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Demand for Water-Based Leisure Activity: the Benefits of Good Water Quality

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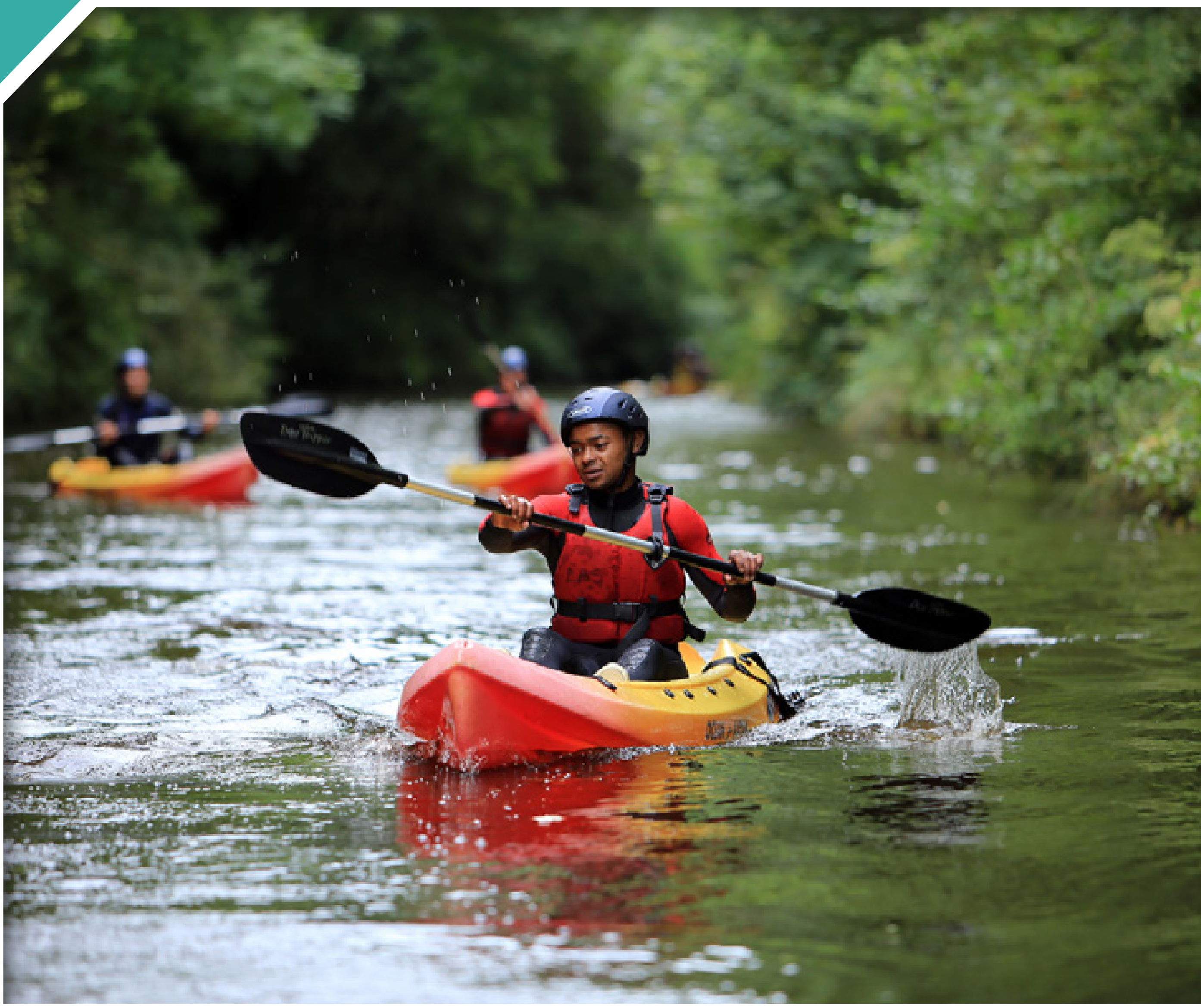

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

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ENVIRONMENTAL PROTECTION AGENCY

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- intensive agriculture *(e.g. pigs, poultry)*;
- the contained use and controlled release of Genetically Modified Organisms *(GMOs)*;
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- waste water discharges;
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- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

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EPA RESEARCH PROGRAMME 2014–2020

Demand for Water-Based Leisure Activity: the Benefits of Good Water Quality

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by

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The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

The objective of this research was to determine how water-based recreational activities in Ireland are affected by differences in water quality across recreational sites. The draft river basin management plan for Ireland (2018–2021) reports that, since the first river basin management plan was implemented, 900 monitored rivers and lakes showed a change in status (i.e. either improved or worsened), with a net decline of 3% in the number of water bodies with satisfactory ecological status (DHPCLG, 2017). In general the Environmental Protection Agency (EPA) has concluded that insufficient progress is being made with improving Ireland's surface water quality (EPA, 2016). Furthermore, the EPA in its most recent 'State of the Environment' report states that:

> until the real environmental cost of using water resources is internalised into the decision-making processes within all sectors that use the resource, overuse and misuse are highly likely to escalate into the future as demands for catchment services increase. In order to put a value on these resources, sectors must first understand and be aware of the services that catchments provide them with and the value that they obtain from these services (EPA, 2016, p. 86).

This research addresses these issues, identifies how recreational water users are affected by water quality and puts a value on the recreational benefits of water amenities.

The research was undertaken in two parts. First, recreational site choice decisions were examined, identifying the extent to which water quality levels at recreational sites affect the decisions of recreational users about where to begin their water-based activity. This part of the research is confined to recreational boating activity. Second, recreational trip durations were considered, identifying the extent to which water quality levels at recreational sites affect the length of the trip. The premise here is that recreational users undertake trips of longer duration at sites with better water quality. In the analysis of trip durations, four categories of recreational users are considered: anglers; boaters; those engaged in other water sports (e.g. canoeing, water skiing, rowing); and those engaged in activities for which access to water is not essential, specifically walking and cycling.

On the issue of recreational site choice, the research finds that boaters are responsive to water quality conditions, as indicated by both biochemical oxygen demand (BOD) and phosphorus (P) levels. Boaters are more likely to choose recreational sites that have higher water quality levels. For a 1 mg O_2/l increase in BOD level, the odds that a specific site is selected for a boating trip falls by 70%. For a 1 mg P/l increase in phosphate level, the odds that a site is chosen for a boating trip falls by almost 100%.

As one might expect, the probability that a specific site is visited declines as travel distance to water-based recreational sites increases. For each 10 km increase in distance to a site, the probability that it is visited declines by approximately 10%. Recreational water users are more likely to engage in their boating activity at their 'local' waterway. This finding reaffirms the importance of achieving good water quality across all sites, not just at designated or high-use recreational sites.

In examining the duration of recreational trips, the research found strong statistical evidence that recreational users spend more time engaged in their recreational activities (e.g. boating, fishing, walking) at sites with higher water quality levels, as measured by chemical status. The research found no statistical association between overall Water Framework Directive (WFD) status (i.e. high, good, moderate, poor or bad) and the duration of the recreational trip, which indicates that WFD status is of limited practical use for recreational users. WFD status is assigned as the minimum status of biological and chemical components. In many instances the designation of 'poor' WFD status is due to 'poor' biological rather than chemical status. While biological status may be of interest to anglers, it has little relevance to other recreational users (e.g. boaters, walkers).

