Working Paper No. 623

June 2019

Modelling anglers' fish release choices using logbook data

Gianluca Grilli[abc], John Curtis[ab], Stephen Hynes[c]

Abstract: In this paper we model recreational anglers' decisions to voluntarily release their catch to improve fish stock conservation. Using a random utility framework, we compare anglers' utility of retaining and consuming fish versus increased stock conservation achieved by fish releases. The analysis is based on a dataset of fish landings from anglers fishing for salmon and sea trout in Ireland during the seasons 2010--2016. Results indicate that there is a statistically significant inverse association between the weight of a fish and the probability of release, with larger fish more likely to be retained for consumption. On average, anglers were willing to sacrifice around 2.5 kg of fish to improve conservation of salmon and sea trout stocks, with a median value of 1.48. Results also indicate that the release probability varies based on fishing methods, with the use of spinners, fly-fishing and shrimps as bait to be more likely to be used for catch and release and live bait (i.e. worms) to retain the fish. Licence types and anglers' nationality are also important variables explaining release probability.

**Corresponding author:* gianluca.grilli@esri.ie

Acknowledgements: Funding from Inland Fisheries Ireland is gratefully acknowledged.

a. Economic and Social Research Institute, Dublin
b. Trinity College Dublin
c. Socio-Economic Marine Research Unit, Whitaker Institute, National University of Ireland, Galway

1. Introduction

Valuing environmental goods and services is useful for policy and planning, for example to obtain values for cost-benefit analyses but, at the same time, it is extremely challenging. Balmford et al. (2002) estimated that economic benefits of conserving wild nature exceed the costs with a 100:1 ratio. While some natural resources are traded in markets and have ready-to-use monetary values, other benefits that people derive from nature are non-marketed and their economic values are difficult to estimate. Welfare-based evaluation proposes that the value of a good or service is measured by the amount of money that people are willing to pay for it, irrespective of whether this good is marketed or not (Bateman et al., 1993). The intuition is that the amount of personal income that an individual is willing to sacrifice to obtain an improvement in the environmental quality can be considered a lower bound estimate of willingness to pay (WTP). In some instances the measure of the cost to be sustained could be non-monetary (Hanley et al., 2009), for example the distance that tourists are willing to travel could be used as a measure of recreational values (Giergiczny et al., 2015; Christie et al., 2007). WTP assessment can be based on data on actual behaviour of individuals (revealed preferences), such as travel cost and hedonic pricing methods, or on stated behavioural intentions (stated preferences, e.g. contingent valuation (CVM) and choice experiment (CE)), in particular when revealed data are not available (Champ et al., 2003). Traditionally non-use values and passive use values of the environment are evaluated using stated preferences because it is difficult to collect data that reveal the underlying preferences. Biodiversity, landscape and habitat conservation have been valued mainly using CVM and CE (White et al., 2001; Jacobsen and Hanley, 2009; Amigues et al., 2002; Notaro et al., 2018).

With respect to recreational angling, the literature is rich in papers that investigate recreational values of fishing sites using travel cost (Englin and Cameron, 1996; Shrestha et al., 2002; Curtis and Breen, 2017; Grilli et al., 2018) or site choice models (Hunt, 2005; Morey and Waldman, 1998; Hunt, 2008), while preferences for fish conservation and fishery management options are usually estimated using stated preferences techniques. Johnston et al. (2006) provide a comprehensive meta-analysis on factors affecting stated WTP for recreational angling, finding a systematic WTP variation associated with anglers' characteristics, site and type of resource. When conservation represents a matter of concern for a fishery, increasing fish stocks can be achieved by either improving habitat quality or reducing harvest. WTP for river habitat quality has been investigated, for example, by Loomis et al. (2000), who carried out a CVM study to assess WTP for restoring ecosystem services of a river basin. They found that the benefits of restoration are larger than the opportunity costs or other uses of the river in all scenarios. Other contributions are provided by Del Saz-Salazar et al. (2009), who investigated social benefits to restore water quality, Bateman et al. (2006), which made a comparison of CVM and contingent ranking methods for valuing water quality improvements, and Stithou et al. (2012) and Bockstael et al. (1989) who examined WTP to achieve good river ecological status. Understanding public preferences for water pollution abatement is also a topic of scientific interest (Mahieu et al., 2012). Concerning fish stocks, some papers investigate WTP for increased catch (e.g., Cantrell et al., 2004; Olaussen and Liu, 2011) or for stock conservation using stated preferences, in which stocks are one attribute in the fishery management scenarios (Chhun et al., 2013; Drymon and Scyphers, 2017; Smyth et al., 2009). The wide employment of stated preference data is largely due to the difficulty in identifying an objective measure of revealed preferences for fish conservation.

Where fisheries are under pressure due to recreational angling among other factors, management options to reverse declining stocks include reducing angling efficiency (e.g. regulating fishing methods) or limiting effort (e.g. bag limits). Implementing mandatory catch and release is also a potential option to increase conservation. Recent studies suggest that recreational anglers are aware of conservation needs at local level and are willing to accept a more strict legislation or to release fish (Sutton and Ditton, 2001; Hutt et al., 2013), although with some differences within subgroups. Ferter et al. (2013) combined results of some field studies across Europe and reported that catch and release rate was higher than expected in most of the surveyed countries. Most studies on this topic are based on stated data and it is difficult to assess whether stated intentions reflect actual behaviours, mainly because data on number of fish released by anglers are difficult to obtain. Some regulated fisheries require anglers to fill in a logbook in which all catches are recorded, so that angling activity could be monitored in an effective and timely manner. Such logbooks are often voluntary, though in some cases mandatory for all anglers targeting some endangered species (e.g. Prince et al., 2002; Kerr, 2007). Logbooks record data on quantity of fish, location and whether the fish was released or not and provide useful information to fishery managers at a relatively low cost (Pollock et al., 1995). Data recorded on logbooks represent revealed behaviours of individuals who decide to retain or voluntarily release the fish. Despite these advantages, there is not a wide employment of tools to record fishing activity but with some notable exceptions in North America and New Zealand. Mosindy and Duffy (2007) contrasted results of logbook data with creel surveys to assess the most efficient sampling method for stock assessment and in New Zealand Starr (2010); Hartill and Thompson (2016) proposed similar analyses of fish species specific diary schemes data. To the best of the authors' knowledge, there is no example in the literature attempting to interpret logbook data to understand anglers' catch behaviour. Furthermore, it is a rare example of using revealed preference data to examine preferences for conservation.

