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Pike (Esox lucius) stock management in designated brown trout (Salmo trutta) fisheries: Anglers’ preferences

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Abstract: This paper examines anglers' preferences for active stock management of pike populations within designated wild brown trout fisheries in Ireland. While the policy of pike control has a long history, it is not without controversy and conflict. As the objective of pike control is the protection of trout stocks, a superficial view might be that trout anglers favour and pike anglers oppose such management intervention. Pike and trout anglers do not have homogeneous preferences; in fact, a substantial minority of pike anglers also fish for trout and vice versa. The current paper is the first to examine Irish pike and trout anglers' preferences over fishery attributes, including pike stock control methods. Preference data was elicited by means of choice experiments for pike and trout anglers and a latent class site choice model is used to estimate anglers' utility functions. Not surprisingly model results show that pike anglers do not support pike stock control and almost universally would choose fishing sites where there are no pike stock controls, all else equal. We find that the majority of trout anglers, 61%, are negatively disposed towards pike stock control, and all else equal, are more likely to choose fishing sites where pike stocks are not actively managed. A substantial minority of trout anglers (i.e. 39%) could be considered advocates of pike control, with about one-third of these being more extreme in their preferences, with site choice probabilities of such anglers being largely determined by the pike control managementoption.

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1 Introduction

Stock management is a regular feature of recreational fisheries, through habitat enhancement, stocking programmes and harvesting (Arlinghaus, 2006; Patrick et al., 2006; Marco-Rius et al., 2013; Arlinghaus et al., 2014; Thuesen et al., 2011; Schaufler et al., 2015). Stocking programmes often are based on the simple premise that stocking increases fish abundance, which leads to higher catch rates and more satisfied anglers (Loomis and Fix, 1998; Patterson and Sullivan, 2013), an idea that has been demonstrated as flawed under certain circumstances (Schultz and Dodd, 2008; Patterson and Sullivan, 2013). Active stock management is generally in response to declines in (wild) fish stocks, which can be related to recreational fishing or its management practices (Arlinghaus et al., 2002), as well as a symptom of a wide range of other activities that damage aquatic ecosystems (Cowx et al., 2010; Craig, 2016). Structural and functional changes in fish stocks and aquatic ecosystems can arise due to recreational fishing pressures (Lewin et al., 2006; Johnston et al., 2013; Post, 2013) and stocking itself can have unintended impacts (Lorenzen, 2005, 2008; Larsen et al., 2005; Støttrup and Sparrevohn, 2007).

Anglers are a heterogeneous group and multiple angler cohorts have been identified across many fisheries (Connelly et al., 2001; Arlinghaus and Mehner, 2005; Hutt and Bettoli, 2007), with various angler cohorts seeking different fishing experiences (Fisher, 1997). Many anglers support stocking programmes (Aas and Kaltenborn, 1995; Arlinghaus and Mehner, 2005) but anglers often comprise both vocal stakeholder groups and a 'silent majority' with conflicting positions on the merits of stock management (Hunt et al., 2010, 2014). Specifically, a number of papers show that angler participation or fishing effort increases when stock management increases the population of target fish (Loomis and Fix, 1998; Ready et al., 2005; Dabrowska et al., 2014), whereas Fayram et al. (2006) additionally find that in some instances increased effort can be attributed to the act of stocking, independent of any impact it may have on fish population size. In essence, anglers respond to perceived, as well as actual, fishing conditions. These responses to stocking may reflect underlying preferences for catch experiences believed to be affected by stocking (Teisl et al., 1996). Other angler cohorts can oppose stocking, as they prefer catching wild rather than stocked fish (Hunt et al., 2010; Churchill et al., 2002; Olaussen and Liu, 2011).

Within specific fisheries, stock management decisions have the potential for conflict, though Charles (2001) suggest that conflict tends to be the rule rather than the exception in fisheries due to their complexity and dynamic nature, and because of the many interactions among ecosystems, humans and institutions. The current study is a case in point. Within designated wild brown trout (*Salmo trutta*) fisheries in Ireland pike (*Esox lucius*) populations are actively managed with the objective of protecting trout stocks (IFI, 2014). With different angler cohorts targeting pike and trout, conflict inevitably arises, both between angler cohorts and between anglers and the fishery management body. While there is scientific debate whether pike are a native Irish species (Pedreschi et al., 2014; Ensing, 2015) and public debate on the merits of pike population management (Viney, 2015), the objective of the analysis here is to gain a more detailed understanding of anglers' preferences for pike stock management. There is an growing consensus that fisheries management is as much about people management as it is about fish stock management (Wilen et al., 2002; Arlinghaus, 2004; Hilborn, 2007; Arlinghaus et al., 2017). Specifically, Arlinghaus et al. (2005) suggest that one of the most pressing needs in recreational fisheries is the management of 'people conflicts' because such conflicts can hamper any progress towards sustainability.

A prerequisite for managing conflict is an understanding of each party's position and perspective. Public discussion on pike management is increasingly polarized. Conflict arises between angler cohorts and especially between anglers and Inland Fisheries Ireland, the fishery management body. Pike anglers argue for the abandonment of pike stock management, as specimen sized fish are removed from a number of important lake fisheries. Pike predate on trout and consequently trout anglers are perceived to favour continuation of pike stock management. Most anglers will have a personal view on the existent pike management policy, but similar to angler conflicts elsewhere (e.g. Hunt et al. (2010, 2014)) a number of angler representative bodies vociferously argue their perspective on behalf of their affiliated angling club membership. Sustainable management of recreational fisheries requires a transition from single objective management to ecosystem management and aquatic stewardship (FAO, 2012; Arlinghaus et al., 2017) and therefore requires knowledge of fish biology, aquatic ecosystems, as well as all stakeholders. The information base on the human dimensions of recreational fisheries is particularly weak in many European countries (Arlinghaus et al., 2005) with Ireland being no exception. Arlinghaus (2006) argues that management success in recreational fisheries is primarily dependent on overcoming human obstacles. The focus of the current analysis is the human dimension surrounding this fishery management issue, specifically concentrating on anglers. Greater insight into anglers' preferences, not just for stock management, but also for other characteristics of the fishery such as catch rates, will help better inform future management decisions.

