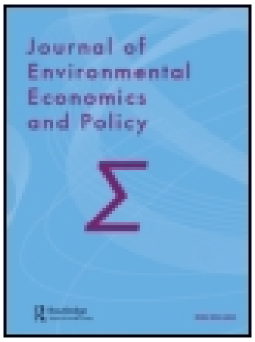

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Water quality and recreational use of public waterways

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ABSTRACT
This study combines routinely collected water quality data from Ireland and an on-site survey of waterway users to evaluate whether trip duration is responsive to changes in water quality. Four categories of recreational users are considered: anglers, boaters, other water sports (e.g. rowing, swimming, canoeing, etc.) and land-based activities at water sites, specifically walking and cycling. Water quality measures included in the analysis include Water Framework Directive (WFD) status, biochemical oxygen demand, ammonia, phosphorus and faecal coliform. The analysis finds evidence that higher levels of recreational demand (i.e. trips of longer duration) occur at sites with better water quality. However, we also find no statistical association between the overall WFD status and the duration of the recreational trip, which indicates that WFD status is of limited practical use for recreational users.

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Water-based recreation; travel cost; water quality; Water Framework Directive

1. Introduction

That people benefit from access to natural and manmade water bodies is well documented (Reinhard and Pouli 2011; Völker and Kistemann 2011, 2013). Increasing the visibility of blue space in urban areas has been associated with lower psychological distress (Nutsford et al. 2016) and there is evidence that exposure to blue spaces during physical activity shortens perceived exercise duration and increases willingness to repeat such exercise in the future (White et al. 2015). Nature-based recreation, aside from the health benefits, has been shown to produce synergistic effects and impact positively on individuals' emotional well-being (Korpela et al. 2014; White et al. 2015). Over 50% of the adult population in the developed world frequently access public waterways for recreational purposes (Williams and Ryan 2004; Environment Agency 2009; Outdoor Foundation 2013). Good water quality enhances the enjoyment which recreational water users derive from their chosen activity (Wade et al. 2010; Dorevitch et al. 2011; Arnold et al. 2013; Aminu et al. 2014; Dorevitch et al. 2015; Lee and Lee 2015) but users do not always recognise poor water quality or its associated risks (Westphal et al. 2008). This has been argued as primarily due to a delay in chronic health impacts and difficulty in perceiving the presence of pollutants (Burger, Staine, and Gochfeld 1993) though Hynes, Hanley, and Scarpa (2008) and Boeri et al. (2012) suggest that the implied health risk may not be an important aspect of a dedicated water sports recreationalist's choice of site, unless the level of water pollution is extreme. Thus good water quality, when it can be perceived by recreational users, contributes positively to utility and is likely to increase demand for recreation activities at public waterways. However, waterway users risk negative health outcomes due to the difficulty of detecting pollutants. Recreational water-users cannot factor poor water quality levels into their

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perception of an overall recreational experience until a perceptible negative outcome associated with poor water quality arises, such as digestive illness or eutrophication. Aside from health impacts, pollution can reduce the enjoyability of recreational activities by interfering with the user ability to perform an activity, producing offensive odours and reducing the sightliness of a water way site (Food and Agriculture Organisation 1996; Lipton 2004; Dodds et al. 2008).

Waterway managers attempt to ensure a high-quality experience for recreational water users. One of the ways that managers can measure the impacts of various management actions on recreational user satisfaction is to quantify changes in recreation demand at public waterways sites, given changes in waterway characteristics. This task, like management of waterways, is difficult as waterway users engage in diverse types of recreational activities and will have contrasting preferences for different types of site characteristics. In addition, while some factors affecting recreation demand lie within managers' control, such as access, pricing and facilities, others will not, such as hydromorphological features and weather. While managers may be charged with water quality monitoring and governance, the diversity and extent of water-use (e.g. agricultural, manufacturing, sewage, etc.) mean that waterway managers may ultimately have only limited control of a site's water quality. An understanding of which water quality metrics recreational users are most sensitive towards would enable waterway managers to concentrate resources towards achieving favourable values for those metrics.

This study attempts to estimate how recreational user demand is associated with varying levels of water quality defined by different water quality metrics. This can inform managers about potential public health risks (in the event that users appear to ignore changes in the presence of dangerous pollutants in public waterways) and possibly pre-emptively avoid them. Second, it can identify which water quality measures are incorporated into the utility function of recreational users, thus partially driving recreation demand. This information can equip waterway managers with a better understanding of the biological and physico-chemical characteristics which, if successfully controlled, will benefit waterway-user welfare and improve demand for public waterway use. It will also highlight some of the loss in public welfare (and impacts on recreation demand) that could arise in the event of increased pollution of public waterways.