In this paper we analyse anglers' release decisions in a random utility setting, using data on recreational angling of salmon (*Salmo salar*) and sea trout (*Salmo trutta*) in Ireland. Due to several years of declining stocks, commercial salmon fishing was curtailed in the early 2000s and a drift net ban was introduced in 2007. Recreational angling is allowed but constantly monitored and some rivers may be regulated as catch and release when stocks are low. Anglers must complete logbooks to record catches, regardless to whether the fish was retained or not. When anglers release fish voluntarily after a landing they are revealing a preference for stock conservation over wild fish consumption and reveal behaviours that can be analysed in terms of utility.

2. Methods

2.1. Theoretical framework and econometric approach

Whenever an angler catches a fish, he/she has two options: release the fish back to the water or retain for consumption. When a fish is released in safe conditions there is a high survival probability, therefore releasing fish contributes to stock enhancement and conservation (Gingerich et al., 2007). This choice can be described by the economic theory of individual utility (Fishburn, 1970). An angler that decides to release a fish is willing to sacrifice the consumption of a given amount of wild fish to contribute to stock conservation, because the utility of conservation is larger than the utility of wild fish consumption. The sacrifice that the angler is willing to undertake can be quantified by the weight of the fish. When a fish is retained for consumption, the angler neglects conservation to fulfil his/her consumption needs. Our dependent variable is a dummy equal to one when the fish is released and zero when the fish is retained. Within a random utility model (RUM) setting (Manski, 1977), the utility of fish conservation Uc_i of individual i can be described by the following equation (Haab and McConnell, 2003):

$$Uc_i = v(q) + \epsilon_i \tag{1}$$

where q is the quantity of fish (fish stock) and ϵ is an i.i.d. random unobservable disturbance, for which distributional assumptions lead to different econometric models (Cameron and Trivedi, 2005). This specification of individual utility can be described by the dichotomous choice approach, for which the most common solution to utility estimation is the 'utility difference approach' proposed by Hanemann (1984), postulating that the probability of fish j being released is:

$$Pr(Release_j) = Pr\{v(q_1, Cu_i - w_j, e_i, s)\} + \epsilon_i \geq Pr\{v(q_0, Cu_i, e_i, s)\} + \epsilon_i \tag{2}$$

where q_1 and q_0 is the fish stock when the fish is released and retained, respectively; Cu represents the individual food consumption, w is the weight of the fish, e_i is a set of angler's related characteristics and s a vector of site-specific variables. This means that an angler will release the fish if the utility of a larger stock is higher than the utility of consuming the fish. Larger fish are a greater sacrifice in anglers' consumption, therefore we may expect an inverse relationship between fish weight and the release probability.[1] The statistical analysis of this model depends on the assumption made on the observable component v and on the random disturbance ϵ. The simplest case is to assume a linear deterministic component of the utility as follows :

$$v_i = \alpha + \beta w \tag{3}$$

where β is a coefficient indicating the effect of fish weight on utility. The econometric specification is completed assuming a distribution for the random disturbance, the most common options being normal or logistic. We assume a logistic distribution for ϵ and obtain a binary logit model, whose probability function is the following (Greene, 2003):

$$Pr(Release_j) = \frac{e^{v_i}}{1 + e^{v_i}} \tag{4}$$

According to the utility difference welfare measure can be retrieved from equation 3 with the following formula (Hanemann, 1984):

$$C = \frac{\alpha}{\beta} \tag{5}$$

Normally C represents expected willing to pay for the related good or service. In our work β is not associated with a monetary attribute but fish weight, therefore an analogous welfare measure could be described as the expected fish weight at which an angler is willing to consume a fish in lieu of forgone conservation benefits.

In estimating the model we specify α as a function of covariates such that $\alpha = \alpha_0 + \gamma Z$, where Z comprises both angler characteristics and site specific variables.

2.2. Data description

When fishing for salmon and sea trout in Ireland a State licence is required and a fishing permit or club membership may also be required at some locations. Salmon and sea trout angling is subject to the 'Wild salmon and sea trout tagging scheme' administered by Inland Fisheries Ireland (IFI). The main objective of this scheme is to collect accurate information on nominal catch and estimate stock exploitation in order to develop adequate management strategies for the long-term sustainability of salmonid fisheries. When an

[1] In some cases anglers may depart from this basic assumption and decide to release big fish because they are likely to carry many eggs, which can be considered a warm glow effect (Nunes and Schokkaert, 2003).

angler purchases a licence they also receive a logbook and gill tags. Anglers must attach a gill tag to all salmon and sea trout harvested and record all details of the catch in the logbook. All released fish must also be recorded, not just harvested fish. Information recorded in the logbook includes date and location, length and weight of the fish, the species (salmon or sea trout), fishing method (i.e. type of bait), and whether the fish was released or not. While returning logbooks at the end of the season is mandatory, approximately 30% of logbooks are not returned. The majority of non-returned logbooks are associated with 1-day licences where catches are relatively few due to low effort and possibly angler inexperience, or where no catch is recorded. Our dataset is composed of all recorded catches between 2010 and 2016. Each row of our dataset is a fish and each angler occupies a number of rows equals to the number of fish caught, therefore we have an unbalanced panel of catches by angler for a total of about 193,392 observations, ranging between 17,409–35,352 landings per year.