The objectives of this study are to: (1) understand the preferences of pike and trout anglers for stock management tools; (2) identify the heterogeneity within anglers regarding preferences for pike stock management; and (3) evaluate the impact on angler activity levels of different stock management policy scenarios.

2 Methods

2.1 Choice Experiment

Stock management decisions are made as part of a suite of decisions on the management of a complex aquatic ecosystem (e.g. on bag limits, etc.). Likewise, where anglers may have views on stock management practices, these views may reflect underlying preferences for catch experiences (e.g. size and abundance) believed to be affected by stock management practices (Teisl et al., 1996). Anglers' real underlying preferences on stock management are likely to be more subtle and complex than the results of a straight poll on whether anglers supported stock management or not. Consequently, isolating stock management from the wider management setting is likely to abstract from reality. Instead of a simple poll, we employ a choice experiment (CE) to elicit information on anglers' preferences. A choice experiment survey is a quantitative technique for eliciting preference data based on a realistic hypothetical 'market' for the service or good under consideration. In the current instance the 'market' is a choice between multiple fishing opportunities, which, *inter alia*, incorporates different stock management options. Survey respondents are asked to state their choice over different hypothetical alternatives, the responses from which allows researchers to determine the relative worth of specified fishery attributes. While choice experiments are increasingly used across a wide range of issues only a few applications exist in recreational fisheries (e.g. Aas et al. (2000); Oh and Ditton (2006); Dorow et al. (2010); Lew and Larson (2014)).

The Random Utility Model (RUM) of McFadden (1973) is the standard statistical economic framework used to estimate behavioural choice models. Within a RUM model an angler chooses from a number of alternatives (e.g., fishing sites) and selects the one that yields the highest expected utility level on any given choice occasion. Fishing sites comprise a number of attributes (e.g. stock management, average catch, bag limit, etc.), with the level of the attributes differing across choice alternatives. The utility that angler n would obtain from site i is

$$U_{ni} = \beta x_{ni} + E_{ni} \tag{1}$$

where x_{ni} is a vector of observed variables, β a vector of unobserved coefficients and E_{ni} is an unobserved error term. An angler chooses among J possible site alternatives. Whenever the utility from angling at site i is greater than the utility from all other sites, site i will be chosen. The RUM model can be specified in different ways depending on the distribution of the error term. Assuming the error terms are identically and independently distributed (iid) extreme value, the RUM model is specified as a conditional logit (CL) (McFadden, 1973). The probability of choosing site i is:

$$Pr(i) = \frac{exp(\beta x_{ni})}{\sum_{j=1}^{J} exp(\beta x_{nj})} \tag{2}$$

The CL model is the workhorse for analysing discrete choice data with many applications (e.g. Siderelis et al. (1995); Parsons and Massey (2003); Provencher and Bishop (2004); Pradhan and Leung (2004)). An assumption of the model is that anglers are generally a homogeneous group but there may be good reason why this is not the case. Anglers differ by country of origin, income, social class, as well as other unobserved characteristics and these traits may manifest themselves as differences in preferences. One approach allowing heterogenous preferences is the random parameter logit model, which allows the unobserved coefficients of the model to vary randomly over anglers (Train, 2009). An alternative approach, and the one which we follow here, facilitates variability in preferences across anglers through a mixture or latent class model (LCM). The idea behind the model is that the observed distribution of angler preferences is a mixture of the preferences of a finite number of groups or classes (McLachlan and Peel, 2000). The analyst does not observe directly into which class, c, each angler fits, $c \in C$, and class membership must be estimated. The LCM is also a mixed logit model and within the latent class structure the probability of angler n within class c choosing site i is similar to equation (2) except that it is conditional on the class c:

$$Pr(i \mid c) = \frac{exp(\beta_c x_{ni})}{\sum_{j=1}^{J} exp(\beta_c x_{nj})} \tag{3}$$

The expected probability of site i being chosen by angler n is the expected value (over classes) of the class-specific probabilities.

$$Pr(i) = \sum_{c=1}^{C} \pi_c Pr(i \mid c) \tag{4}$$

where π_c is the membership probability for class c. The logit formulation for the probabilities, $\pi_c = exp(\theta_c)/(\sum_{c=1}^{C} exp(\theta_c))$, with $\theta_C = 0$ is a convenient estimation parametrisation that ensures that the estimated probabilities satisfy the basic properties of a probability: $0 \leq \pi_c < 1$ and $\sum_{c=1}^{C} \pi_c = 1$. The log likelihood for the LCM model is

$$logL = \sum_{n=1}^{N} log \left[\sum_{c=1}^{C} \pi_c \frac{exp(\beta_c x_{ni})}{\sum_{j=1}^{J} exp(\beta_c x_{nj})} \right] \tag{5}$$

Both the CL and the LCM models depend on differences among alternative characteristics. Changes in site attributes affect the probability that a site is chosen. The impact of a particular site attribute, including actions such as pike stock management, on the choice decision can be examined by comparing the relative probability of choosing a site, with and without the attribute (or at different levels of the attribute).

2.2 Selection of angler sample

The sample for this study was drawn from a panel of anglers that had volunteered to participate in research surveys on fishing. The panel is not species specific and includes anglers who fish in Ireland but are not necessarily resident in Ireland. Only anglers that indicated that they fish for either brown trout or pike were selected for the survey. The panel itself does not purport to be a representative sample of anglers. As there is no register of anglers in Ireland there is no means to gauge the representativeness of the panel or sample. Also as neither pike nor brown trout anglers require a licence to fish, there is no reliable information on the population of such anglers. Panellists were recruited via a web-page where contact details, target species, and county location are recorded. The angler panel itself was publicised via social media, national and local newspapers including notices in 'angling notes', local radio interviews, posters in fishing tackle shops, and direct communication with both angling representative bodies and angling clubs. The alternative to using the angler panel was to follow the approach of recent Irish angler surveys, which have either been on-site intercept surveys or random surveys of the general population, but these were impractical for the purposes of the current study.

