly anticipate fisher's response to these policies and incentives as much as possible. Improved understanding of recreational fisher's likely adaptation decisions and the nature and timing of these decisions can help avoid unintended consequences of management decisions. Based on a survey of recreational fishers in the south-east Australian climate hotspot, we identify 4 relevant dimensions to recreational fisher's behavioural adaptation. There are differences in adaptation timing (early, late, and non-adaptors). Non-adaptors are characterised by greater cultural attachment to fishing and stronger perceptions of the factors that influence abundance change. The fisher's preferred adaptation responses and the timing of the behavioural response differs between decreasing versus increasing fish abundance. Insight into perspectives and expectations on how recreational fishers might adapt to changes is useful to develop a set of behavioural incentives that appeal to different groups but remain efficient and effective in their implementation. Such knowledge can create new pathways to achieve meaningful and targeted adaptation responses for different types of recreational fishers.

1. Introduction

Climate change, combined with overfishing, pollution, and other anthropogenic impacts, are transforming the oceans. These changes will require behavioural adaptation of all marine resource users including recreational and commercial fishers [1]. To date, most discussions of behavioural change necessary to adapt to climate change in the marine space have been concerned with commercial or subsistence fishing, or biodiversity [2], despite the social, cultural [3,4], and economic [5] importance of recreational fishing. The importance of hypotheses about fisher behaviour for predicting, understanding, and designing efficient fisheries regulation programs is well established [6,7]. This study addresses an empirical research gap, that is understanding recreational fishers behavioural intention to change and adapt, and the timing of any adaption, in fast warming south-east Australia [8] to help policy design and increase the likelihood of sustainable marine resource use outcomes.

Recreational fishing is a leisure activity, like swimming, surfing, diving, and boating, that is central to many people, particularly those who live on the coast [9]. Around the world, over 3 billion people live within 100 km of the coast (UNEP http://www.unep.org/pdf/Green_Economy_Blue_Full.pdf; UN Atlas of the Oceans—www.oceansatlas.org). In Australia, the proportion is particularly high with around 80% of the country's 24.1 million people living on the small strip along the coastal margin [10]. People who live on the coast often have a strong affinity with the ocean [11], and many of coastal dwellers participate in recreational fishing activities.

Globally, around 11% of the population participate in the sporting and social aspects of recreational fishing [12,13]. In Australia over 3.4 million people take part in recreational fishing each year. Recreational

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http://dx.doi.org/10.1016/j.marpol.2016.11.034
Received 27 September 2016; Received in revised form 28 November 2016; Accepted 28 November 2016

catches have increased globally and in Australia over the past decades, due in part to population increases but also to technology improvements [14,15]. In Australia, annual recreational fish catches are now approximately 30,000 t [16]. In some regions and in some Australian fisheries, the recreational harvest even exceeds the commercial harvest [17] and can lead to localised depletion [18,19]. Competition for fish between recreational and commercial fishers, and differences in beliefs about appropriate management objectives [20], can create resource sharing issues and conflicts may ensue [21].

In Australia both recreational fishers and commercial fishers have to deal with many pressures that impact marine resources, and as a consequence, they will have to adapt to changes in the marine environment. Some of the pressures affecting the coastal waters are (a) coastal inundation and erosion [22], (b) nutrient input and chemical pollution [23,24] and, (c) climate-related change in marine species and ecosystems [25,26]. These combined effects are likely to (positively and negatively) affect future catches of species due to abundance and distribution changes [2,27]. In the south-east and south-west of Australia the ocean temperature is warming faster than in most other parts of the world [8]. Consequently the effects of warming are already being observed [28,29] and adaptation to these changes is paramount.

Human behaviour change has long been a topic of research in all social sciences. The theory of planned behaviour [30], which details the key aspects that shape an individual's behavioural intentions and behaviours, forms the theoretical basis of much empirical research on behaviour change. Expansion on this theory incorporate ‘context’ as an external causal variable of behaviour change, along with other aspects such as habit, routine, and personal capability [31]. Better information, or more appropriate incentives, are such external variables that are thought able to influence individual behaviour and promote sustainable outcomes [32]. Actively influencing external factors may achieve positive adaptive behaviours by avoiding ‘path dependency’ which has a tendency to limit responses to policies [33]. Regardless of the ability to influence external factors, not all marine resource users will adapt to change in the marine environment in the same way or at the same time. However, it is important to understand their behavioural intentions and the timing of their adaptation to help resource managers create meaningful, efficient, and targeted policies that facilitate the inevitable need to adapt.