Across the four categories of recreational users (i.e. anglers, boaters, water sports participants, and walkers and cyclists) the minimum estimated value of a day's recreational activity in excess of expenses incurred during the recreational trip is €66, and slightly higher for international visitors at €76/day. With approximately half the adult population participating at least once per year in a water-based recreational activity, these estimates illustrate the potential magnitude of the net benefit to recreational users of Ireland's marine and freshwater resources.

1 Introduction

The objective of this research is to determine how water-based recreational activities in Ireland are affected by differences in water quality across recreational sites. The draft river basin management plan for Ireland (2018–2021) reports a net decline of 3% in the number of water bodies with satisfactory ecological status since 2009, with changes in status across some 900 monitored rivers and lakes (DHPCLG, 2017). While the 3% figure suggests only a modest decline, the figure masks significant numbers of improvements and deteriorations. Preliminary assessment by the Environmental Protection Agency (EPA) indicates that changes in phosphorus (P) concentrations appear to be the most prevalent contributory factor for the changes in status (DHPCLG, 2017). Among the results of this research is that recreational water users' activities, both choice of recreation location and duration of recreation activity, are correlated with P levels. Therefore, these changes are likely to have a substantial impact on recreational users.

The EPA has concluded that insufficient progress is being made with improving Ireland's surface water quality and that:

> until the real environmental cost of using water resources is internalised into the decision-making processes within all sectors that use the resource, overuse and misuse are highly likely to escalate into the future as demands for catchment services increase. In order to put a value on these resources, sectors must first understand and be aware of the services that catchments provide them with and the value that they obtain from these services (EPA, 2016, p. 86).

This research addresses these issues, identifies how recreational water users are affected by water quality and puts a value on the recreational benefits of water amenities.

The research was undertaken in two parts. First, recreational site choice decisions were examined, identifying the extent to which water quality levels at recreational sites affect the decisions of recreational users about where to begin their water-based activity. This part of the research is confined to recreational boating activity. Second, recreational trip durations were considered, identifying the extent to which water quality levels at recreational sites affect the length of the trip. The premise here is that recreational users undertake trips of longer duration at sites with better water quality. In the analysis of trip durations, four categories of recreational users are considered: anglers; boaters; those engaged in other water sports (e.g. canoeing, water skiing, rowing); and those engaged in activities for which access to water is not essential, specifically walking and cycling.

2 Water-Based Recreational Activity in Ireland

The draft river basin management plan (2018–2021) identifies a number of sectors and activities that are of substantial importance to the economy and which also create significant water pressures, causing water bodies to be at risk of not meeting the objectives of the Water Framework Directive (WFD) (DHPCLG, 2017, chapter 9). These sectors and activities include the agriculture and forestry sectors, as well as urban wastewater treatment and potable water production. The plan recognises that the wider water environment supports important social activities but acknowledges that further research is necessary to quantify those benefits. The sole evidence it quotes on the social benefits is an economic study of recreational angling, which estimates an annual contribution of €755 million to the Irish economy (TDI, 2013). Though the study is recognised as demonstrating important social benefits of surface waterways, the study itself does not assess the effect of water quality on angling activity. A motivation for this research study is to extend the knowledge base on how social benefits are affected by changes in the quality of Ireland's water resources.

Recreational water users are an important stakeholder group in the context of decisions affecting water basin catchments throughout the country. For example, decisions on water extraction, water discharge (both licensed and unlicensed) and riparian development can all have an impact on the enjoyment of recreational activities. Having a better understanding of the decisions surrounding recreational activity, as well as how those decisions are affected by water quality, is valuable information that would enable engagement between water basin catchment stakeholders.

The State expends considerable resources preserving, maintaining and improving the quality of its surface waters. The public consultation document on river basin management planning for the period 2018–2021 provides an indication of the scale of activities being undertaken (DHPCLG, 2017). Ireland's waterways, including rivers, lakes, canals and coastal waters, are widely used by the public for recreational purposes. Based on survey data, Williams and Ryan (2004) estimate that just under half (49%) of the adult population participate in some form of water-based leisure activity per annum. Participants in most water-based recreational activities come into close contact with the water, with the possible exception of those engaged in recreational walks. For instance, some 12% of adults swim at least once during the year, 7% of adults engage in angling activity, 5% engage in boating and sailing activities, with smaller proportions participating in other water-based sports (Williams and Ryan, 2004). Accordingly, the status of Ireland's water bodies has a direct impact on a significant proportion of the population as they engage in recreational activity. However, very little is known about recreational users' views on the environment in which they undertake their recreational activity and how their recreational activity is affected by water quality, either positively or negatively. In particular, little is known about whether the destination or duration of water-based recreational activity is influenced by the quality of water at recreational sites.

Several studies have examined the public's preference for water quality improvements or associated ecosystem services (Norton *et al*., 2012; Stithou *et al*., 2012; Murphy *et al*., 2013; Buckley *et al*., 2014). These studies provide valuable insight into preferences but were not specifically designed to investigate whether or not the destination or duration of water-based recreational activity is influenced by the quality of water at recreational sites. Findings from Buckley *et al*. (2014) show that recreational users are willing to pay for water quality improvements in Irish rivers but somewhat perversely also find that willingness to pay increases with distance travelled to the recreational site. For the general public, and not specifically recreational users, Murphy *et al*. (2013) find positive willingness to pay for higher levels of water quality across various quality metrics. Looking specifically at the River Boyne, Stithou *et al*. (2012) find that the public positively value and are willing to pay for improvements in river ecology. These types of study can be helpful to those involved in decisions about policy or investments related to water bodies, including in undertaking cost–benefit analyses of policy decisions. These studies focused on the general public and not specifically water-based recreational users, nor do they distinguish by water user type (i.e. angler, swimmer, boater, etc.). Therefore, they provide limited information on how specific user types would respond to changes in environmental quality. Several studies have also examined the activities of specific types of recreational water users, including anglers (TDI, 2013) and boating enthusiasts among others (Ipsos MRBI, 2010; Amárach Research, 2014). When combined with information on national participation rates (e.g. Williams and Ryan, 2004) these studies provide detailed information on the scale of such activities on Irish waterways. However, a missing element of the research reviewed is the relationship between water quality and recreational activity.

One Irish study that attempts to bridge that gap combines the data on anglers from TDI (2013) with publicly available WFD water quality status data from http://gis.epa.ie/. Curtis and Stanley (2016) find that anglers' trip duration is affected by water quality, as indicated by WFD status. Salmonid game anglers' fishing trips are substantially longer (0.3–4 days total duration) in waters with higher ecological status than in lower status waters. Coarse fish species are more tolerant of poorer water quality than game species and this difference is reflected in anglers' behaviour. Coarse anglers fishing in lower ecological status waters spend roughly 0.7 days more per trip than those fishing in high-status waters, and over the year they fish for approximately 9 days more. Water quality affects not only activity but also the value of recreational activity. Curtis and Stanley (2016) estimate that the value to game anglers benefiting from higher status water quality is up to €122 per day. With anglers fishing on average 10 days per annum (Curtis and Stanley, 2016), the loss to anglers associated with poor water quality is potentially very large.