2.3 Questionnaire Design

The survey was conducted on-line with an invitation to participate sent to the selected anglers' email addresses. The questionnaire comprised four components. In the first part respondents were asked about their angling activities including locations, target species, frequency, and details about their expenditures on angling. The second and third parts were choice experiments, one each for trout and pike anglers, though each survey respondent only answered one set of choice experiment questions depending on their response to a prior question about whether they were most likely to fish for pike or brown trout. Development of the choice experiment began with two focus groups comprising pike and brown trout anglers at both sessions, each lasting approximately 90 minutes. The focus groups entailed a structured discussion to elicit the issues of most concern to anglers, including ranking of importance, as well as an understanding of the issues within each topic. Through these discussions the six attributes of most importance were selected for inclusion in the choice experiments. A price or cost attribute was not included as it raised a particularly divisive discussion during the focus groups, including the opinion that any fees paid by anglers would not be reflected in additional on-the-ground fishery management initiatives. Each attribute had between three and six levels that were systematically varied to allow estimation of preferences for varying conditions, as outlined in Table 1. The attributes specifically related to angling activity such as average catch, fish length, and bag limits are relatively straight-forward and one would anticipate that all positively impact on angler utility, possibly with the exception of the trout bag limit, as some anglers may feel that high bag limits threaten the sustainability of the fishery and their future utility. *Lagarosiphon major* (curly-leaved waterweed) is a high impact invasive species first recorded in Ireland in 2005. Lagarsiphon rapidly produces a large biomass and competitively excludes native aquatic macrophyte species and communities as well as altering habitat conditions for macroinvertebrate and fish communities (Caffrey et al., 2011). It also physically impedes boating and fishing activity. In addition to pike stock control, the management of this invasive species was the issue of most concern to anglers in the focus group discussions. Anglers also expressed strong concerns about water pollution, including the impact of pollution on visibility through the water column (especially so in the case of trout anglers) compared to the historical experience of anglers. Although visibility through the water column is not necessarily a measure of water quality, anglers clearly associated the two in the focus group discussions.

Pike stocks are routinely controlled at several Irish lakes. The choice experiment presented three control options: electro-fishing only, electro-fishing and gill-netting, and the cessation of pike stock controls. Electro-fishing is a scientific survey method used to sample fish populations to determine abundance, density, and species composition. When performed correctly, it results in no permanent harm to fish. Practitioners can release non-target species such as salmon and trout unharmed. Pike within the target size limit can then be removed to another water body. Electro-fishing is ineffective in deep water, as the electric current cannot penetrate the water column. Gill-netting is used to target pike in deep waters. Gill-netting can also involve killing non-target species, such as trout and salmon. However, such by-catch can be minimised by restricting gill-netting to areas predominantly inhabited by pike.

Table 1: Attributes and levels used in the choice experiments to assess the anglers' preferences for pike stock management

Attribute	Description	Levels
Catch	Average number of pike/trout caught by the average angler per day	1, 2, 3 (status quo), 4, 5 fish per day
Length	The average length of rod-caught pike at the fishery (pike CE only)	55 cm, 70 cm (status quo), 85 cm, 100 cm, 110 cm
Bag limit	The number of trout an angler is permitted to harvest in the course of a day's fishing (trout CE only)	Catch & Release obligatory, 1, 2, 3, 4 (status quo), 6 fish per day
Pike stock control	Pike control method including whether to cease controls	Cease culling, electro-fishing only, electro-fishing & gill-netting (status quo)
Invasive weed management	Annual change in Lagarosiphon cover as compared to the previous fishing season	Complete removal, -50%, -20%, No change, +20% (status quo)
Water visibility	The distance the angler can see into the water column	1.5 metres (status quo), 2.5m, 3.5m, 5m

The attributes and their levels were carefully explained to respondents in advance of any choice decision questions and included a visual image to demonstrate the extent of Lagarosiphon growth. Respondents were also informed that all other unmentioned management measures remain unchanged across the scenarios being presented. In the survey each respondent was faced with 12 choice tasks, each consisting of 3 scenarios; a status quo scenario and two alternatives. The scenario attributes are described above and outlined in Table 1. The 'length' attribute was only included in the CE for pike anglers, whereas the 'bag limit' attribute was only included in the trout angler CE. The combinations of attribute levels presented in the 12 choice tasks were selected in a Bayesian efficient way, i.e., to minimize the determinant of the asymptotic variance-covariance matrix of the parameters (D-error) given the priors on the parameters, which were derived from a pilot survey comprising 26 respondents (Ferrini and Scarpa, 2007; Scarpa and Rose, 2008).

2.4 Survey Response

A total of 565 anglers were invited by email to participate in the survey in October 2016, of which 82% of the email invitations were opened. Of the 466 email invitations opened the response rate was also 82%, though there is item non-response within the questionnaire, including the CE component. A total of 144 respondents completed the CE for pike anglers and 197 respondents completed the CE for trout anglers. In total we have data on 1597 choice occasions from the pike CE and a further 2253 choice occasions from the trout CE.