Not all releases are voluntary because anglers have to comply with conservation regulations. Some rivers are catch and release only fisheries, in which releases are mandatory. In addition, anglers have to respect bag limits for retained fish. For example, bag limit regulations provide for an annual bag limit of 10 fish per angler and provides for a season bag limit of 3 fish between specific days in January and May, a daily bag limit of 3 fish between specific days in May and August, and a daily bag limit of 1 fish from September through the end of the season. Fishing is permitted beyond attaining the relevant bag limits but release of caught fish becomes mandatory. The first task of the analysis is to define rules to identify the fish for which anglers had a free release/retain choice and discard observations on mandatory releases. We assume that all the fish caught in catch and release only fisheries were mandatory releases and the associated observations are excluded from the analysis. All observations of fish caught after reaching daily, seasonal, and annual bag limits were also discarded. For each day, we coded as mandatory releases only the fish that were taken after having reached the daily limit. For example, if an angler catches 5 fish in one day, retains the first three fish and releases the final two fish caught, these fish are released after the bag limit was attained and are considered to be mandatory. If the same angler releases the first two fish and retains the others, then releases are voluntary. A similar discrimination rule applied to seasonal bag limits. After excluding mandatory releases our dataset reduced to 160,365 observations of fish caught, of which 38% was released.

The variables used in the econometric model are summarised in Table 1. The weight of the fish is the main variable of interest. For harvested fish the reported weight is likely to be measured using a scales whereas the weight of released fish is likely to be estimated. The mean weight of caught fish on our reduced sample is 2.49kg. The minimum weight refers to a sea trout. The maximum weight reported of 44.4kg seems unlikely and possibly reflects a weight in pounds (lbs) recorded as kgs. We then control for fish species, fishing method (spinner, flies, worms and shrimp fishing, the baseline is composed by other unspecified methods), licence type (the baseline is the annual licence) and anglers' nationality. Lastly, we control for river fixed effects to account for the panel structure of the data. We also explored the possibility of controlling for angler fixed effects, however the panel was unbalanced and the number of clusters was very high so that the model did not converge.

3. Results

We estimate logit models using three different logit specifications for robustness and to assess the stability of the estimated coefficients. The first model is a logit model that includes only the weight variable,

Table 1: Descriptive statistics of the variables used in the model

Variable	Description	mean	sd	min	max
Weight	Weight of the fish (kg)	2.49	1.36	0.1	44.4
Salmon	1 Salmon 0 sea trout	0.92	0.27	0	1
Spinner	Fishing method - spinner	0.24	0.43	0	1
Fly	Fishing method - fly	0.41	0.49	0	1
Shrimp	Fishing method - shrimp	0.1	0.3	0	1
Worm	Fishing method - worms	0.21	0.41	0	1
Licence A	% of anglers holding an annual countrywide licence	0.36	0.48	0	1
District	% of anglers holding an annual district licence	0.46	0.5	0	1
Juvenile	% of anglers holding a juvenile licence	0.02	0.15	0	1
21-day	% of anglers holding a 21 day licence	0.12	0.32	0	1
1-day	% of anglers holding a 1 day licence	0.01	0.08	0	1
Foyle	% of anglers holding a special licence for river Foyle	0.04	0.19	0	1
Local	% of anglers holding a special local licence	0.001	0.03	0	1
Ireland	1 Irish angler 0 Overseas angler	0.79	0.4	0	1

the second a logit including fishing method, licence and years, the third model contains the same covariates as the second but controls for river fixed effects. Results are available in Table 2. The three models are consistent, there are no changes in the sign of significant variables and only their magnitude varies. The coefficient associated with the fish weight is negative and statistically significant in all models. This result was anticipated and indicates that bigger fish are less likely to be released. Model number 2 provides the smallest estimate in absolute values, while the third model the largest. Both AIC and BIC statistics indicate that Model 3 provides a better fit for the data and is preferred, so the following analysis will be focused on results of this model.

The statistically significant coefficient associated with the fish species variable indicates that salmon are less likely to be released compared to sea trout. Fish are most likely to be released if shrimp or fly-fishing is the fishing method and least likely if worms are used as bait. The coefficients on licence types indicate that fish are more likely to be released by holders of annual A licences, which permit fishing across the whole country. The lowest probability of release is associated with short duration or juvenile licence holders. Irish anglers are more likely to release the fish compared to overseas anglers fishing in Ireland. Lastly with respect to yearly trends, compared to 2010 and with the exception of 2011, the probability of releasing fishing is declining. These seasonal coefficients may reflect changes in angling conditions between years such as impacts associated with weather conditions or stocks of returning spawning fish.