The objective of this research project was to determine how water-based recreational activities in Ireland are affected by differences in water quality across recreational sites. The research complements the existing study by Curtis and Stanley (2016) and provides additional empirical evidence about the benefits to recreational users of improvements in surface water quality.

3 Data Sources and Water-Based Recreational Activity

The volume of economic research on recreational activity within Ireland is small, largely owing to limited data on activity levels. There are no systematic, publicly available data on water-based recreational activity. This research relies on point-in-time snapshots of activity data, combined with water quality monitoring data that are collected for routine reporting under the WFD. This section briefly outlines the data sources used in the research project, while summary information about the data is contained in the appendices of this report.

3.1 Recreational User Data

In Ireland, representative surveys of the general population are the only means to assess the level of engagement in many recreational pursuits, including those that occur on or near water bodies (e.g. Whelan, 1997; Williams and Ryan, 2004). Such survey studies provide a good assessment of aggregate participation rates but usually provide little information on the location of activities. Consequently, such studies provide little insight into how participation rates vary depending on site attributes such as user facilities (e.g. boat ramps or walk-ways), local amenities and environmental attributes (e.g. water quality).

To elicit more detailed information on water-based recreational users, dedicated user surveys are necessary. Waterways Ireland (http://www.waterwaysireland.org/) 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 Ireland and Northern Ireland. Survey reports were subsequently published containing summary information on recreational activity at the surveyed sites (Ipsos MRBI, 2010; Amárach Research, 2014).

Because there are no public registers of water-based recreational users (e.g. of anglers or boaters), dedicated user surveys are usually undertaken as face-to-face interviews on site at waterside locations, which was the case in for the Waterways Ireland surveys undertaken in 2010 and 2014. While dedicated user surveys can elicit detailed information about users' activities and preferences, the nature of the surveys presents analytical challenges. An on-site survey interviewer is more likely to encounter higher frequency users (e.g. anglers, boaters); therefore, on-site surveys may not be representative of all the users at such sites. Low-frequency visitors to the site tend to be under-represented in the sample surveyed. The methods employed to analyse the survey data can control for such sampling biases and therefore on-site interviews do not pose a significant problem. However, the selection of on-site locations for interviews also introduces potential sampling biases. If the analysis pertains to either a single site or all possible sites, this is not an issue. If on-site interviews occur at a sample of potential sites, the chosen sites should be representative of the population of potential sites. In practice, on-site interviews are skewed towards more popular user locations to minimise survey costs and maximise survey respondents. A problem arises if the popularity of such user locations is correlated with the research topic. For example, if the popularity of user locations is due to their pristine water quality, survey data collected solely at such sites will not be useful for understanding how users' preferences vary across sites with different levels of water quality. It would be prohibitively expensive to conduct on-site surveys at all locations. However, automatic/infrared counters, which are frequently used elsewhere to measure visitor numbers (e.g. Lindsey and Nguyen, 2004; Hochmair *et al*., 2012; Gundersen *et al*., 2015), are potentially an economical alternative. Installing automatic counters across multiple locations would provide comprehensive data on recreational user activity compared with point-in-time data associated with on-site surveys, including seasonal variation and peak visitor times. Such data would also show how recreational users are responsive to the full range of site attributes (e.g. visitor facilities, environmental quality).

Waterways Ireland also maintains a comprehensive record of facilities at recreational sites over which it has responsibility, which was also used within the research. The data cover facilities and infrastructure relating to slipways and moorings, washing and laundry, and power and fuel. Other facility and amenity data not included in the research but which could potentially be incorporated in future research on recreational activity include social or recreational opportunities, such as restaurants or public houses. Future research on the choice of recreational location or duration of trip should consider capturing such information within the data collection process.

3.2 Water Quality Data

The majority of water quality data used in the research were originally collected as part of the WFD monitoring programme. WFD data are available for public download via the EPA's environmental data portal (http://gis.epa.ie/). The portal contains data on a wide variety of environmental themes, including water quality and the WFD. While summary data are freely available from the data portal, the research project also utilised detailed chemical monitoring data. Water quality data were also accessed directly from Waterways Ireland, which has responsibility for water quality monitoring on canal sites. WFD water quality monitoring does not include any measure for faecal coliform, which is a potentially important water quality metric of interest to recreational users concerned about health risk. Among the recreation sites within the research study, faecal coliform measurements are recorded only at canal sites.

4 Conclusions and Recommendations

This section summarises conclusions from the research study and outlines some policy recommendations. The conclusions are drawn from two research papers published in peer-reviewed academic journals, which are included as appendices to this report. The papers contain a full discussion of the research methods, results and policy conclusions. Only the key research findings are presented here.

The research first investigated whether or not water quality levels at recreational sites affect boat users' decisions on the location at which to begin their activity. In reality, boat users may not be aware of a site's water quality measurements, as water quality test scores are not posted at recreational sites. Nonetheless, the analysis found that boaters are responsive to laboratory measures of water quality, as indicated by both biochemical oxygen demand (BOD) and P levels. For a 1 mg O_2/l increase in BOD level, which is equivalent to a 70% increase from the mean BOD value in our sample, the odds that a specific site is selected for a boating trip falls by 70%. In the case of phosphates, for a 27-fold increase from the mean phosphate level, which is equivalent to a 1 mg P/l increase, the odds that a site is chosen for a boating trip falls by almost 100%.

As one might expect, as travel distance to water-based recreational sites increases, the probability that they are visited declines. For each 10 km increase in distance to a site, the probability that it is visited declines by approximately 10%. All else being equal, water users are more likely to engage in boating activity at their 'local' waterway. This result reaffirms the importance of achieving good water quality across all sites and ongoing efforts to improve the quality of the EU's waterways.

The second component of the research investigated the extent to which water quality levels at recreational sites affects the length of the trip. The premise here is that recreational users take trips of a longer duration at sites with better water quality. This analysis examined four categories of recreational users: boaters; anglers; those engaged in other water sports (e.g. canoeing, water skiing, rowing); and those engaged in activities for which access to water is not essential, specifically walking and cycling. The research finds strong evidence that higher levels of recreational demand (i.e. recreational trips of longer duration) occur at sites with better water quality. This finding occurs across all four categories of recreational activity, as well as when considering different types of water quality metric (e.g. BOD, ammonia, P, faecal coliform).

The research finds no statistical association between overall WFD status (i.e. high, good, moderate, poor or bad) and the duration of recreational trips, which indicates that WFD status is of limited practical use for recreational users. WFD status is assigned as the minimum status of biological and chemical components. In the recreational sites within our sample that are designated as having '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. The research also found no evidence that recreational users that come into closer contact with the water (e.g. swimmers, rowers) are more responsive to better water quality than those that have less contact (e.g. cyclists, boaters).

Across the four categories of recreational users (i.e. anglers, boaters, water sports participants, and walkers and cyclists) the minimum estimated value of a day's recreational activity in excess of expenses incurred during the recreational trip is €66, and slightly higher for international visitors at €76/day. Given that approximately half the adult population participate at least once per year in a water-based recreational activity (Williams and Ryan, 2004), this illustrates the potential scale of recreational net benefit to users associated with Ireland's marine and freshwater resources. The research also finds that recreational users spend more time at sites where there has been investment in user infrastructure (e.g. toilet facilities), which is a justification for further investment for recreational users, including tourists.