From existing research it is apparent that adaptation responses and timing are influenced by the knowledge that resource users have about the changes happening around them and their own personal observations of this change [34]. Knowledge about the nature of change helps people gain the capacity to manage and deal with change, and ultimately protect and conserve the values that are important to them [35]. Local knowledge and forethought about potential impacts and changes in the marine environment is likely to enable critical adaptation [36–38]. Recreational fishers often observe changes in the environment as they spend much time sampling the natural environment. Recreational fisher's observations can provide valuable insights into changes in species composition, richness and range shifts [39–41] if data are collected, shared and used appropriately (such as with Redmap www.redmap.org.au, a citizen science website used by the Australian community to map out-of-range marine species sightings countrywide) [40].

Even though research suggests that knowledge and exposure (through observation) to information of change [28] will influence the capacity of resource users to adapt to change [42,43], there are many other factors to consider. For instance, combined future impacts on the marine environment may not be equally distributed between resource user groups, each individual has a different capacity to adapt, and their approach to adaptation might vary. Importantly, as in other sectors, a fisher's adaptation behaviour may be influenced by their dependence on fishing, and attachment to fishing as a recreational activity [44] because recreational fishing is not only about catching fish, but also about being out on the water and spending time with family or friends [45].

In this study the influence of (cultural and historical) dependence on fishing [12] on adaptation behavioural intentions is established in conjunction with information on the fisher's knowledge of environmental change gained through personal observations. To guide development and support of adaptation strategies for recreational fishers the case study focuses on the fast-warming south-east Australia, where change is already being experienced.

By means of a survey, a sample of Australian recreational fishers' adaptive behavioural intentions were assessed and classified for both increases and decreases in fish abundance resulting from change in the marine environment. A typology of adaptive behaviours was developed and related to the relative complexity of the adaptation. Subsequently, demographic, motivation and attitudinal variables were modelled to explain fisher adaptation behavioural intentions and adaptation types.

This research considers the differential impact of planned future adaptation policies and communicating the need to adapt to change in the marine environment on different types of resource users. The behavioural model developed here is capable of transparently predicting fisher response to environmental conditions not yet experienced [46]. Insight regarding the variables that contribute to fishers being early, late or non-adaptors, will be useful for resource managers seeking to create and support meaningful and targeted adaptation responses for different resource user groups.

2. Material and methods

Data used in this study were collected in a survey of recreational fishers in south-east Australia administered as part of the Belmont Forum's *Global Understanding and Learning for Local Solutions* (GULLS) project [47]. The GULLS project (https://belmontforum.org/funded-projects/global-learning-local-solutions-reducing-vulnerability-marine-dependent-coastal) was designed to characterise, assess and predict the future of coastal-marine food resources in fast-warming marine (hotspot) countries (http://www.marinehotspots.org/index.php/featured-projects/gulls). The Australian version of the GULLS survey was administered to recreational fishers in south-east Australia comprising Tasmania, Victoria, and New South Wales as an online survey using the Survey Monkey software. Fishers accessed the survey via a link advertised on the Redmap website (www.redmap.org.au) and Facebook, which was promoted to males and females of all ages that had fishing and fish-related interests. Fishers were able to access the survey from July 2015 to early April 2016, and it was actively promoted on two separate occasions using the Redmap facebook page and website. On each occasion a pulse of responses was received in the 4–6 days following the advertisement. To encourage participation a small prize (a book on fishes in Australia) was offered for completing the survey to three randomly selected respondents.

The Australian survey consisted of 129 questions organised into two parts. Results presented in this paper drew on responses to a subset of these questions. In the first part of the survey standard demographic information was gathered (e.g. age group, residence, household size). From the second part of the survey, the following information was gathered: (a) respondents fishing activity (e.g. number of days, target species, gear, boat ownership); (b) observations of environmental and biophysical marine changes in their local fishing area (change in environmental quality, fish abundance, fish species, number of fishers etc.); and (c) their cultural and social links to fishing and the physical environment in which the recreational fishing activity took place (near their place of residence and community). Respondents were also asked what adaptive behavioural changes they would make in response to a change in fish abundance (both increasing and decreasing), and their confidence in their personal ability to respond to this environmental change. Responses to these questions formed the basis of the explanatory modelling and the adaptor typology discussed below.

In total 128 online survey responses were received of which 104 were complete and used here. The 24 incomplete surveys were either missing crucial demographic information or less than half of the total questions had been completed.

2.1. Exploring intended fisher adaptation

Understanding intended or stated adaptive behaviour intentions allows the prediction of fishers' adaptive behaviour to changing environmental conditions [48]. From a policy development or behavioural incentive perspective, being able to predict how fishers might adapt under different environmental conditions will assist in achieving sustainable resource management. Having supplementary information on the likely timing and sequencing of fisher's adaptive behaviours will provide the agents responsible for sectoral resource management an additional tool to match the urgency of the policy or behavioural incentive. Being better able to target policies and behavioural incentives to the right types of fishers, at the right time, and importantly using the right message, is likely to be welcome information for resource managers who are aiming for maximum efficiency and effectiveness.