Numerous studies have analysed the impact of water quality on recreational water-use demand. Topics have included angling (Bockstael, Hanemann, and Kling 1987; Curtis and Stanley 2016), swimming (Needelman and Kealy 1995), beach visits (Hanley, Bell, and Alvarez-Farizo 2003), boating (Lipton 2004) and many other water-based recreational activities (Binkley and Hanemann 1978; Gürlük and Rehber 2008; Hynes, Hanley, and Scarpa 2008; Paudel, Caffey, and Devkota 2011). A contribution of this paper is its use of revealed user data to determine which water quality measures users are most responsive towards and whether the response varies by recreational activity. The paper has parallels with Egan et al. (2009) who find recreational anglers to be responsive to the full set of water quality measures used by biologists. The overarching water quality measure in Europe is defined by the European Union's Water Framework Directive (WFD), which requires that water bodies be of good ecological status, a description that covers indicators such as biological quality (i.e. fish, benthic invertebrates, aquatic flora), hydromorphological quality, physical–chemical quality, and chemical status (Directive 2000/60/EC 2000). There are five status classes within the WFD's classification scheme for water quality: high, good, moderate, poor and bad. These are nominally easy to understand but their usefulness to recreational water users may vary depending on the type of activity water users are involved in. Constituent elements of WFD status, covering a number of ecological and physico-chemical measures, may be more useful for recreational users, but such information is less accessible to the general public. We investigate if recreational use is responsive to WFD status, which comprises biological and physico-chemical states, or whether recreational use is more responsive to chemical status that is potentially more relevant to most water users with the exception of anglers.

This paper employs a travel cost model to estimate a demand function for water- and land-based recreational users of waterway sites across Ireland. Including water quality metrics as site attributes within the travel cost model enables us to examine whether boating enthusiasts, as they perceive water quality, are responsive to laboratory measures of water quality. Section 2 of the paper provides a description of the WFD water quality measurements used in the analysis. Section 3 describes the methodology used for the analysis, specifically the travel cost model, and considers its suitability for assessing the impacts of changes in water quality on recreation demand. Section 4 describes the socio-economic and other data sources. Section 5 reports the results of the travel cost model, given the inclusion of different water quality measures. The final section provides concluding remarks and suggestions for further work in the area.

2. WFD water quality measures

The first water quality directive of the EEC, the surface waters directive (Directive 75/440/EEC 1975) focused primarily on the monitoring and protection of drinking water. Upon its inception a series of more general water quality directives were implemented relating to bathing water, dangerous substances, freshwater fish and several other uses. The disjointedness of these various water quality directives eventually culminated in the establishment of the WFD (Directive 2000/60/EC 2000). Under the WFD water quality monitoring takes place at diverse water body types (e.g. rivers, lakes, canals, estuaries, coastal waters, etc.). Water pollution can greatly reduce the demand for recreation (Lipton 2004). Due to the presence of decaying matter, eutrophied water is less suitable for recreational purposes, becoming unsightly and developing slime, weed infestation, and noxious odour from decaying algae.[1] In the extreme case, eutrophication can reduce water oxygen levels, leading to fish kills, significantly impacting recreational fisheries and contributing further to the eutrophication process. Angling and boating activities are physically impeded by eutrophication-driven algal blooms and water users are less likely to swim, boat and fish during algal blooms due to health risks, unfavourable appearance and unpleasant odours (Dodds et al. 2008). Such outcomes can have significant economic impacts. For example in the United States, estimated losses associated with closure of recreational angling and boating sites due to hypereutrophic conditions are between $182 and $589 million per annum (Dodds et al. 2008).

2.1. WFD status

The WFD requires that the status of each water body to be assessed across a number of biological and physico-chemical measures producing an overarching WFD ecological status ranging across five categories from 'bad' to 'high'. The biological component of WFD status is possibly of most interest to anglers but this will have little relevance to most recreational users. The quality metrics of relevance to most recreational activities (e.g. boating, swimming, etc.) are those surrounding the physico-chemical state of water bodies. Therefore, in addition to investigating how recreational use of waterways is responsive to WFD status we also consider a number of other quality metrics, most of which are used in the overall WFD assessment.

2.2. Biochemical oxygen demand

Biochemical oxygen demand (BOD) is a measure of water quality that indicates whether a water body is in a eutrophied state. Higher BOD levels of a water body are associated with lower dissolved oxygen levels. For instance, when large quantities of organic material are present in a water body bacterial uptake of oxygen outstrips the natural replenishment of oxygen from the atmosphere and by photosynthesis. Eutrophication arises when dissolved oxygen levels become so low that respiring aquatic organisms are unable to absorb sufficient oxygen from the water. While individuals involved in water-based activities, such as swimming, are likely to be most sensitive to eutrophic conditions, the demand for all recreational activities near water are likely to be impacted due to impediment of activities, discomfort and visual unpleasantness. Irish regulations giving statutory effect to the WFD and other EU water legislation require rivers with 'good' status have mean BOD levels less than or equal to 1.5 mg/l and that the 95th percentile should be less than or equal to 2.6 mg/l.[2]

2.3. Phosphates

Phosphorous is an essential nutrient required by all organisms for basic life processes. Phosphate carrying pollutants like fertilisers, wastewater, detergents and run-off from paved surfaces can exacerbate algal growth in fresh water systems, leading to algal blooms, eutrophication, and increased BOD. Phosphates are the limiting factor in fresh water plant and algal growth, which makes its control and monitoring critical, if eutrophication is to be avoided. Total phosphates is the sum of orthophosphates, polyphosphates and organic phosphorous.[3] Orthophosphate is the most readily available form for uptake during photosynthesis. High concentrations generally occur in conjunction with algal blooms. For rivers to have 'good' WFD status mean orthophosphate levels must be less than or equal to 0.035 mg P/l and the 95th percentile be less than or equal to 0.075 mg P/l.