This project, like many research projects, faced challenges accessing data. The difficulty in combining data sets containing water quality and recreational activity data contributes to the paucity of research on the preferences of water-based recreational users and specifically the impact of water quality on user preferences. A number of practical steps are outlined below that should facilitate further research on water-based recreational users' preferences.

The EPA's data portal (http://gis.epa.ie/) contains data on a wide variety of environmental themes, including water quality and the WFD. Though data are available specifically for geographic information system (GIS) software, in the non-GIS downloads it is difficult to establish the geographical location associated with specific records within the Excel downloads. The absence of geographical identifiers within the reported Q-value data sets also limits the usefulness of these data for either research or informational purposes.

Consideration should be given to making substantially more water quality monitoring data publicly accessible online. For the most part, no laboratory test results are available for nutrients or other parameters (e.g. BOD) via the data portal. The primary format in which water quality is reported uses the WFD classifications (high, good, moderate, poor or bad, and pass/fail). While this serves the purpose of WFD quality reporting, it strips the reported data of a large amount of useful information that are relevant for research purposes.

Excluding canal sites, for which Waterways Ireland monitors water quality, faecal coliform levels are not monitored at any of the other recreational sites within our sample. While these sites are not designated bathing water sites, they are extensively used as recreational sites. Consideration should be given to monitoring popular recreational sites that are not designated as bathing sites for faecal coliforms and other pathogenic health risks.

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Abbreviations

BOD	Biochemical oxygen demand
EPA	Environmental Protection Agency
GIS	Geographic information system
P	Phosphorus
WFD	Water Framework Directive

Appendix A Site Choice: Recreational Boating Site Choice and the Impact of Water Quality

The research underpinning this project report has been submitted for publication in a peer-reviewed academic journal. This appendix includes the paper that investigates how water quality affects the site choice decision of recreational boaters. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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Recreational boating site choice and the impact of water quality

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Abstract

This paper examines whether water quality has an effect on recreational boating activity. The analysis is based on survey data collected by face-to-face interviews with recreational visitors to 10 waterway sites across Ireland. We model the respondent's choice decision to travel to a specific site for the purposes of beginning their recreational boating activity. Water quality data is from European Union Water Framework Directive monitoring stations. Across recreational sites, which have generally high water quality levels within our sample, we find that boaters favour sites with better water quality; as indicated by biological oxygen demand and phosphates metrics. We also find that for each additional 10 km distance from respondents' homes the probability that a site is visited declines by up to 10%. Preferences for other site attributes, such as boat slipways, parking and toilet facilities, were counter to expectation but reflects the fact that all boat users do not necessarily access or need all facilities provided.

Keywords: Economics, Geography

1. Introduction

The EU Water Framework Directive (WFD) (Directive 2000/60/EC, 2000) has led to the evaluation of European waterways using a suite of metrics. Biological quality

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(i.e. fish, benthic invertebrates, aquatic flora), hydromorphological quality, physical–chemical quality, and chemical status are all now factors that feed into the overall evaluation of a water body's 'status'. The Directive was intended to achieve good status of all EU water bodies by 2015. This target was not met (Hering et al., 2010; Ball, 2016) though significant improvements in water quality have been achieved (Pérez-Domínguez et al., 2012; Wilson et al., 2015; Azimi and Rocher, 2016; Van Grinsven et al., 2016). Discourse around improved application of the WFD in the future, and the quality of EU waterways in general, are ongoing. Central to these considerations will be the value that people place on such improvements.

Many benefits arising from improvements in water quality accrue to recreational users engaged in activities such as swimming, boating and fishing. Recreational user benefits have been widely examined including studies related to fishing (Bockstael et al., 1987; Egan et al., 2009; Curtis and Stanley, 2016), swimming (Needelman et al., 1995), beach visits (Hanley et al., 2003), boating (Lipton, 2004) as well as many other water-based recreational activities (Curtis, 2003; Hynes et al., 2008; Gürlük and Rehber, 2008; Paudel et al., 2011). Recreational users express their preferences for environmental attributes, such as water quality, through decisions regarding site use. For example, the number of trips to a specific location, or the length of time spent at a location. User preferences are also revealed when individuals select a particular site above other alternative sites to pursue their recreational activity. This paper focuses on site choice decisions, specifically examining whether differences in water quality across sites affects the destination for recreational boating trips. The analysis considers boating trips in Ireland and the objective of the paper is to illustrate the extent to which water quality influences boating trip destinations and consequently provide evidence to support investment in water quality improvements. While the achievement of 'good' water quality status under the WFD is a legislative requirement on EU member states, limited economic resources and conflicting sectoral interests mean that investment decisions are prioritised, including funds specifically earmarked for water quality remediation. Information on how recreational users benefit from good water quality will help better inform decisions about investment priorities.

2. Background

Many studies examining demand for recreational pursuits and the associated demand for environmental quality use the random utility model (RUM) framework of McFadden (1973), and build on the early work of Bockstael et al. (1987, 1989). These studies model the decision process of choosing a recreation site from a finite set of mutually exclusive alternative sites. Site choice decisions for each trip are treated as a utility maximisation process, where the person chooses from a number

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of alternative sites (with different site attributes, including environmental quality) and selects the one that yields the highest expected utility level on any given choice occasion. The literature on the impact of water quality on water-based recreational activity ranges across many activities, as mentioned earlier. Work by Farr et al. (2014) suggests that there are substantial differences in the key factors (e.g. income, age, residency duration, and marital status) influencing the probability and frequency of participation in various water-based recreational activities, including boating. Therefore, insights from studies of non-boating activities may not be particularly relevant or useful to understand the impact of water quality on boating activity. In a review of benefits of water quality on marine recreation Freeman (1995) finds just one study of significance that considers boating activity. That study, by Bockstael et al. (1989), suggests that there are substantial benefits in cleaning up perceptible water pollution problems. In the intervening period a small number of studies consider water quality in the context of recreational boating activity. Lipton and Hicks (1999) using a multinomial logit model to examine the determinants of where vessel owners berth their boats find that boat owners' perception of water quality has an important influence on site choice. In a study of boaters in Maryland, USA, Lipton (2004) find that water quality does impact the enjoyment of boating and that boaters would benefit by a significant amount if water quality were to improve. In another study from the United States Egan et al. (2009) consider recreational activities at Iowa's 129 principal lakes, at which boating was the most popular activity along with fishing, picnicking, wildlife viewing and swimming. Their analysis shows that lake visitors are responsive to the full set of water quality measures used by biologists to identify the impaired status of lakes. And finally, in England Ziv et al. (2016) find mixed evidence on the effect of good water quality on boat site visitation. Although the number of studies is limited, the results on effect of water quality on boating activity are consistent; better water quality generally has a positive effect on boating activity. This paper adds to this narrow empirical literature providing the first estimates of the impact of water quality on site choice for boating activity in Ireland. The paper's contribution is as an application of existing methodologies to produce new empirical estimates.