Tables 2 and 3 outline some characteristics of the survey respondents. In several areas the profile of pike and trout anglers are similar. For example, there are similar proportions of anglers that categorise themselves as being a novice or having 'average', 'above-average', or 'advanced' skill levels. The level of angling activity over the past year was also similar among pike and trout anglers in the sample. About 9% fished on average twice per week, 33% fished on average less than once every two weeks (i.e. up to 26 times in the year), and the balance fishing somewhere in between. While the analysis here distinguishes between being a pike or a trout angler, a substantial proportion of anglers target both species. Of survey respondents that typically target trout (and completed the trout CE) 37% indicated that they have also fished for pike in past 12 months, and conversely 38% in the case of pike anglers. There were also differences in the angler profiles. The age profile of pike and trout anglers differs somewhat, with pike anglers having proportionally more anglers in the 25–44 age cohort, with proportionally fewer in older age cohorts, especially those aged 66 and above. Between 80-90% of anglers in the survey fished at lake sites in the past 12 months. Pike stock management occurs at 7 lake sites and just 40% of pike anglers fished in any of those lakes, whereas 68% of trout anglers did so. This suggests that pike anglers are more likely to avoid those specific sites. There are also substantial differences between anglers in relation to catch & release activity. Approximately one quarter of trout anglers stated that they never harvest a caught fish, compared to almost three quarters of pike anglers. Just 1% of pike anglers typically keep the fish they catch 'most' or 'all of the time', whereas 12% of trout anglers do. In terms of expressed importance of various aspects of a day's fishing, pike anglers place a relatively stronger weighting on the level of catch, particularly large or specimen sized fish, whereas trout anglers place a relatively stronger weighting on good in-water visibility and absence of invasive weeds. The survey also asked a number of questions on angling related expenditure, both over the past 12 months and during a typical fishing trip. In terms of annual expenditures the means are broadly similar for pike and trout anglers in the €3,500–3,900 range, though there are large standard deviations. These annual figures include expenditures on both domestic and foreign angling trips, as well as expenditure on such as boats. Mean expenditure by anglers on their most regular or typical fishing trips is €289 for trout anglers and €237 for pike anglers and comprises expenditures on food, accommodation, tackle (bait, lines, etc.), fees, permits, guides, as well as any travel expenses. Median values are approximately €100 in both cases. These mean values for 'typical' trip expenditures are 40–60% lower than a 2012 on-site survey of anglers at 50 prime angling locations across Ireland, which also included brown trout and pike anglers (TDI, 2013). In addition to different sampling approaches that may partially explain the differences, the two studies collect different expenditure information. The current study asked anglers about expenditures on a typical or regular fishing trip, whereas the TDI study collected information on the intercepted trip but such trips might not necessarily be representative of 'typical' trips. Table 4 presents typical expenditure by angling frequency and location for both pike and trout anglers. There is no substantial difference in mean trip expenditure of frequent or occasional anglers compared to the respective means of all pike or trout anglers. However, anglers, both trout and pike, who fish in designated brown trout fisheries that have pike stock management spend considerably more than their peers that fish elsewhere.

3 Results

The dependent variable in all the models estimated, the site choice decision, takes a value of 1 for the site scenario selected (from a choice of 3 options, a status quo scenario or two alternatives) and zero otherwise. As explanatory variables for the choice probabilities we used the following site attributes: average catch, bag limit (if applicable), average length (if applicable), pike stock control methods including no stock control, lagarosiphon cover, and water visibility. We also included an alternate specific constant for the status quo scenario, which is labelled as ASC_{SQ}. We interacted a number of angler characteristics with ASC_{SQ}, such as angling club membership, whether the angler fished in a lake with pike stock management and a number of socio-demographic variables, but the model results are not substantially different that those presented here. The models are estimated from an unbalanced panel of choice decisions, with a total of 2,253 and 1,597 choice observations for the trout and pike choice experiments respectively.

Table 2: Descriptive Statistics: Proportion of respondents by category

	Trout CE	Pike CE
Fished in a lake in past 12 months	0.81	0.90
Fished designated brown trout lake (with pike stock management)	0.68	0.40
Angling frequency in last year		
103+ days	0.10	0.09
27-102 days	0.57	0.58
0-26 days	0.33	0.33
Angler self-assessed skill level		
Novice	0.03	0.01
Average	0.26	0.26
Above-average	0.38	0.42
Advanced	0.33	0.31
Angler Age		
15-24	0.01	0.01
25-35	0.09	0.22
35-44	0.24	0.35
45-65	0.53	0.41
66+	0.13	0.02
Also a pike angler	0.37	na
Also a trout angler	na	0.38
Typically keep (i.e. harvest) fish caught:		
”Never”	0.26	0.73
”most” or ”all of time”	0.12	0.01
On a day’s fishing it is important to:		
Catch at least one fish	0.67	0.78
Catch several fish	0.31	0.52
Catch large/specimen sized fish	0.23	0.53
Not be subject to bag limits	0.18	0.18
Have good visibility through the water	0.80	0.55
Have water free from invasive weeds	0.95	0.79
Number of Respondents	197	144

Table 3: Respondents’ household income and angling related expenditure, €

	N	Mean	Median	Std. Dev	Minimum	Maximum
Total angling related expenditure in past 12 months						
Trout anglers	139	3,512	2,100	4,820	100	36,550
Pike anglers	112	3,887	2,020	4,914	165	33,400
Expenditure on typical fishing trip						
Trout anglers	187	289	105	449	5	3,874
Pike anglers	141	237	100	476	13	4,050
Annual gross household income (based on income category mid-points)						
Trout anglers	196	56,186	42,500	32,935	15,000	150,000
Pike anglers	144	44,670	42,500	20,971	15,000	115,000