In Table 3 we report marginal effects from our preferred model 3; the change in the probability of releasing a fish when the value of the associated covariate changes by one unit. The marginal effect associated with the weight variable indicates that for an increase of 1kg in the weight of the fish, the probability of it being released is 6.7 percentage points lower. At a practical level a fish weighting 4 kg is approximately 20 percentage points less likely to be released compared to a 1kg fish. Salmon are almost 18 percentage points less likely to be released compared to sea trout, all else equal. For the fishing methods the marginal

Table 2: Result of the catch and release model

Variable	Model 1	Model 2	Model 3
Constant	.132***	1.609***	
	(.011)	(.044)	
Weight	-.255***	-.198***	-0.425***
	(.004)	(.005)	(.006)
Salmon (reference category - sea trout)		-1.95***	-1.123***
		(.027)	(.035)
Fishing Method (reference - ‘other’):			
Spinner		.335***	0.433***
		(.032)	(.039)
Fly		.739***	0.981***
		(.031)	(.038)
Shrimp		.883***	0.977***
		(.035)	(.042)
Worm		-1.247***	-0.833***
		(.034)	(.042)
Licence type (reference - Licence A, annual):			
District		-.417***	-0.42***
		(.013)	(.014)
Juvenile		-1.084***	-1.056***
		(.046)	(.051)
21-day		-1.006***	-0.921***
		(.026)	(.028)
1-day		-1.018***	-0.835***
		(.077)	(.081)
Foyle		-0.233***	-0.196***
		(.034)	(.037)
Local		2.108***	1.594**
		(.593)	(.660)
Irish angler (reference - overseas angler)		0.332***	0.056**
		(.02)	(.022)
Fishing year (reference - 2010):			
2011		0.056***	-0.011
		(.02)	(.022)
2012		-0.045**	-0.052**
		(.02)	(.021)
2013		-0.011	0.017
		(.02)	(.022)
2014		-0.189***	-0.131***
		(.024)	(.026)
2015		-0.217***	-0.192***
		(.021)	(.024)
2016		-0.096***	-0.072***
		(.022)	(.023)
Average River FE	No	No	1.94
AIC	209125	179390	153145
BIC	209157	179602	154982
LL	-104560	-89675	-76388
Obs	160365	160365	160365

$*p < 0.1$, $**p < 0.05$, $***p < 0.01$. Standard error in parenthesis

Table 3: Marginal effects of Model 3 variables on release probability

	Margin	Std. Err
Weight	-0.067***	0.001
Salmon	-0.177***	0.005
Spinner	0.068***	0.006
Fly	0.155***	0.006
Shrimp	0.154***	0.007
Worm	-0.131***	0.007
District	-0.069***	0.002
Juvenile	-0.16***	0.007
21-day	-0.143***	0.004
1-day	-0.131***	0.011
Foyle	-0.033***	0.006
Local	0.273***	0.103
Irish	0.009**	0.004

effects are relative to the reference category of ‘other’ fishing methods, with the probability of release approximately 15 percentage point higher among anglers using either a fly or spinner. On the contrary the probability of release among anglers using worms is 13 percentage points lower. For licence types the reference category is the licence type A, which is applicable for the entire season and whole country. Probability of voluntary release is almost 7 percentage points lower among district licence holders while the probability of voluntary release among short duration licence holders (i.e. 1-day and 21-day) is 13–14 percentage lower than the reference category. While there is a statistically significant difference in the probability of release between anglers resident in Ireland compared to visitors from abroad, including Northern Ireland, in practice the difference is negligible .

4. Discussions

Growing concerns on fish stock status highlighted the urgency of reducing harvest not only for commercial vessels but also for recreational anglers. The interest in catch and release as a policy measure to preserve fish stocks should be contrasted with anglers’ response to harvest limits because of potential negative effect for angling tourism. Attitudes towards catch and release are still controversial and while some parts of the literature suggests positive attitudes (Sauer et al., 1997), other authors highlight potential conflicts arising in fisheries (Muir et al., 2013; Arlinghaus et al., 2005). The analysis here provides interesting insight on catch and release decisions and provides useful information for researchers, fishery managers and policy-makers.

4.1. The value of stock conservation for anglers

There is evidence that anglers are willing to trade fish consumption with more salmonid stock conservation. The coefficient associated with the weight of the fish was negative and highly significant in all models, indicating that the effect is robust to different econometric specifications. In our preferred model the marginal effect of weight was -0.067, which is the percentage point decline in the probability of release for each 1kg increase in fish weight. While we have couched our model in terms of a trade-off between the nutritional consumptive value of harvested fish versus the conservation benefit of released fish, the model is consistent with a definition of consumption that includes angler utility associated with harvesting larger or trophy sized fish. Larger fish have greater spawning potential and therefore their prospective contribution to improving the conservation status of fish stocks is higher compared to smaller fish. Using equation 5 we can calculate how anglers evaluate that trade-off between personal consumptive benefits and stock conservation benefits of releasing a fish. On average, the mean weight of harvested fish that anglers are willing sacrifice in lieu of releasing one additional spawning salmonid is 1.48 kg (95% CI: .83–2.15).[2] What is not known about this trade-off is the extent to which anglers are aware of stock conservation benefits associated with releasing caught fish and how these benefits vary with fish size. If anglers were aware of the probabilistic contribution of a single released fish to future stock enhancement would this trade-off value increase in weight?[3]

With the prohibition of sale of angler caught wild Atlantic salmon we don't have a ready market price of the nutritional consumptive value of harvested salmon. Market prices of farmed salmon is readily available from fishmongers and supermarkets and in a recent choice experiment study on the Irish public's willingness to pay for farmed salmon fillets specify price levels between €11–24.50 (Van Osch et al., 2017). Using the highest attribute level from Van Osch et al. (2017), the market value of the 1.48kg at which anglers on average favour harvest over release is €36. Ignoring any non-nutritional benefits associated with harvesting fish, anglers are willing to sacrifice for conservation benefits salmon up to a retail market value of approximately €36, on average.[4] Alternatively, the willingness of salmonid anglers fishing in Ireland to contribute to stock conservation and enhancement via catch and release has a mean value equivalent to €36. This result is similar to the WTP that Campbell (2008) found in a CE for assessing the existence value of Atlantic salmon among other species in Northern Ireland. In a Scottish study, Thomas and Blakemore (2007) estimated a WTP of £37.70 (≈ €43) for a scheme aiming at improving salmon abundance. Despite this estimate being an approximation and being that salmon retail prices vary across countries, this valuation exercise shows that welfare measures are potentially available to inform policy makers' cost-benefit calculations.