An issue with site selection modelling is establishing the set of sites from which the selected or visited site is chosen (i.e. the choice set). Invariably there is data on the site actually chosen by the recreational user but in many instances the researcher has limited or no information on the alternative sites considered, which is the case for our Irish boating dataset. Data on alternative sites can be collated from all known recreational sites within a specific geographic area creating a universal site choice set. In such circumstances researchers often assume that individuals are aware of all elements of this set. Parsons and Hauber (1998) find that there exists some threshold distance beyond which adding more recreational sites into the choice set has negligible effects on welfare estimates, whereas Peters et al. (1995) were among

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the first to demonstrate that using a universal choice set compared to a model that considered a sampled individual's actual choice set produces model parameters and welfare estimates that are quite different. Commonly used rules of thumb, such as distance rules, for defining choice sets do not necessarily lead to the proper choice set specification. Hicks and Strand (2000) make similar findings and conclude that caution must be exercised when defining appropriate choice sets and suggest direct questioning of survey respondents is required to specify the choice set. Parsons et al. (1999) make a counter argument to limiting or deleting sites from the universal choice set. They acknowledge that individuals may be unfamiliar with many of the sites, and that individuals may only credibly consider a narrow set of sites but argue that there is more important preference information in understanding which sites people know about (familiar sites) and sites that they really consider (favourite sites). This information is missing in the approaches that merely delete sites, such as the distance rule. Parsons et al. (1999) retain all sites in the choice set for estimation but specify different site utility functions for familiar and unfamiliar sites on the basis that the role site attributes play in site selection is likely to be different for familiar versus unfamiliar sites. They incorporate favourite sites in the likelihood function as being preferred to unfavoured sites. One difficulty with allowing for familiar or favourite sites during estimation is their identification. Obtaining consistent definitions for familiar and favourite sites can be difficult and identifying such sites during survey interviews can be problematic (Parsons et al., 1999), while Horowitz and Louviere (1995) also question whether the desired information can be acquired. On the basis of Monte Carlo experiments examining choice set formation models in the random utility framework Li et al. (2015) conclude that choice set formation should be central in project design, data collection, as well as during modelling and welfare analysis. More recently Thiene et al. (2017) show that choice set formation is behaviourally relevant and that motivations are important determinants of preliminary site screening for choice set inclusion, as well for site selection.

We add to the literature through a study of recreational boating, examining whether water quality has an effect on boating site choice decisions. In particular, we model the respondent's choice decision to travel to a specific site for the purposes of beginning their recreational boating activity. Consistent with the existing empirical literature we find that boaters prefer sites with better water quality. The rest of the paper is organised as follows: section 2 describes the datasets utilised in our analysis, while section 3 outlines the models employed to model recreational site choice decisions. Model results are presented in section 4 and section 5 offers a discussion, which is followed by a concluding section.

3. Materials

3.1. Survey of waterway users

Waterways Ireland is responsible for 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 of waterway users 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 conducted face-to-face amongst a sample of waterway users across 23 points on the seven waterways. The sampling points were spread across both urban and rural areas with interviews occurring at different times and days across the interview periods. Interviews took 10 minutes on average to complete and were undertaken from August–October 2010 and October–November 2014. 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.

For inclusion in this study we selected respondents that participated in boating activities, which comprises 299 individuals interviewed over the two survey periods and comprises 14 distinct sites. Due to the absence of water quality data at some sites the estimated models relate to the choice decisions of 266 individuals across 10 sites. The two cross-section surveys are similar in terms of socio-demographic variables plus in preliminary model estimation the estimated parameter on a year dummy variable was insignificant. Consequently the two cross-section surveys are pooled to create a single dataset, which provides more degrees of freedom for model estimation. The surveys were not designed to model site choice decisions, nor did they collect information on familiar, favourite or alternative sites that respondents considered in making their boating site choice decision. This means that we cannot follow best practice for defining the choice set, as discussed earlier (Thiene et al., 2017; Li et al., 2015; Parsons et al., 1999). Our method instead is to follow an approach often used in the literature where a universal choice set is created based on known recreational boating sites and a distance based rule is used to define individuals' choice sets (Parsons and Hauber, 1998; Peters et al., 1995). A number of models are estimated based on variations in the distance rule prior to selecting preferred models based on goodness of fit. Our distance rule for populating each respondent's choice set is based on all boating sites within 125%, 150%, 175% and 200% of the distance travelled by the respondent to their selected boating site where they were interviewed. This means that the modelled choice set for each individual potentially differs as the distance rule is altered, and also that the number of alternate

Table 1. Visited sites – travel distances, km.

Waterway	Site	Number of visitors	Mean distance	Std. Dev.	Min	Max
Barrow	Carlow	2	49	44	18	80
Grand Canal	Shannon Harbour	62	123	43	48	195
	Grand Canal Basin	2	104	19	91	118
Royal Canal	Kilcock Harbour	2	85	2	84	86
Shannon Erne	Leitrim Village	22	190	66	43	318
	Keshcarrigan Harbour	17	181	58	43	292
Shannon	Dromineer	13	106	60	22	200
	Athlone	42	126	40	40	209
	Carrick-on-Shannon	101	165	47	40	274
	Terryglass	3	95	66	34	165
	All Sites	266	146	55	18	318

sites varies across individuals (varying from 1 to 9 alternate sites). For example, as the distance rule is relaxed, i.e. from 125% to 150% the choice set for one respondent may remain unchanged, whereas for another it may increase, depending on the distance they actually travelled and their proximity to alternate sites.

Travel distances were calculated using spatial software as the driving distance from the individual's county of residence to the boating site. Mean travel distances to each of the 10 boating destinations is reported in Table 1. For example, 2 individuals visited the Carlow site on the Barrow waterway for boating activities with estimated travel distances of between 18–80 km and a mean of 49 km. The average distance travelled across all sites was 146 km. Though the Carlow site was visited by just two boat users, the site itself is within 125% of the actual travel distance of 29 individuals who have a mean travel distance to the Carlow site of 81 km, as shown in Table 2. There are 37 individuals for which the Carlow site is within 200% of the travel distance to their chosen boating site, with a mean distance of 92 km. As different travel rules are applied in calculating the choice set the potential mean travel distance, as reported in Table 2, does not increase substantially across the sites. There is no obvious threshold at which choice sets change dramatically in terms of mean distance or numbers of individuals potentially considering specific sites in their choice decisions and therefore Table 2 provides no insight on selecting the most appropriate choice set.

3.2. Water quality

Water quality data for 2010 and 2014 were sourced from monitoring stations that were proximate to the waterway sites where surveys were conducted. 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 3. Generally water quality at the sites in our dataset is at a relatively high level

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Table 2. Visitor mean potential travel distances to choice set sites (266 individuals).

Site	Sites within 125% of distance to selected site		Sites within 150% of distance to selected site		Sites within 175% of distance to selected site		Sites within 200% of distance to selected site	
	mean, km	Individuals	mean, km	Individuals	mean, km	Individuals	mean, km	Individuals
Carlow	81	29	87	33	87	35	92	37
Shannon Harbour	115	166	115	187	113	208	114	210
Grand Canal Basin	49	129	53	134	63	143	74	153
Kilcock Harbour	57	133	58	145	69	156	81	175
Leitrim Village	101	179	106	198	115	223	115	238
Keshcarrigan Harbour	107	174	111	188	115	226	114	238
Dromineer	138	115	141	161	143	171	143	173
Athlone	109	179	114	195	107	218	107	222
Carrick-on-Shannon	103	184	106	201	114	226	114	241
Terryglass	136	166	134	187	135	208	134	210

Table 3. Water quality measures.