Table 4: Expenditure on a regular or typical angling trip, €

	N	Mean	Median	Std. Dev	Minimum	Maximum
Trout anglers' expenditure on typical fishing trip						
All trout anglers	187	289	105	449	5	3,874
Fished in designated brown trout lake with pike stock management in past 12 months						
Yes	130	305	125	478	5	3,874
No	57	250	60	376	6	1,650
Frequency of angling						
High: 103+ days in last year	18	280	133	314	10	1,050
Medium: 27-102 days in last year	107	302	110	488	5	3,874
Low: 0-26 days in last year	62	268	90	415	6	2,500
Pike anglers' expenditure on typical fishing trip						
All pike anglers	141	237	100	476	13	4,050
Fished in designated brown trout lake with pike stock management in past 12 months						
Yes	56	373	128	691	15	4,050
No	85	146	85	212	13	1,500
Frequency of angling						
High: 103+ days in last year	13	242	140	400	20	1,500
Medium: 27-102 days in last year	81	230	100	519	15	4,050
Low: 0-26 days in last year	47	246	105	425	13	1,987

The results for the conditional logit model are reported in Table 5. The signs of the estimated coefficients are largely as anticipated in both models, with higher catch rates, greater in-water visibility and less lagarosiphon cover providing a positive inducement to anglers. Pike anglers additionally favour fish of greater length, though trout anglers appear not to have any strong preference on bag limits. As anticipated, the coefficient on gill-netting as a pike stock management option (i.e. the status quo) is strongly negative for pike anglers. The negative sign on the $Gill$ variable in the trout model was unexpected, especially in light of the vocal support for gill-netting by trout anglers including during our focus group meetings. These results can be contrasted with those from the latent class model, which show much more diversity in preferences among both pike and trout anglers.

Model performance statistics such as the log likelihood, Akaike Information Criterion (AIC) and Bayes Information Criterion (BIC) were used for selecting the number of classes in the LCM model and are reported in Table 6. Three latent classes were selected as the preferred model for both trout and pike model estimations. In the case of trout a four latent class model did not estimate and the statistics suggest a better fit with three rather than two classes. In the case of the pike model based on log likelihood and AIC statistics 4 classes is potentially optimum. Though, the 4 class model is only 0.015 times as probable as the 3 class model based on the difference in AIC values. In the 4 class model within one of the latent classes only one explanatory variable had statistical significance, which limits its practical usefulness in understanding angler preferences. The BIC favours a 3 class model. The estimates of both 3 latent class models are reported in Table 7.

3.1 Class membership probabilities

The estimated membership probabilities, $\hat{\pi}_c$, for the three classes of trout anglers are 0.61, 0.26 and 0.13. Preferences differ across the classes for a range of fishery attributes (i.e. catch, invasive weed etc.) but there is clear distinction across classes for pike management controls. The greater proportion (i.e. 61%) of trout anglers are negatively disposed towards gill-netting (coefficient on $Gill$=-1.107), about a quarter are moderately positively disposed (coefficient=0.492) and approximately one-eight of trout anglers are more strongly in favour of gill-netting (coefficient=1.19). Preferences towards electro-fishing only are less clear-cut, as the coefficient on $Electro$ is statistically significant for only one of the latent classes. The coefficient estimates cannot be interpreted directly and we discuss their practical implications later in terms of site choice probabilities conditional on site attributes.

The membership probabilities for the three pike angler latent classes are 0.26, 0.69 and 0.05. Similar to trout anglers, preferences differ across the classes for a range of fishery attributes. For example, the average number of fish caught is not an important attribute for latent class 2, the largest of the three classes, whereas a higher catch rate is a positive attribute for class 1 but negative for class 3. However, all three classes are negatively disposed towards pike stock management. Latent class 2, the largest group at 69%, are the most strongly opposed to gill-netting. This same class are also negatively disposed towards electro-fishing, whereas the $Electro$ coefficient is not statistically significant for the other classes.

3.2 Marginal probabilities

One way of examining anglers' preferences for pike control, as well as other attributes of the fisheries, is to examine changes in choice probabilities under the status quo compared to a scenario option. For example, compare the estimated site choice probabilities for a fishing site under status quo conditions versus a site with no pike stock control, assuming all else equal. We do this in Table 8, where we calculate site choice probabilities for changes in each of the attributes examined in the choice experiments and also for changes in combinations of attributes. The probabilities for the latent classes are calculated using equation 3. The marginal probabilities for the 'Total' refers to the entire sample and is calculated using equation 4. Entries in Table 8 should be read by row. For example, from the first row for a trout angler who is a member of latent class 1, there is a 0.46 probability that the status quo site (described in Table 1) is chosen compared to 0.54 for a site where average catch rates are 1 trout higher, all else equal. Across all three latent classes there is a slightly lower probability (0.53) that the site with the higher mean catch rates is chosen. Pike anglers are more responsive to catch rates. A pike angler in latent class 2 is almost twice as likely (0.64/0.36) to select a site where the mean catch rate is one pike higher. The probability that a pike angler is a member of latent class 2 is 0.69 (see Table 7) and responsiveness of latent class 2 anglers to higher catch rates is reflected in the overall total sample probability of 0.61 compared to 0.39 for the status quo.

Before discussing preferences for pike control we briefly review preferences for the other fishery attributes that were considered. About one-eight of trout anglers (latent class 3) are negatively disposed to reducing the daily bag limit and are 1.4 times (0.58/0.42) more likely to fish at a site with a higher bag limit. Most trout anglers are not averse to a reduction in the daily bag limit and overall there is only a minimal difference in the probability that a site would be selected if it had a daily bag limit of 3 trout, one less than the status quo. Pike anglers are 1.6 times more likely to select a fishing site where the average length of pike caught is 10cm more than the status quo.

Trout anglers are substantially more concerned about the growth of lagarosiphon than pike anglers, which mirrors the focus group discussions. The status quo scenario assumed a 20% growth in lagarosiphon without any management intervention. The scenario examined in Table 8 considers a 20% reduction in lagarosiphon compared to the previous year. Trout anglers are 1.4 times more likely to select a site with that level of lagarosiphon control compared to the status quo, whereas pike anglers are more likely to select the status quo.