2.4. Ammonia

Ammonia is generally present in small amounts in natural waters resulting from the reduction of nitrogen containing compounds by microbiological activity. Aquatic organisms are extremely sensitive to deviations away from the natural ammonia level and in particular, the un-ionised form of ammonia is highly toxic to aquatic animals (Eddy 2005). High ammonia levels produce a noxious odour and are often indicative of sewage pollution. For rivers to have 'good' WFD status mean ammonia levels must be less than or equal to 0.065 mg/l N and the 95th percentile should less than or equal to 0.14 mg N/l.

2.5. Faecal coliform

Faecal coliform originates in human and animal waste and therefore primarily enters a water body through sewage effluent and animal manure run-off. Not all faecal coliform is harmful to humans and the environment but overly high levels in a water body indicate the presence of pathogenic micro-organisms. For example, water-borne diseases like giardis and cryptosporidiosis can cause severe digestive illness in humans. Furthermore, the aerobic (and potentially anaerobic) decomposition of organic matter in which faecal coliform is contained reduces the DO saturation level. Measurement of faecal coliform is not undertaken within the context of WFD monitoring and within our dataset faecal coliform measurement is only available for canal recreation sites.

In summary, though other water quality metrics are assessed as part of WFD water quality monitoring we focus on these measures as being those most likely to capture water conditions that have a direct impact on the quality of the recreational experience. Those impacts may include fish kills, illness or discomfort as well as a reduction in visual aesthetic. The analysis here is not concerned with quantifying these impacts, rather we are interested in determining whether changes in levels of water quality are associated with different durations of recreational activity. We are not attempting to estimate causation, as the data we use is cross section across multiple sites.

3. Methodology

The travel cost method (TCM) is a frequently used approach for estimating the demand for recreational activities (Martínez-Espiñeira and Amoako-Tuffour 2008; Egan et al. 2009; Ovaskainen, Neuvonen, and Pouta 2012; Hynes and Greene 2013). It uses data on the travel costs and other expenses to a location where a specific recreation activity takes place. Travel cost is a revealed 'price' for accessing a site for a specific recreational pursuit, and therefore a proxy for the price an individual is willing to pay to engage in the activity. In addition to travel cost, other variables are included in the model to control for different factors which may also partially explain variation in an individual's demand for a recreational activity. Such factors can be individual specific, such as income, education or age, or alternative specific, such as site facilities or water quality. The TCM can thus provide not only estimates of demand for recreational activities, but show how recreation demand varies in association with different water quality levels. One would expect a decrease in water quality to be negatively associated with recreation demand at sites where the activity takes place. The TCM allows us to evaluate the extent to which this is the case in practice. Trip duration at a recreation site is modelled as a function of individual and site-specific attributes:

$$y_i = f(x_i), \tag{1}$$

where y_i is a discrete count variable indicating the number of trip days that individual i chooses and x_i is a vector of individual- and site-specific variables including travel cost. Though the TCM is more frequently used to model trip demand, it has been used on a number of occasions to model trip duration (Martínez-Espiñeira et al. 2008; Mendes and Proença 2011).

Count models are frequently used to estimate recreational demand models (Martínez-Espiñeira and Amoako-Tuffour 2008; Ovaskainen, Neuvonen, and Pouta 2012; Hynes and Greene 2013) and are usually based on either a Poisson or negative binomial distribution of recreation demand and follow a theoretical underpinning provided by Hellerstein and Mendelsohn (1993). Surveys of outdoor recreationalists are often conducted on-site, which means only visitors to the site with a positive number of visits are interviewed for the survey. Modelling must account for sample truncation at zero. Additionally, the sample is subject to endogenous stratification, which occurs when the survey sample's proportions of site users in terms of frequency of visits does not match population proportions. This arises because frequent visitors to the recreational site have a higher likelihood of being interviewed than infrequent visitors. Carson (1991) was among the first to address the issue of truncation in count models, while Shaw (1988) addresses the issue of endogenous stratification. Englin and Shonkwiler (1995) developed truncated and endogenously stratified recreational demand models based on the Poisson and negative binomial distributions. The Poisson version of the model assumes that the conditional mean and variance of trip demand are equal, which in some instances is likely to be a misspecification. For recreational trip data, the variance is often greater than the mean, implying overdispersion in the data. Where overdispersion arises, the negative binomial model is preferred.[4]Following Englin and Shonkwiler (1995), the probability density function for the truncated and endogenously stratified negative binomial model is given by

$$h_i(y_i|y_i > 0, x_i) = \frac{y_i\Gamma\left(y_i + \alpha_i^{-1}\right)\alpha_i^{y_i}\lambda_i^{y_i-1}[1 + \alpha_i\lambda_i]^{-(y_i+\alpha^{-1})}}{\Gamma(\alpha_i^{-1})\Gamma(y_i + 1)}, \tag{2}$$

where $\Gamma(\cdot)$ is the gamma function, and α_i is the over-dispersion parameter. In estimation, we specify α_i as a constant for all values, though less restrictive specifications such as $\alpha_i = \alpha_0/\lambda_i$ (Englin and Shonkwiler 1995), or $\alpha_i = g(z_i)$ where z_i refers to visitor characteristics (Martínez-Espiñeira and Amoako-Tuffour 2008) are also feasible. Where the data is found not be to subject to overdispersion a truncated and endogenously stratified Poisson model is estimated, the probability density function of which is given by

$$h_i(y_i|y_i > 0, x_i) = \frac{e^{-\lambda_i}\lambda_i^{y^i}}{y_i!(1 - exp(-\lambda_i))}. \tag{3}$$