Three separate but related analyses were used to probe the survey data to gain this understanding. First an adaptor typology based on fishers' stated adaptation intentions was developed; second the consistency of individual fisher adaptor type under different environmental change scenarios was assessed; and thirdly adaptor type were related to personal characteristics (demographics), motivations, and attitudes for a declining abundance scenario using logit analysis [49].

The adaptation intentions of fishers were elucidated by responses to a question which asked which, if any of a prescribed set of behavioural changes respondents would make in the face of hypothetical percentage increases (or decreases) in fish abundance (5%, 25%, 50%, or 75%). In the case of hypothetical decreases in abundance, fishers selected the level of decline at which they would implement a particular behavioural change. There were a total of five behavioural changes, each varying in cost and complexity. These were 1) fish for longer each season, 2) target other species, 3) fish somewhere else, 4) use different gear/technology, and 5) stop fishing altogether. They could also choose to do nothing (i.e. no change to their current behaviour) regardless of the level of abundance decline, which represents a lack of adaptation response. In the case of an increase in abundance, respondents selected a percentage change level to implement each of three behavioural changes; 1) fish for longer each season, 2) use different gear/technology and 3) buy a bigger vessel. Again, respondents could also choose no change to their current behaviour regardless of the abundance increase.

As well as exploring the stated adaptation intentions of respondents in aggregate, a fisher typology was developed based on an individual fisher's total score, calculated to reflect the level of abundance change at which an intention to adapt was first expressed. Each adaptation option was converted to scores on the interval 1–5 as follows (a) 5% decline =1, (b) 25% decline=2, (c) 50% decline=3, (d) 75% decline=4, and (e) "I would not consider doing this" =5. The total maximum potential score was calculated for each individual by summing across the adaptation options (five options in the case of decline, and three options in the case of an increase). Using the criteria in Table 1 an index was constructed for judging the adaptor type under the increasing and decreasing abundance scenarios.

We also assess if the adaptor type is consistent for each fisher (the same) for the decreasing and increasing abundance scenarios. Respondents were classified as i) consistent non-adaptors, ii) consistent early or late adaptors iii) earlier adaptor in declining than increasing abundance, or iv) earlier adaptor in increasing than in declining abundance.

Finally, an ordered logit model [e.g. 49] was used to relate an individual's adaptor type in the face of a hypothetical decrease or increase in abundance to their responses to questions about their observations of change in the marine environment, personal characteristics (demographics), motivations, and attitudes. The regression equation estimated in logit analyses is derived after manipulation of the cumulative logistic probability function where the dependent variable in the regression equation is the natural logarithm of the odds that a particular choice will be made and the right hand side of the regression is a linear combination of parameters. The model for an increase in abundance was not significant and is therefore not discussed further.

Table 1
Criteria used to define the different adaptor types for the typology. Non-adaptors represent individuals who would not make any of the behavioural changes proposed under even the most extreme abundance change (75%).

Decreasing abundance (5 potential behaviour changes)		Increasing abundance (3 potential behavioural changes)	
Score	Adaptor type	Score	Adaptor type
5–14[a]	Early adaptor	3–8	Early adaptor
15–24	Late adaptor	9–14	Late adaptor
25	Non adaptor	15	Non adaptor

[a] Two respondents indicated that there were two adaptations that they would not consider doing in the decreasing abundance scenario while being early adaptors for the remaining three.

3. Results

The general demographic characteristics of survey respondents was broadly similar to that of Australian recreational fishers. For example, almost 80% of respondents were male, consistent with male and female participation in fishing in Australia which is between 1.8 and 2.3 times higher for males than females [13], and with the gender distribution of the users of Redmap of whom 71% are male. Nearly half of the respondents were between 20 and 39 years old. The relatively young age distribution of respondents is similar to the findings of Henry and Lyle [13] who indicate that the greatest numbers of recreational fishers in Australia are in the 30–44 age group, and to the demographics of the fishers who subscribe to Redmap, of whom 53% are less than 44 years of age (Redmap website demographics). Most respondents (55%) lived in households with 3 or more persons, the remainder lived in 2 person- (32%) or single person households (13%). One third of fishers indicated they were in professional employment, the next highest number identifying as technicians and trade workers (26%). Only two respondents indicated they were retired. Most respondents had achieved at least school level education (17%) or certificate level (34%), the remaining 49% had an education higher than those two levels. This compares well to Census data for the south-east region of Australia [10]. Over eighty percent of fishers indicated that they went fishing in the area where they lived and a total of 56% of respondents participated in recreational fishing activity more than one day per week. This is higher than the national average where recreational fishers fished for an average of 6.13 days per year [13]. Flathead was the most commonly caught species for 28% of respondents.