	BOD mg O_2/l		Phosphates mg P/l		Ammonia mg N/l		Dissolved Oxygen % Saturation		Fecal Coliform Count/100ml	
Site	2010	2014	2010	2014	2010	2014	2010	2014	2010	2014
Carlow	0.046	0.046	0.026	0.026	0.046	0.046		94.4		
Shannon Harbour	1.235	0.014	0.017	0.038	0.024	0.014			20	25
Grand Canal Basin	1.500	0.051	0.027	0.059	0.100	0.051			525	1976
Kilcock Harbour	2.703	0.051	0.040	0.080	0.062	0.051			8801	1787
Leitrim Village	2.478	0.021	0.035	0.064	0.030	0.021			30	62
Keshcarrigan Habour	2.478	0.021	0.035	0.064	0.030	0.021			30	62
Dromineer	0.800	0.019	0.013	0.009	0.020	0.019	100.5	110.5		
Athlone	0.658	0.025	0.029	0.025	0.031	0.025	93.7	95.7		
Carrick-on-Shannon	1.190	0.506	0.020	0.051	0.099	0.506	84.1	103.5		
Terryglass	0.850	0.016	0.019	0.010	0.033	0.016	98.8	106.5		

The data presented are site specific annual means.

with two exceptions. There are elevated levels of phosphorus and fecal coliform in the waters at Kilcock Harbour and Grand Canal Basin. Nonetheless, the analysis here is not comparing recreational activity at pristine versus very polluted sites, rather 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. While Table 3 reports summary statistics for several water quality metrics, only biochemical oxygen demand (BOD) and phosphates are included in the reported model estimates because the models with the other water quality variables did not converge during estimation, the most likely reason for which is lack of variability and insufficient data points. For instance, fecal coliform data was only available for 5 canal sites. We confine our discussion of the water quality variables below to BOD and phosphates.

Recreational users 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, boating decisions on site choice are based on a range of

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criteria including individual's 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, e.g. BOD.

3.2.1. Biochemical Oxygen Demand (BOD)

BOD is a metric that indicates whether a water body is in a eutrophied state. Higher BOD levels of a water body are associated with low 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 dissolved 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 in or near eutrophic waters are likely to be impacted due to impediment of activity, discomfort and visual unpleasantness. Irish regulations giving statutory effect to the WFD and Directive 2008/105/EC on environmental quality standards in the field of water policy (Directive 2008/105/EC, 2008) 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.[1]

3.2.2. Phosphates

Phosphate carrying pollutants like fertilisers, waste-water, detergents and run off from paved surfaces can exacerbate algal growth in fresh water systems, leading to algal blooms and eutrophication. 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.[2] Orthophosphate is the most readily available form for uptake during photosynthesis. High concentrations generally occur in conjunction with algal blooms. For rivers with '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.

[1] SI 272/2009 – European Communities Environmental Objectives (Surface Waters) Regulations 2009. Available online: http://www.irishstatutebook.ie/2009/en/si/0272.html.

[2] 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.

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Table 4. Recreational site attribute data.

Sites	*Toilets*	*Showers*	*Laundry*	*Parking*	*FuelPoint*	*Slipway*
Carlow				X		X
Shannon Harbour	X	X	X	X		
Grand Canal Basin	X	X				X
Kilcock Harbour						
Leitrim Village	X	X	X	X	X	X
Keshcarrigan Harbour	X	X	X	X		X
Dromineer	X	X		X		X
Athlone	X	X				X
Carrick-on-Shannon	X	X	X	X		X
Terryglass	X			X		X

X indicates presence of a facility/service.

3.3. Other site attributes

Data on other site attributes are reported in Table 4, which was provided directly by Waterways Ireland. The variables are binary, indicating the presence of the attribute. The attributes include toilet and washing facilities, parking, as well as fuel points and slipways for launching boats.

4. Methodology

The RUM is the standard framework used to estimate behavioural choice models within which a boater chooses between a number of boating sites and selects the one that yields the highest expected utility level on any given choice occasion. Sites comprise a number of attributes (e.g. water quality, washing facilities, slipway, etc.), with the level of the attributes differing across choice alternatives. The utility that boater i would obtain from site j is

$$U_{ij} = \beta x_{ij} + \epsilon_{ij} \tag{1}$$

where x_{ij} is a vector of observed variables, β a vector of unobserved coefficients and ϵ_{ij} is an unobserved error term. A boater chooses among J possible site alternatives. Whenever the utility from boating at site j is greater than the utility from all other sites, site j will be chosen. The RUM model can be specified in different ways depending on the distribution of the error term. Assuming the error terms are identically and independently distributed (iid) extreme value, the RUM model is specified as a conditional logit (CL) (McFadden, 1973). The CL model is the workhorse for analysing discrete choice data with many applications (e.g. Siderelis et al. (1995); Parsons and Massey (2003); Provencher and Bishop (2004); Pradhan and Leung (2004)). The probability of boater i choosing site j is

$$P_{ij} = P(y_i = j) = \frac{exp(\beta x_{ij})}{\sum_{j=1}^{J} exp(\beta x_{ij})} \tag{2}$$

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where y_i is the choice made by boater i. The parameters of the conditional logit model, β, are estimated through the use of maximum likelihood with the following log-likelihood expression:

$$LL(\beta) = \sum_{n=1}^{N} \sum_{i=1}^{J} D_{ij} \, log P_{ij} \tag{3}$$

where N is the number of boaters and D_{ij} is a dummy variable that takes the value of 1 if boater i chooses site j and 0 otherwise.

5. Results

Conditional logit model estimates using four distance rules for generating boaters' choice sets are reported in Table 5. The choice sets include sites within 125%, 150%, 175% and 200% of the distance actually travelled by each individual boater. In addition to the water quality and site attribute variables, the models also include a variable measuring a boater's distance to each specific site, specified in units of 10 km. The distance variable is incorporated to allow site preferences vary by site proximity. A negative coefficient estimate is anticipated indicating more distant sites being less popular. A constant for each site, termed an alternate specific constant (ASC), was incorporated to control for unidentified characteristics associated with each site. For instance, some sites are canal sites, some rivers, and others are combinations of both, while some are in urban and others in rural locations. We begin by comparing the CL models estimates across the four different choice set assumptions.

Standard tests for model comparison are not applicable, i.e. likelihood ratio tests, as the models are not nested. The model is unchanged across estimations in terms of parameters and observations (i.e. boaters) though with different numbers of choice alternatives across the four estimations. We evaluate models using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) statistics and also use McFadden's pseudo-R^2, which compares the log-likelihood from an intercept only model to the log-likelihood from the model with all covariates included (McFadden, 1973). Higher values of McFadden's pseudo-R^2 represent a better fit. Comparing across the four estimated models in Table 5, pseudo-R^2 declines in magnitude as the choice set expands. Although not a formal test of model specification the statistic does suggest that the narrower choice sets (i.e. the 125% set) may more applicable, though as we will discuss shortly it will be discounted for other reasons. Both AIC and BIC are often used to help in model selection, with lower value statistics being considered to be closer to the truth in the case of AIC or more likely to be the true model in the case of BIC. Both statistics suggest that the narrower choice set (i.e. 125%) is the preferred model. Both AIC and BIC

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Table 5. Conditional logit regressions.