Defining λ_i as a function of regressor variables, x_i, converts the model into a regression framework. Thus, we can model demand as a semi-logarithmic function of price, and independent variables including water quality, such that

$$ln\lambda_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_{wq} x_{wq} + \beta_{wqD_m}\left(D_m x_{wq}\right)\ldots \tag{4}$$

where x_{wq} represents the water quality attribute and D_m is a dummy variable for a specific type of recreational activity, m (e.g. boating or angling). Our primary focus is investigating the estimated relationship between the water quality metric and recreational trip duration. Our hypothesis is that recreational users undertake trips of longer duration at sites with better water quality, which would be confirmed by a negative coefficient on the expression $\beta_{wq} + \beta_{wqD_m} D_m$ for recreational activity m in Equation (4). As water quality is generally quite good among the sites within our sample, the magnitude of the expression (and its associated marginal effect) should be treated with caution if extrapolating to recreational sites outside the sample. However, for the given level of water quality within our sample one might anticipate that different recreational users are more responsive to water quality. For instance, recreational users that come into closer contact with the water (e.g. swimmers, rowers) may be more responsive to better water quality, as perceived by the users, than those that have less contact (e.g. cyclists, boaters). We can test this hypothesis by testing the relative magnitudes of $\beta_{wq} + \beta_{wqD_m} > \beta_{wq} + \beta_{wqD_n}$ for recreational activities m and n.

4. Data

Waterways Ireland is charged with the management, maintenance, development and restoration of seven inland navigable waterways on the island of Ireland, principally for recreational purposes. During 2010 and again in 2014, Waterways Ireland commissioned surveys to obtain information on the demographic profile of waterway users, to ascertain satisfaction levels with available facilities and to measure awareness of Waterways Ireland as the management authority on the navigations. The surveys were undertaken at 24 sites around the Republic of Ireland and Northern Ireland. The sampling points were spread across both urban and rural areas with interviews occurring on different days and at different times across the period August–November. Interviewing was weighted towards busier sites and responses were recorded in a face-to-face interview, which took 10 minutes on average to complete. A total of 1632 and 1247 interviews were collected in each year respectively. The sampling methodology employed was 'very next person' interviewing and was weighted towards busier areas to reflect actual usage of the waterways. The dataset is a pooled cross section rather than a panel and is not purported to be a representative sample of Irish recreational waterway users.

Users' recreational activities were classified into four categories; anglers; boaters; those engaged other water sports (e.g. canoeing, water skiing, rowing, etc.); and those engaged in activities for which access to water is not essential, specifically walking and cycling. Observations were excluded in the event that no travel cost data was reported and where trip length exceeded 21 days. For the latter case this was because extended trips are more likely to be associated with multi-purpose visits, not just recreational activity. In total, responses from 1436 survey respondents were used in model estimation. Various information was collected from survey participants including travel expenditures, the length of the current trip, and socio-demographic data.

Survey data used in the analysis are summarised in Table 1. *TripDays* is the dependent variable in the study and is defined as the number of leisure activity days spent on the current intercepted trip. *DailyCost* is denominated in Euro (€) and reflects the expenditure of a single individual for each day of a trip. It comprises expenditure on items such as fuel, food, beverages and accommodation. From Table 1, we can see that those dedicating their leisure time to water-based activities spend slightly more per day than land-based visitors. It is worth noting however that this group also spend more days per trip, so spend substantially more on a per trip basis. The variable *Experience* indicates whether an individual rates themselves as somewhat or very experienced in pursuit of their leisure activity. One might expect more experienced practitioners to dedicate more time to their pursuit. The *Prof/Managerial* variable encompasses individuals who work in a professional or managerial capacity in contrast to lower skilled employment. This variable may also be a proxy for higher income and such individuals may have higher levels of demand for recreational activities than those who are either in non-professional employment or are not employed. Individuals from abroad that are holidaying in Ireland during the trip are identified by the variable *VisitIreland* and may have

Table 1. Summary statistics.

Variable	Mean	Std. Dev.	Description
TripDays	3.14	3.19	Days on current trip
DailyCostDomestic	15.70	46.70	Per day cost, €, if user from island of Ireland
DailyCostForeign	21.51	111.47	Per day cost, €, if user from outside island of Ireland
Land	0.42	0.49	=1 if engaged in walking or cycling, 0 otherwise
Boat	0.34	0.47	=1 if engaged in boating activity, 0 otherwise
Angler	0.14	0.35	=1 if engaged in angling, 0 otherwise
Sport	0.10	0.30	=1 if engaged in water-based sports activity, 0 otherwise
Experience	0.88	0.32	=1 if very or somewhat experienced, 0 if unskilled or novice
Prof/Managerial	0.59	0.49	=1 if professionally employed or managerial, 0 otherwise
VisitIreland	0.27	0.44	=1 if visiting from outside the island of Ireland, 0 otherwise
Age35 +	0.61	0.49	=1 if aged 35 or above, 0 otherwise
Male	0.62	0.49	=1 if male, 0 if female
Toilets	0.86	0.35	=1 if toilet facilities available at location, 0 otherwise
Slipway	0.84	0.36	=1 if slipway facilities available at location, 0 otherwise
N = 1436			

differing demand for water-based leisure activities than Irish-based users. An individuals' age and gender can influence their demand for recreation activities and the variables *Aged*35 + and *Male* are used to control for these characteristics. We also included a dummy variable in our initial analysis indicating which year the survey was administered but found no statistical effect and dropped it from the subsequent models presented here.