3.1. Anticipated changes in fishing behaviour

In the case of declining fish abundance, the level of change which elicited an intended behavioural response from fishers, differed for the five prescribed adaptations (Fig. 1). Only 11% of fishers indicated they would make any of the behavioural changes proposed in response to a small (5%) decline in abundance of fish. Most of these fishers indicated that at this level of change, they would respond by fishing for longer each season. If there was a 25% decline in fish abundance, around one third of respondents would shift their fishing effort to target other species and switch to different fishing gear and/or technology. For a

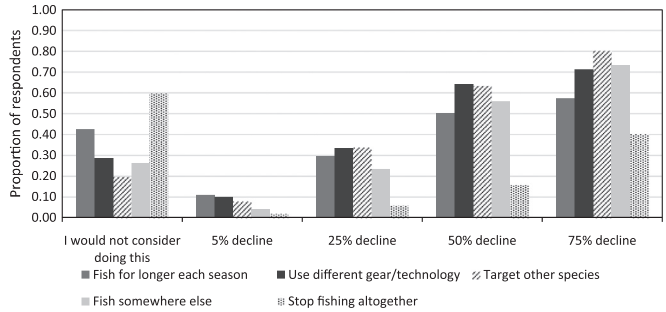

Fig. 1. Cumulative proportion of fisher adaptive behaviour at different levels of fish abundance decline for recreational fishers surveyed in south-eastern Australia.

50% decline in abundance between 50% and 64% of respondents indicated they would undertake most behavioural changes (although they least preferred to fish longer each season), but they clearly would not stop fishing (only 16% of fishers indicated they would stop).

For a 75% decline in abundance, around three quarters of respondents would change their behaviour in several ways (change location, target other species, and use different gear/ technology). However, respondents indicated a reluctance to stop fishing altogether in response to declining fish abundance, with 84% indicating continued participation with stocks at 50% of their current levels and 40% of respondents indicating they would not stop fishing regardless of the magnitude of the decline.

Anticipated behaviour change in response to an increase in fish abundance for the three proposed adaptations also varied (Fig. 2). Progressively larger increases in abundance are associated with a greater proportion of fishers expressing an intention to adapt. Fishing for longer in each season was the most popular adaptation at all levels of abundance increase and buying a larger vessel was least attractive. In total between 34% and 57% of respondents indicated that they would not consider any of the adaptations at any level of fish abundance increase.

Based on fishers stated intentions for the highest level of decreasing abundance (75%), it may be deduced that targeting other species, which is anticipated by 80% of fishers, is potentially the least complex adaptation. Next most complex in a situation of decreasing abundance is fishing elsewhere (74%), using different gear/technology (71%), and lastly fishing longer each season (57%). In contrast, fishing longer each season is the least complex adaptation in a situation of increasing abundance (60% of fishers at 75% increase) with the next adaptation being using different gear/ technology, which is the opposite adaption order compared to the scenario of decreasing abundance.

Respondents were classified into four types of adaptor based on their combined response to the increasing and decreasing scenarios: i) consistent non-adaptors, ii) consistent early or late adaptors iii) earlier adaptor in declining than increasing abundance, or iv) earlier adaptor in increasing than in declining abundance. There is a marked difference in the distribution of respondents across adaptor types depending on whether the effect of climate change on fish abundance is positive or negative (Fig. 3). Respondents were fairly uniformly distributed across adaptor types in the case of increasing abundance, while about 64% of respondents were classified as late adaptors in response to declining abundance. The number of non-adaptors was significantly greater for abundance increases than decreases (F-test F=0.4249, p=0.00001).

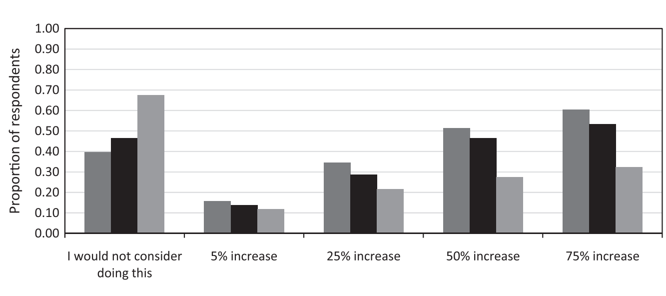

Fig. 2. Cumulative proportion of fisher adaptive behaviour at different levels of fish abundance increase for recreational fishers in south-eastern Australia.

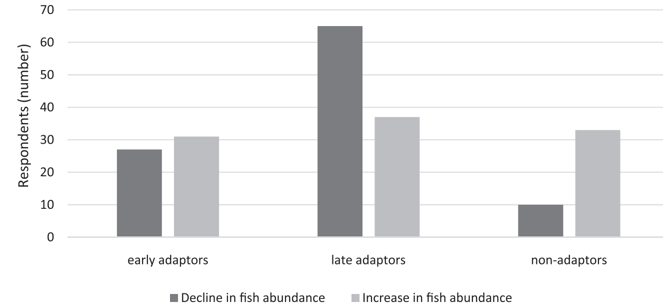

Fig. 3. Number of recreational fishers in the early-, late-, and non-adaptors group.