Pollution and water quality was a prominent issue in the CE focus groups, especially among trout anglers. Based on the model estimates pike anglers are equally if not more concerned. Almost the entire samples of pike and trout anglers favour sites with greater in-water visibility, with pike anglers over twice as likely to visit sites with double the visibility compared to the status quo (i.e. 3 versus 1.5m).

Understanding anglers' preferences for pike control was the primary purpose of the choice experiments. Two alternative pike control scenarios (no control, or electro-fishing only) were compared with the status quo option, which is electro-fishing and gill-netting as described earlier. From the LCM coefficient estimates we know that all pike anglers are negatively disposed to all methods of pike stock control, as there are negative coefficients on the $Electro$ and $Gill$ variables in each latent class. Nonetheless there is a positive probability that some pike anglers (from latent class 1) would choose to fish at a site with pike control versus a site without, all else equal. We could surmise that these pike anglers also fish for trout. But the majority of pike anglers, between 93–96%, would select a site without pike control, all else equal, and there is practically negligible difference in preferences irrespective of whether pike control comprises gill-netting or just electro-fishing.

Trout anglers' preferences for pike control are more nuanced. Across the latent classes in the LCM model the coefficient estimates on the *Gill* variable had both positive and negative signs and the *Electro* variable was significant in one case only. The largest latent class (61%) is 3 times (0.75/0.25) more likely to choose a site that has no pike control compared to the status quo. In contrast the smallest latent class (13%) is 3 times more more likely to choose a site with the status quo controls (i.e. gill-netting) compared to a site with no controls. The third class, which comprises approximately a quarter of the trout sample, are 1.6 times more likely to choose a site with gill-netting pike stock control. Faced with a choice between the status quo and electro-fishing only as pike control methods, trout anglers as a whole are 1.6 times more likely to select the site with electro-fishing only. When the choice is between the status quo and no pike control trout anglers are 1.4 times more likely to select the site with no pike control.

If pike controls are altered it is likely that there will be an impact on the population size and structure of several species, possibly affecting average size and catch rates for both trout and pike. What these changes might be is subject to future research and were not considered within the current choice experiment. Anglers were faced with choices over pike control methods but not its impact. We also examine in Table 8 choice probabilities for a suite of potential policy options. For example, no pike control with a substantial reduction in lagarosiphon, or additionally changes in the bag limit, water visibility, etc.. Such policy scenarios make no practical change in pike anglers' site choice probabilities. Pike anglers are strongly adverse to sites with any form of pike control, regardless of the level other site attributes such as high catch rates. Trout anglers are more likely to substitute between site attributes. If no pike control is combined with a change in lagarosiphon coverage from +20% to -20%, the probability of trout anglers selecting the status quo declines across all three latent classes. Furthermore, if the daily bag limit is reduced by half to two fish (for sustainability reasons) and coincidently if in-water visibility increases by 1 metre, only 30% of trout anglers would select the status quo. In summary, if changes in pike control are combined with changes in other fishery attributes, such as bag limits, weed coverage, or water quality, the proportion of trout anglers supporting such a measure is likely to increase substantially. In the case of the scenario examined here that proportion rises from 59% to 70%.

Table 5: Conditional Logit Model Estimates

	Trout		Pike	
	Estimate	Std. Error	Estimate	Std. Error
Catch	0.115***	0.025	0.127***	0.034
Bag	-0.045	0.036		
Length			0.021***	0.005
Electro	0.039	0.122	-1.383***	0.142
Gill	-0.358***	0.111	-3.271***	0.158
Weed	-0.007***	0.001	-0.005***	0.001
Visibility	0.089***	0.023	0.053	0.035
ASC_{SQ}	-0.270*	0.160	-0.083	0.210
No. of anglers	197		144	
Observations	2253		1597	
Log likelihood	-2180		-810	
AIC	4375		1633	
BIC	4415		1671	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4 Discussion

What is clear from the model estimates is that anglers' preferences for pike stock control are more complex than the superficial story that trout anglers favour pike stock control and pike anglers oppose it. In our sample almost 4 in 10

Table 6: Criteria to select number of classes

	Trout[1]		Pike		
Latent classes	2	3	2	3	4
Parameters	15	23	15	23	31
Log Likelihood	-1895.1	-1819.4	-706.3	-651.0	-638.9
AIC	3820.1	3684.8	1442.6	1348.1	1339.7
BIC	3905.9	3816.4	1523.2	1471.7	1506.4

[1] Model estimates did not converge for 4 latent trout angler classes

Table 7: Latent Class Model Estimates: Trout and Pike Choice Experiments

	Trout		Pike	
	Estimate	Std. Error	Estimate	Std. Error
Latent Class 1				
Catch	0.173***	0.031	0.254***	0.068
Bag	-0.025	0.064		
Length			0.035	0.010
Electro	-0.262	0.163	-0.381	0.282
Gill	-1.107***	0.263	-1.686***	0.313
Weed	-0.011***	0.002	-0.006***	0.002
Visibility	0.096***	0.024	0.083***	0.037
ASC_{SQ}	-1.898***	0.310	-1.545***	0.562
Latent Class 2				
Catch	-0.039	0.051	0.565	0.175
Bag	-0.299***	0.083		
Length			0.058***	0.016
Electro	0.702**	0.325	-4.378**	0.978
Gill	0.492*	0.260	-12.659*	2.778
Weed	-0.003	0.002	0.026	0.011
Visibility	0.125***	0.045	0.920***	0.326
ASC_{SQ}	-0.207	0.288	4.134	1.860
Latent Class 3				
Catch	0.315***	0.092	-0.067***	0.153
Bag	0.324***	0.088		
Length			-0.008***	0.021
Electro	0.444	0.932	-1.917	0.854
Gill	1.190**	0.501	-3.217**	0.837
Weed	-0.012***	0.003	-0.007***	0.002
Visibility	0.307***	0.092	-0.277***	0.063
ASC_{SQ}	1.986***	0.505	2.487***	0.969
π_1	0.613***	0.054	0.257***	0.040
π_2	0.260***	0.052	0.694***	0.041
π_3	0.127***	0.024	0.050***	0.020
N	197		144	
Obs	2253		1597	
Log likelihood	-1819		-651	
AIC	3685		1348	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Marginal Probabilities: Scenario option versus Status Quo