Water quality data for 2010 and 2014 were sourced from monitoring stations within the Republic of Ireland that were proximate to 15 waterway sites where surveys were conducted in the Republic of Ireland.[5] Water quality data were obtained from the Environmental Protection Agency (http://gis.epa.ie/) for river and lake sites and data for canal sites was provided by Waterways Ireland (www.waterwaysireland.org). A summary of water quality metrics is provided in Table 2. Generally, water quality at the sites in our dataset is at a relatively high level, though two sites, Kilcock Harbour and Grand Canal Basin, have elevated levels of phosphorus and faecal contamination. Sites with a 'poor' WFD status are attributable to low biological classifications and not due to physico-chemical status. Therefore, the analysis here is not comparing recreational activity at polluted versus pristine sites, rather is it is comparing recreational activity across sites that are generally of a relatively high standard. Consequently, the results of the analysis are likely to be more muted than if the dataset also contained sites with relatively low water quality standards.

The relationship between water quality and recreational demand is likely to be non-linear, though for simplicity we have assumed it to be linear within the narrow range of water quality values within our dataset. However, our model does not purport to be a model of causation, where recreational users are making decisions based on information about water quality. In reality recreational users will have limited information about water quality because only official bathing sites have a statutory requirement to post monitoring results, none of which are in our dataset. Instead, users' decisions on recreation demand are based on a range of criteria including their own assessment of water conditions. The models are intended to identify whether users' behaviours are responsive to water quality, as indicated by the various quality metrics. In the estimated models we include interaction terms between the water quality metrics and the activity dummy variables to allow variation in demand by activity and water quality.

Table 2. Water quality measures.

		No. sites	Mean	Std. Dev.	Min	Max
WFD status = 'poor'		9	0.556	0.527	0.000	1.000
BOD	mg O_2/l	11	1.834	1.096	0.658	4.408
Ammonia	mg N/l	12	0.044	0.029	0.016	0.100
Phosphates	mg P/l	6	0.038	0.020	0.017	0.076
Faecal coliform	Count/100 ml	6	1651.958	3510.246	20.000	8800.500

Data points are site-specific annual means.

5. Results

Travel cost recreation demand models were initially estimated with the negative binomial specification controlling both for truncation and endogenous stratification (i.e. Equation (2)). The estimates do not show evidence of overdispersion and consequently the models were estimated with a Poisson specification, which are reported in Table 3. As the water quality metrics are related and recreational users may be more responsive to one type of pollution we estimate with only one water quality measure at a time. The dependent variable in all models estimated is *TripDays*, which is the number of days the recreational user spent on the trip. The key variable of interest for this study are the parameters associated with the water quality measure, *WaterQ*. In each model presented, the definition of *WaterQ* changes. The water quality metric, which is represented by *WaterQ*, is indicated in the title of each column of coefficients. For column 1 of Table 3, the variable *WaterQ* is the WFD ecological status measure. In column 2, *WaterQ* represents *BOD*.

5.1. Water quality

The reference user category in the estimated models are those that engaged in cycling or walking. For these land-based users, the change in trip duration associated with different levels of water

Table 3. Recreational activity days demanded.

	WFD status	BOD	Ammonia	Phosphorus	Faecal coliform
DailyCostDomestic	−0.00618***	−0.00201***	−0.00159**	−0.0151***	−0.0114***
	(0.00160)	(0.000709)	(0.000669)	(0.00253)	(0.00222)
DailyCostForeign	−0.0132***	−0.00355***	−0.00304***	−0.00878***	−0.00222
	(0.00204)	(0.000470)	(0.000436)	(0.00251)	(0.00205)
WaterQ	11.76	−1.150***	0.895***	−18.61**	−0.0105
	(548.3)	(0.183)	(0.289)	(8.332)	(0.00820)
WaterQ × *Angler*	0.638	1.161***	−1.599**	−19.12*	−0.0160
	(0.752)	(0.198)	(0.642)	(11.09)	(0.0111)
WaterQ × *Boat*	−0.265	1.067***	−1.411***	−12.94	0.0108
	(0.611)	(0.188)	(0.323)	(8.486)	(0.00807)
WaterQ × *Sport*	0.942	−0.0140	1.056	−9.231	−0.00425
	(0.936)	(0.335)	(0.757)	(15.82)	(0.0157)
Boat	2.721***	0.0990	1.710***	2.099***	1.137***
	(0.587)	(0.224)	(0.0899)	(0.397)	(0.343)
Angler	1.627**	−0.333	1.449***	1.967***	1.810***
	(0.732)	(0.249)	(0.102)	(0.481)	(0.427)
Sport	0.891	0.769*	0.783***	0.686	0.465
	(0.914)	(0.397)	(0.134)	(0.776)	(0.724)
Experience	0.222**	0.256***	0.267***	0.0464	−0.101
	(0.0873)	(0.0866)	(0.0780)	(0.119)	(0.117)
Prof/Managerial	0.0701	0.125***	0.160***	0.00768	0.0649
	(0.0658)	(0.0468)	(0.0451)	(0.0806)	(0.0802)
VisitIreland	0.978***	0.689***	0.649***	0.627***	0.413***
	(0.0949)	(0.0525)	(0.0511)	(0.116)	(0.110)
Age35 +	0.585***	0.322***	0.344***	0.152	0.213**
	(0.0862)	(0.0516)	(0.0502)	(0.0931)	(0.0919)
Male	0.415***	0.295***	0.281***	0.311***	0.351***
	(0.0683)	(0.0485)	(0.0462)	(0.0836)	(0.0834)
Toilets	0.338	0.802***	0.904***	0.942**	2.206
	(0.351)	(0.144)	(0.143)	(0.377)	(2.371)
Slipway	−11.58	−0.0321	0.0263	0.465***	−0.239***
	(548.3)	(0.0684)	(0.0702)	(0.130)	(0.0919)
Constant	−2.753***	−0.359	−2.205***	−1.229**	−2.237
	(0.647)	(0.293)	(0.179)	(0.565)	(2.532)
N	513	992	1086	346	346
Log-Likelihood	−1001.24	−2177.05	−2368.36	−673.961	−682.638
AIC	2036.479	4388.108	4770.725	1381.921	1399.276
BIC	2108.563	4471.403	4855.559	1447.311	1464.666