Examination of the consistency of individual respondents stated behavioural intention across the two abundance scenarios showed that more than half of the fishers are classified as the same adaptor type regardless of the direction of change in abundance (the two grey bars in Fig. 4). In other words, if fishers are classified as late adaptors when stocks are in decline - they are also classified as late adaptors when stocks increase.

However, 30% of respondents indicated that they will respond 'earlier/sooner' given a decline than for an increase in fish abundance (i.e. if they were early adaptors for declining abundance they may be either late or non-adaptors for an increase) and 15% of fishers will adapt sooner for an increase than for a decrease in fish abundance (i.e. they may be late or non-adaptors for a decrease but early adaptors for an increase in fish abundance) (black bars in Fig. 4).

For the decreasing fish abundance scenario the multinomial logit analysis showed eight variables explain membership of the early adaptor type (significant at p=0.05) while seven explain the late adaptor types (Table 2). A table with the full set of variables included in the initial model is shown in Table A1 (Appendix A). Stepwise regression was used to obtain the final set of variables. For 15 of the 104 survey responses, data were missing for one or more of the explanatory variables. These were dropped from the analysis leaving 98 observations (15 early adaptor, 62 late adaptors and 10 non-adaptors). Non-adaptors form the control group. The constant term is not significant. Model statistics indicate that the adaptor-type model is significant with a Log Likelihood of constants-only model (LL(0)) of −85.708 and a p-value <0.001. McFadden's Rho-Squared (which mirrors the adjusted R-squared in ordinary least squares regression) is 0.415. The model has a 68.2% prediction accuracy (Table 3). For each of the adaptor types, at least 50% of respondents were correctly

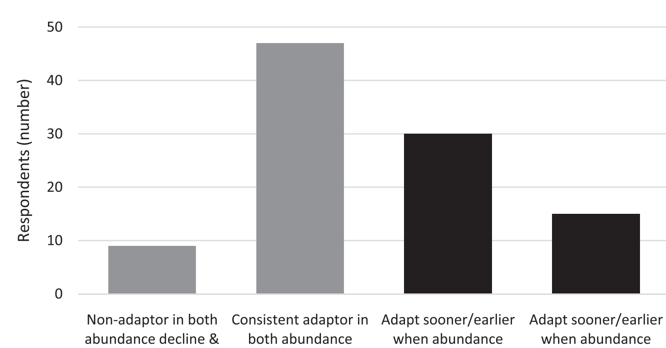

Fig. 4. Consistency of adaptor type between situation of increasing and decreasing abundance. Consistent adaptors are those individuals who consistently adapt with the same speed whether abundance increases or declines (i.e. early in both cases or late in both cases).

Table 2
Logit model results for recreational fisher adaptor types and variable code and description (**denotes variables significant at the 10% level).

Description	Variable code	Early adaptors				Late adaptors			
		Estimate	S.E.	t-ratio	p-value	Estimate	S.E.	t-ratio	p-value
n/a	CONSTANT	7.345	8.239	0.891	0.373	7.010	7.704	0.910	0.363
Adaptor type in increasing abundance	INCR_AD_TYPE	−4.393	1.617	−2.717	0.007	3.667	1.579	−2.323	0.020
Respondent age group	AGE	2.874	1.194	2.407	0.016	2.129	1.085	1.961	0.050
Ideas about ensuring sustainability of fish caught	IDEAS_SUST	2.480	0.974	2.545	0.011	1.980	0.910	2.175	0.030
Negative impact of commercial fishing	COMM_FISH_IM	2.893	1.565	1.848	0.065**	3.579	1.525	2.347	0.019
Respondents fishing culture/ identity	CULTURE_FI	2.171	0.700	3.102	0.002	1.603	0.662	2.423	0.015
Past family involvement in fishing	FAMILY_FISH	−6.321	2.272	−2.783	0.005	−4.542	2.158	−2.105	0.035
Perception of recreational fishers breaking rules	OBEY_RULES	−6.724	2.459	−2.735	0.006	−4.804	2.311	−2.079	0.038
Empowerment to make change	PERS_CHANGE_ENV	1.716	0.801	2.143	0.032	0.742	0.710	1.046	0.296

*In this coding all values were normalised to between 1 and 4 and higher values indicated lower vulnerability. See also table A1 for explanation.

Table 3
Model prediction success table.

Actual Choice	Predicted Choice			Actual
	Early adaptor (n)	Late adaptor (n)	Non-adaptor (n)	Total
Early adaptor	13	12	1	26
Late adaptor	12	47	3	62
Non-adaptor	1	3	6	10
Prediction Total	26	62	10	98
Correct (%)	52	76	63	68
Total Correct (%)	68			

allocated with the late predictors being allocated to their correct group most often (75.7% of cases). Of the 62 late adaptors, 12 were incorrectly classified as early adaptors and 3 as non-adaptors, and 3 non- adaptors were incorrectly classified as late adaptors.