		Trout						Pike					
Scenario	Latent	Status Quo			Scenario			Status Quo			Scenario		
	Class	Prob	Std. Err.		Prob	Std. Err.		Prob	Std. Err.		Prob	Std. Err.	
Avg Catch:	1	0.46	0.01	***	0.54	0.01	***	0.44	0.02	***	0.56	0.02	***
+1 fish	2	0.51	0.01	***	0.49	0.01	***	0.36	0.04	***	0.64	0.04	***
	3	0.42	0.02	***	0.58	0.02	***	0.52	0.04	***	0.48	0.04	***
	Total	0.47	0.01	***	0.53	0.01	***	0.39	0.03	***	0.61	0.03	***
Trout: bag limit =3	1	0.49	0.02	***	0.51	0.02	***	0.41	0.02	***	0.59	0.02	***
or	2	0.43	0.02	***	0.57	0.02	***	0.36	0.04	***	0.64	0.04	***
Pike: length +10cm	3	0.58	0.02	***	0.42	0.02	***	0.52	0.05	***	0.48	0.05	***
	Total	0.49	0.01	***	0.51	0.01	***	0.38	0.03	***	0.62	0.03	***
Pike control:	1	0.30	0.04	***	0.70	0.04	***	0.21	0.04	***	0.79	0.04	***
Electro-fishing	2	0.45	0.04	***	0.55	0.04	***	0.00	0.00		1.00	0.00	***
only	3	0.68	0.16	***	0.32	0.16	**	0.21	0.14		0.79	0.14	***
	Total	0.39	0.03	***	0.61	0.03	***	0.07	0.01	***	0.93	0.01	***
Pike Control:	1	0.25	0.05	***	0.75	0.05	***	0.16	0.04	***	0.84	0.04	***
No control	2	0.62	0.06	***	0.38	0.06	***	0.00	0.00		1.00	0.00	***
	3	0.77	0.09	***	0.23	0.09	***	0.04	0.03		0.96	0.03	***
	Total	0.41	0.03	***	0.59	0.03	***	0.04	0.01	***	0.96	0.01	***
Lagarosiphon:	1	0.39	0.02	***	0.61	0.02	***	0.44	0.02	***	0.56	0.02	***
-20% p.a.	2	0.47	0.02	***	0.53	0.02	***	0.74	0.09	***	0.26	0.09	***
	3	0.39	0.03	***	0.61	0.03	***	0.43	0.02	***	0.57	0.02	***
	Total	0.41	0.01	***	0.59	0.01	***	0.65	0.06	***	0.35	0.06	***
In-water	1	0.46	0.01	***	0.54	0.01	***	0.47	0.01	***	0.53	0.01	***
visibility	2	0.45	0.02	***	0.55	0.02	***	0.20	0.08	**	0.80	0.08	***
+1.5m	3	0.39	0.03	***	0.61	0.03	***	0.60	0.02	***	0.40	0.02	***
	Total	0.45	0.01	***	0.55	0.01	***	0.29	0.05	***	0.71	0.05	***
No pike control	1	0.17	0.04	***	0.83	0.04	***	0.13	0.04	***	0.87	0.04	***
& lagarosiphon	2	0.59	0.07	***	0.41	0.07	***	0.00	0.00		1.00	0.00	***
-20% p.a.	3	0.67	0.11	***	0.33	0.11	***	0.03	0.02		0.97	0.02	***
	Total	0.35	0.03	***	0.65	0.03	***	0.03	0.01	***	0.97	0.01	***
No pike control &	1	0.15	0.05	***	0.85	0.05	***	0.16	0.04	***	0.84	0.04	***
lagarosiphon -20% &	2	0.41	0.09	***	0.59	0.09	***	0.00	0.00		1.00	0.00	***
visibility +1m &	3	0.74	0.11	***	0.26	0.11	**	0.04	0.03		0.96	0.03	***
Trout: bag limit =2 OR Pike: length -10cm	Total	0.30	0.04	***	0.70	0.04	***	0.04	0.01	***	0.96	0.01	***

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

pike anglers also fished for brown trout in the past twelve months, and similarly for trout anglers fishing for pike. These facts are reflected in the model estimates, which also suggest that there is no 'typical' pike or trout angler in respect of preferences towards pike stock control. Even among pike anglers, where all are negatively disposed towards pike stock control measures, the weight of feeling towards stock control, compared to other fishery attributes, varies considerably.

An important question that arises from analysis of this type is what are the likely impacts of a change in pike stock control measures? Prior to attempting to answer such a question it is important to acknowledge that while our sample does afford important insights on anglers' potential responses, the analysis is based on a sample that might not be representative of the populations of pike and trout anglers. The angler panel from which our sample is drawn was widely advertised and its membership covers a broad spectrum of anglers in terms of their residency and target species but the panel cannot be presumed to be a representative sample. It is reasonable to assume that there is some unknown threshold before anglers volunteer to become panel members, though we have not detected evidence of any other systematic bias in membership. The samples of pike and trout anglers are broadly similar in terms of angling frequency and self-assessed proficiency. Consequently, it is reasonable to say that the samples are of similarly committed pike and trout anglers and it is fair to compare preferences across these two samples. There is also a wide distribution of anglers across age cohorts and other socio-demographic characteristics suggesting that membership of the angler panel itself has not been confined to a narrow cohort of anglers. So while the analysis does provide important insights on anglers' preferences, without an established representative sample it is not possible to project with confidence the scale of response to any changes in pike stock control measures.