While the 1.48kg is a mean value, the probability that a fish is released varies by angler attributes, in particular licence type and fishing method. Table 4 shows the minimum mean harvest weight associated with a number of angler attribute combinations. The most notable difference is observed between fish species, with sea trout anglers being willing to sacrifice a much larger consumption compared to salmon anglers. A surprising result is the similarity in the willingness to release between fly and shrimp anglers, because fly fishing is often associated with a positive attitude towards catch and release (Zwirn et al., 2005) while natural baits such as shrimps and worms reduce catch per unit effort (Matlock et al., 1993) and are used when anglers want to retain the quarry. The use of worms provides a negative estimate of weight that anglers are willing to sacrifice, which means that they are more likely to retain fish and require a compensation to release.

4.2. Policy implications for fisheries

Understanding factors affecting anglers' decision to release fish is important in a context of declining stocks and action required to manage harvests. It is not possible to assume that the effect of catch and release fishing on fish stock is neutral (Cooke et al., 2006), but the impact can be reduced to close to zero

[2]Confidence intervals were estimated using the Krinsky-Robb simulation method using 10,000 random draws (Krinsky and Robb, 1986).

[3]e.g. Accounting for probabilities associated with post-release mortality, prediation, spawning, smolt survival, and survival and sea to return to spawn.

[4]At lease some of the non-nutritional benefits associated with harvesting fish, e.g. photos with large or trophy fish, are also feasible if the fished is released.

Table 4: Expected sacrifice of kgs based on species, fishing method and angler's nationality

	Mean WTP	95% lower CI	95% upper CI
General mean	1.48	0.83	2.15
sea trout anglers only	3.24	3.91	4.59
Salmon anglers only	0.62	1.27	1.92
Spinner fishing anglers	0.84	1.50	2.15
Fly fishing anglers	2.14	2.79	3.44
Shrimp fishing anglers	2.12	2.78	3.43
worm fishing anglers	-2.16	-1.48	-0.83
Irish anglers	0.86	1.51	2.16

under some circumstances, i.e. respecting species-specific release guidelines, increasing anglers' awareness and knowledge (Booth et al., 1995; Cooke and Suski, 2005; Cooke et al., 2006). Despite the fact of recreational angling being considered a consumptive activity, providing food in addition to leisure, there is considerable evidence that some fishing methods cause minimal harm to fish when landed and can be safely released back to the water (Clark JR, 1983; Zwirn et al., 2005). The literature shows mixed results of anglers' attitude towards catch and release. Muir et al. (2013) and Bartholomew and Bohnsack (2005) report that in some cases anglers are reluctant to release fish because they prefer to retain fish for the table or for ethical considerations related to animal welfare. Arlinghaus (2007) suggests that catch and release fishing may create unexpected and illogical conflicts between angler groups. Other studies find that catch and release fishing are positively perceived by anglers and the fishing activity is not negatively affected by harvest restrictions (Grilli et al., 2019; Nguyen et al., 2013). Sutton and Ditton (2001) argue that individuals for whom fishing is a central leisure activity are more likely to be in favour of catch and release. This heterogeneity suggests that preferences for catch and release fishing could be site-specific and difficult to generalise, therefore additional studies should be carried out.

Our application highlighted that when mandatory releases are excluded, anglers fishing in Ireland voluntarily release 38% of the fish they catch. The research also quantifies the threshold at which anglers trade-off harvesting versus conservation. These are valuable pieces of information for fishery managers and should be useful in helping assess the impact of angling activity on fish stocks. At specific river stock level the information can assist in management decisions on the angling status of fisheries with threatened or vulnerable fish stocks (i.e. whether fisheries are classified as open, catch and release only, closed for recreational angling).

The statistical significance of the year dummies compared to 2010 suggests that the propensity to engage in catch and release is influenced by angling conditions (e.g. water levels, fish runs, etc.). The extent to which angling activity impacts on sufficient fish spawning to achieve stock conservation thresholds will therefore also vary from year to year, as propensity to engage in catch and release varies. Consequently, the regulation of angling activity (e.g. bag limits, fishery status, etc.) for the management of fish stocks should be mindful that participation in voluntary catch and release is neither constant nor increasing with time. In future fishery management decisions a precautionary approach should be taken on the extent to which anglers engage in catch and release in any particular year.

4.3. *Further developments and applications*

The availability of logbook data has potentially many applications and could be employed to monitor a wide range of fish species and for other useful purposes, for example to estimate anglers' catch per unit effort (CPUE). With some appropriate changes, similar data collection could also be useful to manage resources other than fish, for example biodiversity collection or more generally all the resources in which there is a choice between conservation and exploitation. All environmental choices made by individuals may reveal the utility of conservation relative to exploitation and may be recorded and used for policy.