Table 2 shows the differences between the early and late adaptors and the non-adaptors (the control group). None of the variables that relate to recreational fisher observations of environmental change (See Table A1 – also for the relevant survey questions) are significant, but eight other variables are significant (Table 2).

The signs of the coefficients are the same for early and late adaptors for all but one variable: the way they behave in a situation of increasing abundance (INCR_AD_TYPE). For example a fisher who adapts fast when fish are less abundant indicated they might not adapt their behaviour as fast (or at all) when there is an increase in fish abundance and are thus a late or non-adaptor in the latter situation. Late adaptors generally behave in the same way for both increasing and decreasing abundance. For one variable (PERS_CHANGE_ENV) early adaptors differed from non-adaptors but late adaptors did not. Early adaptors are more likely to feel that they can make a difference in improving the health of the environment (PERS_CHANGE_ENV) compared to non-adaptors.

For all other variables early and late adaptors differ from non-adaptors in the same way (i.e. the signs on the coefficients are the same). Early and late adaptors are less likely to have past parental (FAMILY_FISH) involvement in fishing than non-adaptors. Early and late adaptors are also less likely to feel that most recreational fishers obey the rules (OBEY_RULES). The effect is more pronounced for early adaptors (the negative coefficient is larger) than for late adaptors.

Even though early adaptors feel they can make a difference, they seem to have fewer ideas about ensuring sustainability (IDEAS_SUST) of the main species they catch than late adaptors but they both have fewer ideas than non-adaptors. In other words, non-adaptors will not adapt their behaviour, but they seem to have many ideas on how sustainability can be ensured. Early adaptors also have less of a fishing culture (higher positive coefficient for CULTURE_FI) than late adaptors but both have a stronger fishing identity than non-adaptors. Lastly, early and late adaptor's perception of the potential reasons for low abundance is more strongly attributed to a negative impact of commercial fishers (COMM_FISH_IM).

4. Discussion

Recreational fishing is a very important sport and leisure activity for many people living in coastal Australia [50]. The impact of climate-related changes on recreational fishing is already becoming evident in some fast warming regions [39,41]. When resource abundance alters substantially, adaptation by the resource users to the new situation is required and governments and management institutions will sometimes need to develop policies and incentives to encourage behavioural change [6]. However, it is important that the fishers respond to these policies and incentives is as anticipated as possible [51,52]. This study addresses an empirical research gap to better understand recreation fisher's behavioural intention to adapt, and the nature and timing of their adaption, in fast warming south-east Australia [8]. Studies on fisher behavioural adaptations and decision-making as in this current research provide key information on which the outcomes of policies and incentives can be modelled [53].

In regions of change, formerly common species may decline in abundance, and new species become more abundant [40,54,55]. This case study in south-east Australia revealed that 58% of survey respondents had recently perceived change in the marine environment in the form of a decrease in desired fish abundance, which is in line with scientific observations [21]. The link between reduced abundance and the consequent greater difficulty in catching their desired fish was acknowledged in the survey responses by the majority of fishers (78%) as they were already experiencing this in their local area. Overall recreational fishers are more willing to adapt when the desired fish abundance decreases compared to when the abundance increases (10% and 33% respectively). Although the need to adapt to these changes would seem inevitable, some recreational fishers are unwilling to adapt their current fishing behaviour.

Well-designed and appropriately timed adaptive responses to changing abundance due to climate stressors may dampen the impact and appropriately policies and incentives can help in this regard. More flexible and population responsive bag limits and catch regulations for recreational fishers have been suggested in other studies [1] and were corroborated by our survey, where regulations governing the use of particular gear were also favoured by respondents. Regulating recreational fishing effort in response to abundance change need to also be mirrored in dealing with professional fishing effort to avoid or resolve resource sharing issues and address any (mis)understanding between user groups. This is exceedingly important to ensure a sustainably managed marine environment [56], especially since this survey and others find that the majority of recreational fishers perceive commercial fishers negatively (over 55%) [57] and assume that their catches are impacted by the commercial sector (77% this survey).

The results presented in this research suggest that fishers who were willing to adapt their fishing behaviour, adopted increasingly complex and potentially costly adaptations only at higher levels of climate-related declines in desired fish abundance. Surprisingly, fishing for longer was seen as the least attractive adaptation to declining abundance, but was the most favoured response across all levels (5–75%) of increasing abundance. It is most likely that when there is a small abundance decline in fish abundance (e.g. 5%), recreational fishers might feel they can compensate for the decrease, but for larger proportional decreases (e.g. 50%) an attempt to fish longer for the same species might be futile, so fishers will instead start targeting other species. In contrast, if abundance were to increase substantially (> 50%) fishers will try to benefit from the large increase by fishing longer, perhaps reflecting an anticipated catch benefit. Similarly, using different fishing gears was the second-least attractive change in response to decreasing abundance, while it was the second-most attractive in the increasing abundance scenario. This current research illustrates that adaptation choices in situations of increasing and decreasing abundances cannot be assumed to be similarly ordered.