Standard error in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table 4. One-tailed z-tests: null hypothesis that water quality metric is associated with zero or positive differences in recreational trip duration versus an alternative hypothesis that deterioration in water quality is associated with shorter recreational trip duration.

User category	Null hypothesis	WFD status	BOD	Ammonia	Phosphorus	Faecal coliform
Land	H_0: $\beta_{wq} \geq 0$	0.02	6.29***	3.10	2.23**	1.29*
Angler	H_0: $\beta_{wq} + \beta_{wqD_{Angler}} \geq 0$	0.02	0.14	1.23	4.53***	3.20***
Boat	H_0: $\beta_{wq} + \beta_{wqD_{Boat}} \geq 0$	0.02	1.57*	3.11***	7.20***	0.95
Sport	H_0: $\beta_{wq} + \beta_{wqD_{Sport}} \geq 0$	0.02	4.10***	2.77	2.00**	1.08

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

quality are given by the coefficient on the *WaterQ* variable. In the case of BOD and phosphorus, the parameter estimates are negative and significantly different from zero, as reported in Table 3. Our hypothesis is that either 'poor' WFD status or higher levels of BOD, ammonia, phosphorus or faecal coliform were anticipated to have a negative association with recreational demand. We formally test the hypothesis using a one-tailed z-test and report the results in Table 4. We fail to reject the null hypothesis in the case of the WFD status quality metric, from which we can conclude that there is no category of recreational user where recreational trips are shorter in duration at water bodies that are designated with a 'poor' WFD ecological status. For all the other water quality metrics examined we reject the null hypothesis in several, though not all instances. In the case of faecal coliform trip duration of anglers, walkers and cyclists decline as faecal coliform contamination increases. We cannot draw the same conclusion for boaters or those involved in other water sports (i.e. *Sport* category). One would not have anticipated this result in the case of the *Sport* category, as these are the recreational users that have the potential to come into closest contact with water, sometimes being submerged in the water. This result is consistent with research by Hynes, Hanley, and Scarpa (2008) and Boeri et al. (2012) who suggest that water quality and the implied health risk may not be an important aspect of a dedicated water sports enthusiast's choice of site, unless the level of water pollution is extreme. In the case of the phosphorus water metric, we reject the null hypothesis for all four recreational user categories, so higher levels of phosphorus are associated with shorter trip durations. There is a similar result in the case of BOD levels, except for anglers. Only in the case of boaters are higher ammonia levels associated with shorter trip durations. While the tests are not unanimous, neither across user types nor water quality metrics, there is strong evidence longer trip durations are associated with higher levels of water quality. But it also appears to be the case is that there is no association between trip duration and WFD status. WFD status is assigned as the minimum status of biological and chemical components. In the recreational sites within our sample that are designated 'poor' WFD status, the designation is due to 'poor' biological rather than chemical status. While biological status may be of interest to anglers, it will have little relevance to other recreational users hence it is not surprising that we fail to reject the null hypothesis in the case of the WFD status metric.

The second issue of interest with respect to water quality is whether different categories of recreational users are more responsive to changes in water quality. We examine this issue through one-tailed z-tests with a null hypothesis that one recreational user category's trip duration is greater than or equal to trip duration of another recreational user category versus the alternative that it is less. Our prior is that *Sports* users are more responsive that *Anglers*, who in turn are more responsive than *Boat* users, with *Land*-based users (i.e. walkers and cyclists) being the least responsive. We report a series of these tests in Table 5, where the overwhelming evidence is that we are unable to reject the null in favour of our speculated hypotheses. In just two tests related to faecal coliform do we find that angler trip duration is less than boater trip duration as faecal coliform contamination increases, and similarly for boaters compared to walkers and cyclists. Across the two sets of tests in Tables 4 and 5, we can conclude that there is sufficient evidence to say that recreational users are responsive in terms of the length of their recreational trips to changes in water quality, as recorded by a number of water quality metrics. However, while there are differences across recreational user

Table 5. One-tailed *z*-tests: null hypothesis, for a given water quality metric, that for a specific recreational user category, trip duration is greater than or equal to trip duration of another recreational user category versus an alternative hypothesis that recreational trip duration is less.