Accuracy of the research depends on the reliability of logbook data, which is in turn determined by anglers' environmental consciousness and enforcement levels. One of the limits of our dataset is that anglers are not tracked across years. Our dataset comprises annual catch records with anonymised but unique identifiers for anglers. But angler identifiers do not carry across years so it is not possible to control for within variation efficiently. Our sample did not show significant differences between the cross-section model and the fixed effects model, therefore augmenting the panel dimensions may not change results in a significant manner in this instance. However, controlling for individual effects over years may be advantageous in other cases. Gray et al. (2015) found that anglers' ecological knowledge increases with specialisation, therefore an angler may be more aware of conservation needs after a few years of experience and decide to release more fish. As expertise increases, anglers may also improve the fish release techniques. The collection of better data on angling effort would also be particularly welcome in this instance. At present logbooks request data on annual angling effort, which is subject to high item non-response. More accurate collection of angling effort is particularly important if issues surrounding CPUE are to be considered. The current dataset only contains information on fishing occasions in which anglers had a positive catch and no information is recorded for fishing days without landings. Additionally data on socio-demographic variables would be also useful if the analyst wishes a better description of anglers' profile and activity.

5. Conclusions

Declining fish stocks worldwide are causing increased concern about the sustainability of fisheries management and a wide range of data is required to constantly and efficiently monitor harvest. Voluntary engagement in catch and release is one measure that enables anglers to continue to participate in their recreational activity in a sustainable manner. In this paper we propose a random utility framework to analyse recreational anglers' decision process between harvesting or releasing caught fish. Using anglers' logbook data we model anglers' decisions to voluntarily release their catch. Results indicate that anglers are willing to trade harvest fish up to 2.5 kgs in favour of stock conservation by releasing the fish, on average across all anglers. The probability of release varies by fishing methods, licence types and nationality of the anglers. These research findings are useful to inform policy makers' cost-benefit calculations and to efficiently monitor catch and stock levels in fisheries. Our results indicate that many anglers already show environmental consciousness and voluntarily release fish after being caught, therefore a wider promotion of catch and release may represent a viable management option in fisheries showing declining stocks. Considering the large impact of recreational activities on habitat and fish populations, a recommendation for fishery management is to extend the use of logbooks and collect additional information on anglers' effort to obtain insights on the environmental impact of recreation and to increase the efficiency of monitoring activities.

6. Acknowledgement

Funding from Inland Fisheries Ireland is gratefully acknowledged. We are grateful to IFI for providing access to anonymised logbook data returns and thanks to Kealan O'Higgins and Paul O'Reilly who provided assistance with the data.

7. References

Amigues, J.-P., Boulatoff, C., Desaigues, B., Gauthier, C., and Keith, J. E. (2002). The benefits and costs of riparian analysis habitat preservation: a willingness to accept/willingness to pay contingent valuation approach. *Ecological Economics*, 43(1):17–31.

Arlinghaus, R. (2007). Voluntary catch-and-release can generate conflict within the recreational angling community: a qualitative case study of specialised carp, cyprinus carpio, angling in germany. *Fisheries Management and Ecology*, 14(2):161–171.

Arlinghaus, R. et al. (2005). A conceptual framework to identify and understand conflicts in recreational fisheries systems, with implications for sustainable management. *Aquatic Resources, Culture and Development*, 1(2):145–174.

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R. E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., et al. (2002). Economic reasons for conserving wild nature. *science*, 297(5583):950–953.

Bartholomew, A. and Bohnsack, J. A. (2005). A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries*, 15(1-2):129–154.

Bateman, I., Turner, R. K., and Bateman, S. (1993). Extending cost benefit analysis of uk highway proposals: environmental evaluation and equity. *Project Appraisal*, 8(4):213–224.

Bateman, I. J., Cole, M., Georgiou, S., and Hadley, D. (2006). Comparing contingent valuation and contingent ranking: A case study considering the benefits of urban river water quality improvements. *Journal of environmental management*, 79(3):221–231.

Bockstael, N. E., McConnell, K. E., and Strand, I. E. (1989). Measuring the benefits of improvements in water quality: the chesapeake bay. *Marine Resource Economics*, 6(1):1–18.

Booth, R. K., Kieffer, J. D., Tufts, B. L., Davidson, K., and Bielak, A. T. (1995). Effects of late-season catch and release angling on anaerobic metabolism, acid–base status, survival, and gamete viability in wild atlantic salmon (salmo salar). *Canadian Journal of Fisheries and Aquatic Sciences*, 52(2):283–290.

Cameron, A. C. and Trivedi, P. K. (2005). *Microeconometrics: methods and applications*. Cambridge University Press.

Campbell, D. (2008). Identification and analysis of discontinuous preferences in discrete choice experiments. In *European Association of Environmental and Resource Economists Annual Conference Gothenburg, Sweden*, pages 25–28.

Cantrell, R. N., Garcia, M., Leung, P., and Ziemann, D. (2004). Recreational anglers willingness to pay for increased catch rates of pacific threadfin (polydactylus sexfilis) in hawaii. *Fisheries Research*, 68(1-3):149–158.

Champ, P. A., Boyle, K., and Brown, T. C. (2003). A primer on non-market valuation, the economics of non-market goods and services.

Chhun, S., Thorsnes, P., and Moller, H. (2013). Preferences for management of near-shore marine ecosystems: a choice experiment in new zealand. *Resources*, 2(3):406–438.

Christie, M., Hanley, N., and Hynes, S. (2007). Valuing enhancements to forest recreation using choice experiment and contingent behaviour methods. *Journal of Forest Economics*, 13(2-3):75–102.

Clark JR, R. D. (1983). Potential effects of voluntary catch and release of fish on recreational fisheries. *North American Journal of Fisheries Management*, 3(3):306–314.

Cooke, S. J., Danylchuk, A. J., Danylchuk, S. E., Suski, C. D., and Goldberg, T. L. (2006). Is catch-and-release recreational angling compatible with no-take marine protected areas? *Ocean & Coastal Management*, 49(5-6):342–354.

Cooke, S. J. and Suski, C. D. (2005). Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? *Biodiversity & Conservation*, 14(5):1195–1209.