The succession from incremental to more transformational adaptive behaviour facilitates effective adaptation to progressively more severe and cumulative impacts [58,59]. Our results show heterogeneity among recreational fishers in terms of the speed with which they would undertake behavioural changes thus requiring different engagement and information gathering strategies. For example, early adaptors might be more readily engaged in citizen science activities [7], supported as community leaders [59], and involved in research activities [39]. Early adaptors could be actively engaged to create behavioural norms that may lead to intent of adaptive behaviour, by highlighting and depicting the behaviours of the early adaptors [7]. To assist late adaptors, fishery managers might seek to build forums or networks that connect them with early adaptors to facilitate exchange of experiences and information [60,61]. Non-adaptors, who may be a difficult group to engage, might be influenced by continued information delivery of evidence for the need for adaptation that is consistent with their world view [62]. Non-adaptors are quite distinct from early and late adaptors - they are characterised by a greater likelihood of family involvement and cultural identity linked to fishing. Non-adaptors reported more ideas about sustainability than the other two groups (they were not significantly different in terms of the changes they observed). They are also less likely to hold commercial fishers responsible for low abundances and are more likely to feel that fishers obey the rules. These cultural characteristics and group perceptions may make them try to hold on to their current practices longer, amplified by their perceptions of the things that do and do not contribute to observed abundance changes. Longitudinal tracking is needed to shed further light on the behaviours of these groups and their adaptation actions in response to incentives offered by fishery managers [52,63].

We observe heterogeneity in the timing of responses, the type of adaptation response, but also in the consistency of adaptor types. Only a small proportion of people were non-adaptors both in increasing and decreasing abundance (9%). Even though most recreational fishers who are early adaptors for increasing abundance will also be early for decreasing abundance (46%), some 30% of early adaptors in the case of decreasing abundance change to being late or non-adaptors in the case of increasing abundance. This group appears to not be 'interested' in taking measures that would increase their catch beyond its current level (indicating satisfaction with what they have) but also do not want to lose catches. A further 15% of recreational fishers are opportunistic - they are early adaptors when abundance increases but late or non-adaptors for decreases, indicating a lack of willingness to modify their behaviour when their desired species declines, but a desire to benefit from higher catches if they are available. This may reflect a belief that climate-related declines in fish abundance are inevitable and there is therefore no point to showing individual restraint, or that adaptation to a decline in abundance is too costly or difficult.

Thus there are four aspects to recreational fishers adaptation behaviour i) adaptation timing (early, late, and non-adaptors), with ii) non-responders characterised by greater cultural attachment to fishing and perceptions of the things influence abundance change; and iii) differences in preferred adaptation responses in decreasing and increasing abundance of their desired species (i.e. fishing longer being the first option under increasing abundance, but the last under decreasing abundance); as well as iv) different behavioural responses in decreasing and increasing abundance (i.e. an early adaptor in decreasing abundance might be late adaptor in increasing abundance). These four key aspects of heterogeneity in adaptation responses may help develop well targeted and timed management responses [52]. Fisher typologies such as the one developed in this research can be used in analytical and model based Management Strategy Evaluation (MSEs) [64,65] and improve model predictions (compared to say assuming fishing effort per sector stays constant).

Even though our results do not indicate a relationship between recreational fisher's observations of environmental change and their adaptation intentions, this does not mean that the timing of adaptation responses cannot be influenced by improving information delivery to recreational fishers. By improving their understanding about existing and potential changes through improved information delivery could support adaptation. For example, physical ocean changes, like sea temperature and ocean current changes, may not be observed, or may not be at the top of fishers minds when they consider drivers of biophysical change, even though evidence has shown that water temperatures are increasing in south-east Australia [66,67] and this has already changed the distribution and abundance of some species (e.g. kelp beds (*Macrocystis pyrifera*), sea urchin *Centrostephanus rodgersii* and Maori octopus (*PinnOctopus cordiformis*) [68–70]. By providing this extra information, effectively expanding their observational base, the fishers can make more informed decisions.

A stronger willingness of recreational fishers to become more engaged in management in the face of declining fish abundance will also help expose this group to observations of change [7,39,71]. A greater role in management decision making for recreational fishers could open the door to more effective and robust data capture by means of fisher diary and tagging programs (http://recfishingresearch.org/wp-content/uploads/2013/05/TacklingClimateChange.pdf) and initiatives such as Redmap.