	WFD status	BOD	Ammonia	Phosphorus	Faecal coliform
H_0: $\beta_{wqD_{Sport}} \geq \beta_{wqD_{Angler}}$	0.36	4.00	2.93	0.63	0.74
H_0: $\beta_{wqD_{Angler}} \geq \beta_{wqD_{Boat}}$	1.96	1.01	0.31	0.73	3.24***
H_0: $\beta_{wqD_{Boat}} \geq \beta_{wqD_{Land}}$	0.43	5.68	4.37	1.52	1.34*

By definition, $\beta_{wqD_{Land}} = 0$. *$p < 0.10$, ***$p < 0.01$.

categories we find insufficient evidence to say that the recreational users in closest contact with the water (e.g. swimmers, rowers, canoeists, etc.) are the most responsive to changes in water quality. It is important to restate here that these results do not imply causation, as the dataset comprises a cross section of recreational trips.

The results that are potentially most surprising are those relating to faecal coliform, which for our dataset relates only to canal recreation sites. While all faecal coliform is not harmful to humans, its existence in high concentrations may indicate the presence of pathogenic micro-organisms, which pose a risk to health. One could speculate that water-based recreational users, especially those in close contact with the water, avoid sites with high faecal coliform levels but we find no evidence that this is the case. Within the dataset, we have small number of recreational sites with high faecal coliform contamination. Waterways Ireland, who are responsible for those sites, have actively discouraged recreational activities at these sites. The evidence from the models suggest that time spent on site is not responsive to the level of faecal contamination. As noted earlier, Hynes, Hanley, and Scarpa (2008) and Boeri et al. (2012) suggest that water quality and the implied health risk may not be an important aspect of a dedicated water sports recreationalist's choice of site, unless the level of water pollution is extreme.

Although the analysis is focused on recreational sites with generally good water quality with minor exceptions, the results echo previous findings on recreational water users from elsewhere. For example, in the United States Egan et al. (2009) find that recreational water users are responsive to the full set of water quality measures used by biologists and that the changes in these quality measures translate into changes in the recreational usage patterns and well-being of users. But there is also evidence that water pollution is a priority issue only for a minority of recreational users and not of much concerns to others (Beardmore 2015). Furthermore, where water pollution has an implied health risk some dedicated users are undeterred in their activities unless the level of pollution is extreme (Hynes, Hanley, and Scarpa 2008; Boeri et al. 2012).

Direct interpretation of the coefficient estimates within the travel cost model is not straightforward and marginal effects are frequently calculated instead, as they are more useful for policy analysis purposes. As the number of recreational sites included in our sample is relatively small and because the water quality at those sites is generally quite good the marginal effects associated with the models estimated here are of limited use for policy purposes. The coefficient estimates and associated hypothesis tests are sufficient to draw conclusions on the sign of the impact of water quality on recreational demand but the magnitude of the marginal effects is not necessarily representative of recreation sites in general and is therefore of negligible use for policy analysis purposes.

5.2. Other explanatory variables

The estimated models include a number of explanatory variables indicating the presence of a variety of facilities or services available at recreational sites including toilets and boat slipways as well as socio-demographic variables. Whether a particular site characteristic or facility (e.g. presence of a boat slipway) has importance to a recreational user will depend on the activity. In addition, the site characteristic may be more relevant to the site choice rather than site duration decision. The analysis here focuses on whether site characteristics are associated with the length of time spent on site. The estimated coefficients on these variables vary across the models estimated but there are a number of clear results. The first is that the length of time spent on site is higher at sites with toilet facilities. One potentially counter-intuitive result are the estimated coefficients on the *Slipway* variable. Not all water-based users, including many boat users, require the use of slipway facilities but it is surprising to find negative coefficients on this variable. In most instances where a slipway is required (e.g. to launch a boat) it should not materially affect the duration of a trip and hence finding statistical insignificance for this variable might be more reasonable.

The travel cost model allows us to examine the sensitivity of water site users to the cost of engaging in their recreational activity. The estimated coefficient on the travel cost variable, *DailyCost*, is negative and statistically significant in almost all models estimated. Consumer surplus, which is the value of the trip in excess of trip cost is a welfare measure indicating the benefit associated with recreational trips. From Hellerstein and Mendelsohn (1993), mean consumer surplus per day is given by $-1/\beta_p$, where β_p is the estimated coefficient on the *DailyCost* variable. Across the five models the minimum estimated consumer surplus per day for Irish users is €66 (s.e. €11) and for international visitors it is €76 (s.e. €12), though there is a wide variation across models. We note the consumer surplus to illustrate the potential scale of the recreational benefit to users, though given the wide variety of recreational activities considered within the user survey further research is required to quantify welfare benefits in more precision. However, these consumer surplus estimates are comparable with the existing literature on the value of benefits from water-based recreational activity. For example, estimates of per trip consumer surplus or willingness to pay for boating trips in the United States exceed several hundred dollars (Bockstael, Hanemann, and Kling 1987; Park, Bowker, and Leeworthy 2002; Bhat 2003), though estimates can be substantially lower. For example, Vesterinen et al. (2010) estimate WTP/trip of approximately €23 for swimming, fishing or boating trips in Finland. Previous studies of Irish recreational water users include WTP estimates for swimming of approximately €102/trip and €35/trip for boating (Curtis 2003); €22/trip for beach visits (Barry, van Rensburg, and Hynes 2011); €152/trip for white-water kayaking (Hynes and Hanley 2006), and €371/day for angling (Curtis and Stanley 2016).