	Choice set includes sites within % of actual travel distance			
	125%	**150%**	**175%**	**200%**
Distance	0.246***	0.023	−0.069**	−0.101***
	(0.063)	(0.038)	(0.027)	(0.032)
BOD	−0.421	−0.594*	−1.188***	−1.010**
	(0.324)	(0.326)	(0.346)	(0.411)
Phosphates	−10.459	−34.483*	−19.994	−25.540
	(21.211)	(18.366)	(13.005)	(17.288)
Toilets	0.106	−1.915	−2.842*	−2.388
	(1.904)	(1.920)	(1.688)	(2.121)
Showers	2.398**	3.832***	3.496***	3.902***
	(1.099)	(1.348)	(1.231)	(1.295)
Laundry	2.049**	2.213***	2.396***	1.958***
	(0.818)	(0.769)	(0.638)	(0.743)
Parking	−1.084**	−0.865*	−0.508	−0.513
	(0.516)	(0.489)	(0.433)	(0.416)
FuelPoint	−0.133	0.715	−0.206	0.025
	(0.490)	(0.459)	(0.416)	(0.401)
Slipway	−1.313	−1.256	−0.454	−1.514
	(1.528)	(1.326)	(1.104)	(1.347)
ASCs	yes[a]	yes	yes	yes
Pseudo R^2	0.282463	0.227744	0.217178	0.224755
Log Likelihood	−263.255	−320.984	−354.462	−361.077
AIC	562.5	678.0	744.9	758.2
BIC	627.0	742.5	809.4	822.7
Observations	266	266	266	266
Site choices	1566	1764	1955	2063

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.
ASCs = Alternative Specific Constants.
[a] Algorithm was unable to estimate a standard error for ASCs.

indicate relative quality between alternatives but neither say anything about absolute quality or interpretation of the models. Comparing the parameter estimates across models there are substantial differences in their magnitude, which is consistent with Peters et al. (1995) who find that model parameter estimates can be quite different depending on the choice set used in estimation. The positive sign on the *Distance* variable in some of the models is not as anticipated, indicating that people prefer more distant sites. The statistically significant coefficient in the 125% choice set model with an associated odds ratio of 1.28, indicates a site 10 km further distance is 28% more likely to be visited. This is counter to intuition though not inconsistent with some empirical findings in the literature, where it is argued that there is positive value in travel time or distance (e.g. Cao et al., 2009; Jain and Lyons, 2008; Ory and Mokhtarian, 2005). For instance, if some boating trips are a part of annual vacation, as opposed to everyday recreational activity, respondents may have a preference towards more distant sites to get away from the normal routine. Other parameter estimates that draw doubt on the narrower choice sets (i.e. 125%–150%) are the negative and statistically significant coefficient on the *Parking* variable indicating that boating participants disregard parking facilities in their decisions. Also the maximum likelihood algorithm was unable to estimate a standard error for the ASCs

Table 6. Odds ratios – conditional logit model.

	Choice set includes sites within % of actual travel distance			
Variable	**125%**	**150%**	**175%**	**200%**
Distance	1.28***	1.02	0.93***	0.90***
	(0.08)	(0.04)	(0.03)	(0.03)
BOD	0.66	0.55**	0.30***	0.36***
	(0.21)	(0.18)	(0.11)	(0.15)
Phosphates	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Toilets	1.11	0.15***	0.06***	0.09***
	(2.12)	(0.28)	(0.10)	(0.19)
Showers	11.00	46.15	32.97	49.52
	(12.09)	(62.23)	(40.60)	(64.14)
Laundry	7.76	9.15	10.98	7.09
	(6.35)	(7.03)	(7.00)	(5.27)
Parking	0.34***	0.42***	0.60	0.60
	(0.17)	(0.21)	(0.26)	(0.25)
FuelPoint	0.88	2.04	0.81	1.03
	(0.43)	(0.94)	(0.34)	(0.41)
Slipway	0.27*	0.28*	0.64	0.22***
	(0.41)	(0.38)	(0.70)	(0.30)

Standard errors calculated by the delta method in parentheses.
* p<0.10, ** p<0.05, *** p<0.01. Null hypothesis odds ratio = 1.

(not reported) in the case of the 125% specifications using a number of algorithms (i.e. Gauss–Marquardt, Davidon–Fletcher–Powell, Newton's method, Berndt, Hall, Hall, and Hausman). Even though the information criterion statistics suggest the narrower choice set models (i.e. 125%–150%) are preferable in terms of which models describe the data better, these models have less credibility from an economic or practical sense. For the remaining models based on the 175%–200% choice sets there is not much to distinguish between them. The models have similar McFadden's pseudo-R^2 statistics, and similar relative probability based on the AIC statistics. With the parameter estimates not directly interpretable the related odds ratios reported in Table 6 are more useful.[3] The magnitude of the odds ratios are broadly similar across the two preferred models. The very high (and incredible) odds ratio estimate for the `Showers` variable is not statistically significant from 1. However, the odds ratios associated with the *Toilets* and *Slipway* variables are unanticipated but statistically significant. We discuss the interpretation of the parameters in the next section.

6. Discussion

6.1. Data limitations

Prior to discussing the model estimates it is important to review some of the limitations of the dataset. The first point is that the boating recreation dataset was not

[3] With a logit model the odds ratio is calculated as the $exp(\beta_k)$ where β_k is the parameter associated with attribute x_k (Greene, 2012).

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collected for the purposes of estimating a recreational site choice model. As noted earlier, both Li et al. (2015) and Thiene et al. (2017) suggest that investigating choice set formation should be central in project design and data collection, and not just an issue for data analysis stages. Misspecification of the choice set can under estimate welfare measures by 30–50% (Li et al., 2015). Welfare estimates with that level of bias could substantially mislead policy decisions and hence we do not undertake welfare analysis here. Instead, the primary focus is on whether water quality affects or coincides with site choice preferences for recreational boating activity. The original survey dataset limits the methodological approaches feasible and the current best practice approach could not be followed. However, within the bounds of the existing dataset the approach taken to generate choice sets has been widely used previously (Parsons and Hauber, 1998; Peters et al., 1995). Consequently, the analysis does provide insights into recreational boaters' preferences, in particular with respect to water quality where there has been relatively limited empirical research. Empirically demonstrating such a relationship is also important information for decision makers involved in water resource protection and management.

An issue not previously discussed is that the analysis is confined to 10 specific sites. These sites are among the most popular boating recreational locations on the waterways that Waterways Ireland has responsibilities. However, there are potentially many other boating sites within the Waterways Ireland network and even more boating sites on other waterways. The implication for site choice modelling is that individuals' real choice sets may include sites beyond the 10 sites included in the analysis. The potential existence of such unknown sites echoes the concerns of Thiene et al. (2017); Li et al. (2015); Hicks and Strand (2000) among others. Unfortunately, there is no framework to remedy this issue within the current dataset.

The earlier discussion of water quality noted that sites within the analysis had relatively high water quality (see Table 3). Mean values for the BOD and $Phosphates$ variables are approximately equal to the threshold between 'moderate' and 'good' status for those metrics for rivers under the WFD. Accordingly, there may be potential sample selection issues within the dataset. The most popular recreation sites, where the face-to-face interviews were conducted, may occur at sites with relatively high levels of water quality. Boating activity may be more likely to occur at these sites because site facilities and water quality may be superior compared to other potential boating sites. To capture the full extent of the impact of differences in water quality on recreational boaters would require data across a sample of recreational sites covering the spectrum of water quality (and other boating facilities).