Regardless of adaptive behaviour it is possible that the satisfaction level with fishing as a consequence of reduced catch quantities will decrease [57]. Reduced satisfaction with fishing may result in fewer active fishers [72]. Recreational fishers might seek other alternative recreation activities in the marine space if they live near the ocean and have an affinity with the sea. Any such change may reduce fishing pressure on a declining species – while this may be environmentally beneficial, the social and economic consequences are largely unknown. Given the importance of recreational fishing to coastal communities, this aspect of adaptation deserves more attention.

Even though this study addresses an empirical research gap, there are a number of limitations. This case study included an adequate but nevertheless limited sample of recreational fishers in a fast-warming region. Regional comparisons including areas where change is less evident, will be needed to gain a full understanding of recreational fisher behaviour and adaptation decision-making in situations where there is no push to change. In addition, adaptation responses that were not investigated here (such as fishing in larger groups of people, or going on charter fishing expeditions) should be considered in future studies to expand the behavioural response set.

Acknowledgments

The authors wish to recognize Belmont country partner funding provided by national and regional science agencies. We appreciate the involvement of many in-country stakeholders in our research and outreach. GP was supported by an ARC Future Fellow (FT140100596).

Appendix A

See Table A1 here.

Table A1
Variable names, descriptions, mean values and standard deviations for variables included in the initial logit model.

Variable Name	Question in the survey	Coding*	Mean value	St. Dev.	Obs (N)
INCR_AD_TYPE	Adaptor type in increasing abundance	1= early 2= late 3= non	2.020	0.800	101
AGE	What is your age	1= more than 75 years 2= 60–75 years 3= 40–59 years 4= 20–39 years 5= less	2.711	0.626	103
IDEAS_SUST	How many ideas would you say you have about how to ensure the sustainability of the main species you catch?	1= many ideas 2= some ideas 3= few ideas 4= no ideas	2.824	0.837	102
COMM_FISH_IM	Would you say your fish catches are impacted negatively by the presence of commercial fishing?	4= much impacted 3= somewhat impacted 2= little impacted 1= not impacted	1.919	0.817	99
CULTURE_FI	Does your family have a fishing identity/culture?	4=strong fishing culture 1= no fishing culture	2.485	1.507	103
FAMILY_FISH	Was your family involved in fishing in the past	4= family history 1= no family history	3.272	1.292	103
OBEY_RULES	Would you say that everyone or no-one obeys the recreational fishing rules the managers set?	4=everyone 3=most people 2=a few people 1= no-one	2.859	0.378	99
PERS_CHANGE_ENV	How possible is it for you personally to make a difference in improving the health of the marine environment in your area?	1=very possible 2=possible 3=slightly possible 4= impossible	2.961	0.900	102
KNOWL_ENV	How would you describe your knowledge about the environment in which you fish?	1= very good 2 = good 3 = reasonable 4 = not very good	3.157	0.805	102
ENV_WORSE_IMPROVE	Over the past 5 years, has the local marine environment worsened or improved?	1.6= Improved 2.4 =Stayed the same 3.2= Worsened	2.175	0.747	103
FREQ_FISH	On average, how often do you go recreational fishing?	0.7 =Less than once /month 1.3=1 d per month 2=3 days per week 3.3=2 days per week 4=1 d per week	1.896	0.844	103
CONFIDENT_GOOD_END	How confident are you that things will turn out well regardless of the changes and challenges you confront?	1=Not at all confident 2=Slightly confident 3=Confident 4=Very confident	2.363	0.920	102
ADAPT_LIKELY	How likely are you to adapt to change compared to others you know?	1=Not likely at all 2=Not likely 3=Somewhat likely 4=Very likely	3.373	0.612	102
WAVE_CHANGE	Have you noticed a change in wave height in the past 5 years?	1.3 = increase 2.7 = decrease 4.0 = stayed the same	3.404	1.117	94
SEALEVEL_CHANGE	Have you noticed a change in sea level in the past 5 years?	1.3 = increase 2.7 = decrease 4.0 = stayed the same	3.326	1.157	97
WIND_CHANGE	Have you noticed a change in windiness in the past 5 years?	1.3 = increase 2.7 = decrease 4.0 = stayed the same	2.762	1.288	98
TEMP_CHANGE	Have you noticed a change in sea temperature in the past 5 years?	1.3 = increase 2.7 = decrease 4.0 = stayed the same	2.372	1.293	95
ROUGH_CHANGE	Have you noticed a change in the roughness of the sea in the past 5 years?	1.3 = increase 2.7 = decrease 4.0 = stayed the same	3.038	1.273	97
RAIN_CHANGE	Have you noticed a change in rainfall in the past 5 years?	1.3 = increase 2.7 = decrease 4.0 = stayed the same	2.778	1.054	96

* The coding is based on that used in the GULLS project (Hobday et al., 2016) in which a socio-ecological vulnerability analysis will be undertaken. In this coding all values were normalised to between 1 and 4 and higher values indicated lower vulnerability.

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