Curtis, J. and Breen, B. (2017). Irish coarse and game anglers' preferences for fishing site attributes. *Fisheries Research*, 190:103–112. http://doi.org/10.1016/j.fishres.2017.01.016.

Del Saz-Salazar, S., Hernández-Sancho, F., and Sala-Garrido, R. (2009). The social benefits of restoring water quality in the context of the water framework directive: A comparison of willingness to pay and willingness to accept. *Science of the Total Environment*, 407(16):4574–4583.

Drymon, J. M. and Scyphers, S. B. (2017). Attitudes and perceptions influence recreational angler support for shark conservation and fisheries sustainability. *Marine Policy*, 81:153–159.

Englin, J. and Cameron, T. A. (1996). Augmenting travel cost models with contingent behavior data. *Environmental and Resource Economics*, 7(2):133–147.

Ferter, K., Weltersbach, M. S., Strehlow, H. V., Vølstad, J. H., Alós, J., Arlinghaus, R., Armstrong, M., Dorow, M., de Graaf, M., van der Hammen, T., et al. (2013). Unexpectedly high catch-and-release rates in european marine recreational fisheries: implications for science and management. *ICES Journal of Marine Science*, 70(7):1319–1329.

Fishburn, P. C. (1970). Utility theory for decision making. Technical report, Research analysis corp McLean VA.

Giergiczny, M., Czajkowski, M., Żylicz, T., and Angelstam, P. (2015). Choice experiment assessment of public preferences for forest structural attributes. *Ecological Economics*, 119:8–23.

Gingerich, A. J., Cooke, S. J., Hanson, K. C., Donaldson, M. R., Hasler, C. T., Suski, C. D., and Arlinghaus, R. (2007). Evaluation of the interactive effects of air exposure duration and water temperature on the condition and survival of angled and released fish. *Fisheries Research*, 86(2-3):169–178.

Gray, S., Hilsberg, J., McFall, A., and Arlinghaus, R. (2015). The structure and function of angler mental models about fish population ecology: the influence of specialization and target species. *Journal of Outdoor Recreation and Tourism*, 12:1–13.

Greene, W. H. (2003). *Econometric Analysis*. Pearson Education India.

Grilli, G., Curtis, J., Hynes, S., and O'Reilly, P. (2019). Anglers' views on stock conservation: Sea bass angling in ireland. *Marine Policy*, 99:34–41.

Grilli, G., Landgraf, G., Curtis, J., and Hynes, S. (2018). A travel cost evaluation of the benefits of two destination salmon rivers in Ireland. *Journal of Outdoor Recreation and Tourism*. https://doi.org/10.1016/j.jort.2018.02.004.

Haab, T. C. and McConnell, K. E. (2003). Valuing environmental and natural resources: the econometrics of non-market valuation. *Journal of Energy Literature*, 9:80–80.

Hanemann, W. M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. *American journal of agricultural economics*, 66(3):332–341.

Hanley, N., Barbier, E. B., and Barbier, E. (2009). *Pricing nature: cost-benefit analysis and environmental policy*. Edward Elgar Publishing.

Hartill, B. and Thompson, F. (2016). Review of self-reporting tools for recreational fishers. *New Zealand Fisheries Assessment Report*, page 06.

Hunt, L. M. (2005). Recreational fishing site choice models: insights and future opportunities. *Human Dimensions of Wildlife*, 10(3):153–172.

Hunt, L. M. (2008). Examining state dependence and place attachment within a recreational fishing site choice model. *Journal of Leisure Research*, 40(1):110–127.

Hutt, C. P., Hunt, K. M., and Anderson, D. K. (2013). Measurement of angler catch-related attitudes: an assessment of model structure and metric invariance. *Leisure Sciences*, 35(4):382–398.

Jacobsen, J. B. and Hanley, N. (2009). Are there income effects on global willingness to pay for biodiversity conservation? *Environmental and Resource Economics*, 43(2):137–160.

Johnston, R. J., Ranson, M. H., Besedin, E. Y., and Helm, E. C. (2006). What determines willingness to pay per fish? a meta-analysis of recreational fishing values. *Marine Resource Economics*, 21(1):1–32.

Kerr, S. J. (2007). Characteristics of ontario muskellunge (esox masquinongy) fisheries based on volunteer angler diary information. *Environmental Biology of Fishes*, 79(1-2):61–69.

Krinsky, I. and Robb, A. L. (1986). On approximating the statistical properties of elasticities. *The Review of Economics and Statistics*, pages 715–719.

Loomis, J., Kent, P., Strange, L., Fausch, K., and Covich, A. (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey. *Ecological economics*, 33(1):103–117.

Mahieu, P.-A., Riera, P., and Giergiczny, M. (2012). Determinants of willingness-to-pay for water pollution abatement: a point and interval data payment card application. *Journal of environmental management*, 108:49–53.

Manski, C. F. (1977). The structure of random utility models. *Theory and decision*, 8(3):229–254.

Matlock, G. C., McEachron, L. W., Dailey, J. A., Unger, P. A., and Chai, P. (1993). Management briefs: Short-term hooking mortalities of red drums and spotted seatrout caught on single-barb and treble hooks. *North American Journal of Fisheries Management*, 13(1):186–189.

Morey, E. R. and Waldman, D. M. (1998). Measurement error in recreation demand models: the joint estimation of participation, site choice, and site characteristics. *Journal of Environmental Economics and Management*, 35(3):262–276. https://doi.org/10.1006/jeem.1998.1029.

Mosindy, T. E. and Duffy, M. J. (2007). The use of angler diary surveys to evaluate long-term changes in muskellunge populations on lake of the woods, ontario. *Environmental Biology of Fishes*, 79(1-2):71–83.