Other socio-economic explanatory variables in the models enable us to distinguish differences in demand preferences among various types of recreational users. For example, the estimated coefficient on *Male* is positive and statistically significant in all of the models, indicating that men take recreational trips of longer duration than women. The coefficient on *VisitIreland* is positive and significant, indicating that international tourists take trips to waterway sites of longer duration that people living in Ireland. The user survey captures two types of waterway visit; those as part of a longer annual holiday and shorter weekend-type trips. People resident in Ireland are more likely to engage in both types of trip, whereas international tourist visitors are less likely to incur such travel expense for short trips. The *Professional* variable may be capturing an income effect, but the effect is not significant across all models. The *Experience* variable is a respondent assessment of their skill or ability level in their recreational activity. We had an *ex ante* intuition that highly skilled individuals spend more time pursuing their activity which would be reflected in trip length (or equally in trip frequency for which we have no data). We find evidence that that is the case but only in three of the five models.

6. Conclusion

This paper sought to identify if recreational water users' demand for recreational activities at key waterway sites around Ireland is responsive to the level of water quality at those sites. This issue has wider policy significance within the context of the European Union's ambition for all water bodies to achieve 'good' status and the associated benefits to stakeholders. As outlined in Section 1, the paper had a number of purposes. First, the analysis was intended to inform water managers about potential public health risks (in the event that users appear to ignore changes in the presence of dangerous pollutants in public waterways) and possibly pre-emptively avoid them. Second, identify which water quality measures are incorporated into the utility function of recreational users, thus partially driving recreation demand. This information can equip waterway managers with a better understanding of the water body characteristics which, if successfully controlled, will benefit waterway-user welfare and improve demand for public waterway use.

The most important finding from the analysis in the context of WFD and associated water quality monitoring is the finding that there appears to be no association between trip duration and WFD status. The result is based on a narrow empirical study and therefore further research elsewhere is necessary to confirm the finding. However, it does indicate that WFD status as a measure of water quality is not particularly useful for recreational users. The result is not unsurprising, as WFD biological status, which is unlikely to be of relevance to most recreational users, is an important determinant of overall WFD status. Another reason why WFD status is of limited practical use to recreational users is that WFD status does not include any measure for faecal coliform, which is a metric that should be of particular interest to recreational users concerned about health risk. We find that some, though not all, recreational users are responsive in terms of trip duration to the level of faecal coliform contamination.

While there is no evidence from the estimated models of an association between trip duration and overall WFD status, we find sufficient evidence to say that recreational users are responsive to the chemical status of water bodies. Across all four categories of recreational user, longer trip duration is associated with recreational sites with better water quality. This provides clear evidence that recreational users benefit from efforts to improve the water quality in line with WFD ambitions. The consumer surplus estimates are indicative of the high value users place on water-based recreational sites, which are at risk if water quality hinders recreational activity. Contrary to our *ex ante* expectation, we were unable to find evidence that recreational users in the closest contact with the water (e.g. swimmers, rowers, canoeists, etc.) are the most responsive to changes in water quality, though we conjecture that result may be specific to this dataset.

From the perspective of waterway managers, a number of other policy implications arise. The first is that there is clear evidence that recreational users spend more time at sites with toilet facilities, which provides support or justification for investment in such facilities at recreational sites. Waterways Ireland have actively discouraged activities at sites experiencing high levels of faecal coliform, which may have caused users to visit alternative sites. However, for users that actually visited such sites, the models find no evidence that the duration of recreational activity is curtailed at sites with high faecal coliform measurements. Depending on the nature of such recreational activity, this is likely to be a concern to waterway managers. It is not obvious whether users lack or disregard information on faecal coliform measurements and its risk to health. More generally, faecal coliform measurements are taken at relatively few recreation sites (i.e. just at canal sites) and consideration should be given to extending such measurements to all popular recreation sites.

The paper focuses on demand for recreation time at water sites conditional on the site choice decision. Factors such as water quality or site facilities may have an equally important influence on site choice decisions and consequently the current analysis only partially examines the importance of water quality and other site characteristics in recreation demand. Future research should examine recreational site choice decisions as a function of the site attributes at waterway sites in Ireland.

Notes

1. For example, see http://www.fao.org/docrep/w2598e/w2598e06.htm.
2. SI 272/2009 - European Communities Environmental Objectives (Surface Waters) Regulations 2009. http://www.irishstatutebook.ie/2009/en/si/0272.html.
3. Phosphates arise in waterways in organic or inorganic form. Sources of the former include sewage and the breakdown of organic pesticides. Inorganic phosphates are made up of orthophosphates and polyphosphates. Orthophosphates are commonly referred to as reactive phosphorous, and it is this form of phosphorous directly taken up by plant cells to grow. Polyphosphates, commonly used in detergents, are unstable and eventually convert to orthophosphates.

4. Hilbe (2014) discusses the derivation of the negative binomial as a Poisson-gamma mixture model in which the dispersion parameter is gamma shaped. The gamma PDF is pliable, allowing for a wide variety of shapes meaning most count data can be appropriately modelled.
5. One exception is WFD status, which was only available for 2010. At the time of the analysis, a WFD status had not been assigned for 2014.

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