Conditional on the data samples available it is possible to infer a number of things about the likely impacts of a change in pike stock control measures. In the first instance, if pike stock controls in designated brown trout fisheries either cease or are limited to electro-fishing only it is likely that the number of pike anglers frequenting such fisheries is likely to increase. All else equal, pike anglers (almost universally) would choose to fish at a site with lower levels of pike control, and especially so if pike controls cease altogether. Unfortunately, as just mentioned above the methodology does not enable us to estimate the numbers of additional pike anglers visiting such sites.

If pike controls change, the probability that trout anglers visit a site changes; some are more likely to visit, whereas others are less likely to visit. In our sample about 61% of trout anglers are negatively disposed to gill-netting and they are 3 times (0.75/0.25) as likely to visit site with no pike controls compared to a status quo situation. Across the entire trout sample the probability that a no pike control site is preferred to the status quo situation is 0.59. Therefore, if the sample were representative of all trout anglers the numbers of trout anglers visiting such sites are likely to be no less than the status quo situation. We cannot attest to the representativeness of the sample but it is reasonable to say that if the majority of trout anglers preferred the status quo our trout angler sample is a considerable distance from being representative. We have no evidence that this is the case.

Our assessment is that when faced with two similar fishing destinations, one in which pike stocks are managed by gill-netting (and electro-fishing) and a second where pike stocks are not actively managed, the probability that an angler, irrespective of targeting trout or pike, will choose the no pike control site is higher and therefore it is likely that the number of anglers visiting a site with no active pike management would increase. However, the composition of anglers visiting the site may change. Some trout anglers that previously fished at the site may visit less frequently, other anglers may visit that had not fished there previously, or others visit more frequently. With a different composition of anglers the economic impact, in terms of anglers' expenditures in the vicinity of the fishing site, could change. However, on a per-angler basis any changes are likely to be negligible, as there is no substantial difference in either pike and trout anglers' expenditures from Table 4 or the composition of expenditure in Table 9.

Thus far we have considered only first order impacts of any potential changes in pike stock management, i.e. the response of anglers to the management change. A change in pike control will have a direct impact on pike stocks and consequent impacts on aquatic ecosystems in general. Establishing what these impacts might be requires further research, though the impacts are unlikely to be negligible. For instance, a study of natural versus human-induced selection of pike stocks on Windermere lake in the UK found that natural selection consistently acted against small pike and human-induced selection consistently favoured small pike (Carlson et al., 2007). Additionally, ceasing stock management, which primarily targets older larger pike, may result in considerable benefits for the pike fishery both in terms of quality and its long-term conservation (Arlinghaus et al., 2010). Therefore, changes in pike population structure could mean significant changes in the attributes of both trout and pike fisheries, including attributes over which anglers have preferences. Some of these as yet unknown changes may be considered positively by anglers and lead to a higher probability of site selection (and consequently more angler visits). Equally, the opposite is also likely. Therefore, we have not been able to consider how anglers are likely to respond to any longer term impacts associated with a change in pike stock control.

Table 9: Composition of typical trip expenditure

Variable	N	Mean	Median	Weighted Mean*
Trout Anglers				
Food	160	77	25	66
Accommodation	74	187	100	74
Fishing tackle	119	35	20	22
Fees, permits, guides	115	87	50	53
Travel expenses	180	57	30	54
Other	43	81	20	19
Total	187	289	105	289
Pike Anglers				
Food	129	61	20	56
Accommodation	34	219	100	53
Fishing tackle	125	36	26	32
Fees, permits, guides	32	77	25	18
Travel expenses	136	63	30	60
Other	30	85	20	18
Total	141	237	100	237

* Weighted for item non-response

5 Conclusion

This paper examines anglers' preferences for active stock management of pike populations within designated wild brown trout fisheries in Ireland. While the policy of pike control has a long history (IFI, 2014), it is not without controversy and conflict. Pike stocks are controlled with the objective of protecting trout stocks, and the naive assumption would be that trout anglers favour such management intervention. The reality is quite a different picture. The majority of trout anglers in our sample are opposed to pike stock control, and all else equal, are more likely to choose fishing sites where pike stocks are not actively managed. Conversely there is a substantial minority (39%) of trout anglers that could be considered advocates of pike control, with about one-third of these being more extreme in their preferences. Not surprisingly pike anglers do not support pike stock control.

Within the paper we consider pike and trout anglers as being distinct. The survey distinguished such anglers by asking respondents to specify the fishery in which they are most likely to fish. In reality many pike anglers also fish for trout and vice versa. In our sample that proportion is approximately 37%. It is therefore not surprising that there is such heterogeneity in anglers' preferences towards pike stock control. Even among pike anglers, all of whom experience dis-utility from pike stock control, preferences are quite heterogeneous with respect to pike stock control. The majority of pike anglers are strongly opposed to gill-netting, with smaller proportions of anglers having progressively more moderate, though negative, preferences towards gill-netting.

An important policy question arises is how anglers are likely to respond to any potential future changes in pike stock control measures? Assuming our samples of pike and trout anglers are broadly representative, and we have no strong evidence to assume otherwise, a change in the fishery management policy with respect to pike stock control at designated sites is unlikely to see a reduction in either pike or trout anglers visiting such sites. The empirical evidence suggests that the probability of visiting such sites would actually be higher in the case of no pike controls. Unfortunately we do not have any accurate measure of the population of pike and trout anglers and therefore it is not possible to estimate absolute changes in angler visits in response to changes in pike control policy.

The paper considers only first order effects of a management change towards pike stock control, essentially anglers preferences for the act of pike stock control. But changes in pike stock control are likely to have wider ecosystem impacts including on attributes of trout and pike fisheries over which anglers have preferences (e.g. catch rates, length, etc.). The nature of these ecosystem impacts are as of yet unknown and therefore it is not possible at this point to estimate the longer term response of anglers. Once information on the longer term biological impacts is available the current models can be used to assess anglers' responses in the longer term.

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