Muir, R., Keown, A., Adams, N., and Farnworth, M. (2013). Attitudes towards catch-and-release recreational angling, angling practices and perceptions of pain and welfare in fish in New Zealand. *Animal Welfare*, 22:323–329.

Nguyen, V. M., Rudd, M. A., Hinch, S. G., and Cooke, S. J. (2013). Recreational anglers' attitudes, beliefs, and behaviors related to catch-and-release practices of pacific salmon in british columbia. *Journal of environmental management*, 128:852–865.

Notaro, S., Grilli, G., and Paletto, A. (2018). The role of emotions on tourists willingness to pay for the alpine landscape: a latent class approach. *Landscape Research*, pages 1–14.

Nunes, P. A. and Schokkaert, E. (2003). Identifying the warm glow effect in contingent valuation. *Journal of Environmental Economics and Management*, 45(2):231–245.

Olaussen, J. O. and Liu, Y. (2011). On the willingness-to-pay for recreational fishingescaped farmed versus wild atlantic salmon. *Aquaculture Economics & Management*, 15(4):245–261.

Pollock, K. H., Jones, C. M., and Brown, T. L. (1995). Angler survey methods and their application in fisheries management. *Reviews in Fish Biology and Fisheries*, 5(3):378–380. https://doi.org/10.1007/BF00043009.

Prince, E. D., Ortiz, M., and Venizelos, A. (2002). A comparison of circle hook and" j" hook performance in recreational catch-and-release fisheries for billfish. In *American Fisheries Society Symposium*, pages 66–79. American Fisheries Society.

Sauer, W., Penney, A., Erasmus, C., Mann, B., Brouwer, S., Lamberth, S., and Stewart, T. (1997). An evaluation of attitudes and responses to monitoring and management measures for the south african boat-based linefishery. *South African Journal of Marine Science*, 18(1):147–163.

Shrestha, R. K., Seidl, A. F., and Moraes, A. S. (2002). Value of recreational fishing in the brazilian pantanal: a travel cost analysis using count data models. *Ecological economics*, 42(1-2):289–299.

Smyth, R. L., Watzin, M. C., and Manning, R. E. (2009). Investigating public preferences for managing lake champlain using a choice experiment. *Journal of Environmental Management*, 90(1):615–623.

Starr, P. (2010). Fisher-collected sampling data: lessons from the new zealand experience. *Marine and Coastal Fisheries*, 2(1):47–59.

Stithou, M., Hynes, S., Hanley, N., and Campbell, D. (2012). Estimating the value of achieving good ecological status in the boyne river catchment in ireland using choice experiments. *The Economic and Social Review*, 43(3, Autumn):397–422.

Sutton, S. G. and Ditton, R. B. (2001). Understanding catch-and-release behavior among us atlantic bluefin tuna anglers. *Human Dimensions of Wildlife*, 6(1):49–66.

Thomas, R. H. and Blakemore, F. B. (2007). Elements of a cost–benefit analysis for improving salmonid spawning habitat in the river wye. *Journal of environmental management*, 82(4):471–480.

Van Osch, S., Hynes, S., O'Higgins, T., Hanley, N., Campbell, D., and Freeman, S. (2017). Estimating the irish public's willingness to pay for more sustainable salmon produced by integrated multi-trophic aquaculture. *Marine Policy*, 84:220–227.

White, P. C., Bennett, A. C., and Hayes, E. J. (2001). The use of willingness-to-pay approaches in mammal conservation. *Mammal Review*, 31(2):151–167.

Zwirn, M., Pinsky, M., and Rahr, G. (2005). Angling ecotourism: issues, guidelines and experience from kamchatka. *Journal of Ecotourism*, 4(1):16–31.

Year	Number	Title/Author(s)
2019		
	622	Recreational angling demand in a mixed resource fishery *Gianluca Grilli, Soumyadeep Mukhopadhyay, John Curtis, Stephen Hynes*
	621	Senior cycle review: analysis of discussions in schools on senior cycle pathways and structures in Ireland *Emer Smyth*
	620	FIR-GEM: A SOE-DSGE model for fiscal policy analysis in Ireland *Petros Varthalitis*
	619	The effects of an incremental increase in the Irish carbon tax towards 2030 *Kelly de Bruin, Aykut Mert Yakut*
	618	Household savings constraints, uncertainty and macroprudential policy *Philip Economides, Kieran McQuinn, Conor O'Toole*
	617	It's not just for boys! Understanding gender differences in STEM *Judith Delaney, Paul Devereux*
	616	Optimal development of electricity generation mix considering fossil fuel phase-out and strategic multi-area interconnection *Desta Fitiwi, Muireann Lynch, Valentin Bertsch*
	615	The effects of spatial position of calorie information on choice, consumption and attention *Deirdre A. Robertson, Pete Lunn*
	614	The determinants of SME capital structure across the lifecycle *Maria Martinez-Cillero, Martina Lawless, Conor O'Toole*
	613	Monetary policy normalisation and mortgage arrears in a recovering economy: The case of the Irish residential market *Rachel Slaymaker, Conor O'Toole, Kieran McQuinn, Mike Fahy*
	612	Can official advice improve mortgage-holders' perceptions of switching? An experimental investigation *Shane Timmons, Martina Barjaková, Terence J. McElvaney, Pete Lunn*
	611	Underestimation of money growth and pensions: Experimental investigations *Féidhlim P. McGowan, Pete Lunn, Deirdre A. Robertson*
	610	Housing Assistance Payment: Potential impacts on financial incentives to work *Barra Roantree, Mark Regan, Tim Callan, Michael Savage, John R. Walsh*

For earlier Working Papers see http://ww.esri.ie