The sample of boaters used in the analysis is relatively small at 266 individuals, each taking a single trip. This limits the power of the model to estimate parameters across the full range of preferences. Mindful of this and the other data issues, we nonetheless

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proceed with estimation, as the analysis provides insight in an area where there is little prior empirical work.

6.2. Water quality

Boat users may not be aware of a site's water quality measurements, as water quality test scores are not posted at recreational sites in this sample. Including water quality metrics as site attributes within the site choice model enables us to examine whether boating enthusiasts, as they perceive water quality, are responsive to laboratory measures of water quality. The results suggest that boaters are responsive to water quality conditions, as indicated by both BOD and phosphorus levels. Based on the odds ratio estimates from the 175%–200% choice set models, for a 1 mg O_2/l increase in BOD level the odds that a site would be selected for a boating trip is 64–70% less. Odds ratio estimates are constant and independent of the level of the underlying variable but to put it in context a 1 mg O_2/l increase in BOD level is equivalent to a 70% increase from the mean value in our sample. For a 1 mg P/l increase in phosphates the odds that a site is chosen for a boating trip is almost 100% less. An increase by 1 mg P/l is equivalent to 27-fold increase from the mean phosphates level within our sample of sites. As the sample of sites in our data is not representative and our user sample is relatively small the estimated scale of the odds ratio may have limited policy application for other non-sample sites. However, the odds ratio estimates are statistically significantly different than one, which is an important result indicating that recreational boaters are sensitive to water quality levels in terms of preferred boating locations.

As mentioned earlier the water quality at the sites in our sample is quite high and the magnitude of the water quality levels reported in Table 3 would not be immediately visually perceptible to waterways users. This has potential implications for the conclusions that we can draw from our model. In particular, do the estimated BOD and phosphates odds ratios capture boater response to water quality levels or are they are correlated with some other unknown factor. We know that Waterways Ireland discouraged recreational activity a number of sites due to high fecal coliform contamination, namely the Kilcock Harbour and Grand Canal Basin sites. These sites are among the sites with higher BOD and phosphate levels so the estimated model may be capturing a correlation between fecal coliform and BOD and phosphate levels. Consequently, the magnitude of the estimated odds ratios may not be fully attributable to BOD and phosphate levels but the conclusion that recreational boaters are sensitive to water quality levels is still valid.

The results above are consistent with previous research on the impact of water quality on recreational boating activity. For instance, Lipton and Hicks (1999) find that boat owners' perception of water quality has an important influence on site choice

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while Egan et al. (2009) find that water users, including boaters, are responsive to the full set of water quality measures used by biologists to identify impaired water status. However, more recent research by Ziv et al. (2016) finds that water quality, as indicated by WFD status, is a poor predictor of sites with high levels of recreational use. Ziv et al.'s results may reflect an alternative methodological approach. First, WFD status is used as the sole water quality metric, which none of the prior boating studies use. WFD status comprises an assessment across a number of biological and physiochemical measures with WFD status itself assigned as the minimum status of biological and chemical components. The biological component of WFD status will have little relevance to boaters but may be the determining factor in WFD status so it is not surprising that WFD status is a poor predictor of recreational use. However, Ziv et al. (2016) make an important point that recreational users' preferences with respect to water quality may be determined by the actual recreational choices available. If there is limited availability of relevant infrastructure (e.g. moorings, slipways, etc.) preferences with respect to water quality may be compromised in favour of the practical alternatives available.

6.3. Other site attributes

While travel distance might not be considered a site attribute, it is an attribute to boaters considering between alternative boating sites. In the larger choice set models (i.e. 175% & 200%) the coefficient on the *Distance* variable is negative, as one would anticipate. As distance to sites increases, the probability that they are visited declines. The odds ratios in Table 6 suggest that for each 10 km increase in distance to a site, the probability that it is visited declines by 7–10%.

When we examine other site attribute variables we have several results different than one might anticipate. Boat ramps or slipways (*Slipway*) facilitate access to waterway sites and would generally be considered a positive attribute for a recreational boating site. The point estimate across all the models estimated is negative, which is counter to intuition, though may reflect the fact that many users do not trailer boats to their recreational sites. The odds ratio for the *Toilets* variable in the 175%–200% models being substantially less than 1 is also counter to intuition. Many 'cruiser' boats have toilets on board so such water-side facilities are not needed by many boat users. With the exception of two sites, all locations have toilet facilities available. Consequently, the toilets result may be capturing other factors associated with these sites. One of the sites without toilets, Carlow, has relatively poor opportunities for longer range navigation due to low water levels. So the result may be capturing the absence of boating opportunities at the site compared to other sites that have much more extensive boating opportunities available. The parameter estimate on the *Parking* variable is also negative. Designated parking facilities are available at 7 of

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the 10 sites and generally would be considered a positive attribute. However, absence of designated parking does not mean absence of parking, as on-street parking is generally available. It is more conceivable that parking is not a particularly important site attribute for boaters, which is the case in the preferred 175%–200% models where the coefficient estimates are not statistically significant. In general the revealed preferences for slipways, parking and toilet facilities that are counter to expectation may reflect the possibility that many boaters do not necessarily access or need all available facilities. Alternatively, the variables may also be correlated with some other negatively perceived attribute not considered within the model. For instance, opportunities for social engagement, such as those that occur at waterside restaurants and pubs, are frequently considered an important component of boating excursions are not captured within the estimated models. Finally, it should also be noted that these results reflect the fact that model estimation is based on only 266 individuals, leaving limited scope to fully resolve the complexity of boat users' preferences.

7. Conclusion

This paper models recreational boating site choice decisions for the purpose of investigating the extent to which water quality influences the site selection decision. The paper is based on an existing survey of recreational waterway users in Ireland, with the analysis confined to boaters using ten specific waterway sites. The use of a pre-existing dataset presented a number of challenges for the analysis. These included how to model the actual site choice set when the survey data only indicated the site actually visited by boaters, and the fact that the analysis pertains to just ten sites, albeit popular boating sites. With the analysis confined to a small number of waterway sites, which have generally high water quality levels, it is likely that sample selection issues arise. The analytical difficulties encountered during the research confirm the difficulty of modelling site choice decisions and the need to use a bespoke dataset. Mindful on these difficulties, we estimate a model that provides some insight into boaters preferences for site attributes, including water quality.

Water quality test scores are not posted at recreational boating sites, nor are they easily accessible online without concerted effort and expertise to retrieve the results. Consequently, it is likely that most boaters are unaware of a site's water quality measurements. Including water quality metrics as site attributes within the site choice model enables us to examine whether boating enthusiasts, as they perceive water quality, are responsive to laboratory measures of water quality. Our results find that boaters are responsive to water quality conditions, as indicated by both BOD and phosphorus levels. The results may also reflect official guidance discouraging waterway users from engaging in activities at a number of sites with high fecal coliform levels. While we are unable to separately control for such guidance within

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our model, conclusions of the analysis remain that recreational boaters are sensitive to water quality. Due to this and also because the analysis is based on a small unrepresentative sample of both sites and users it is not reasonable to undertake welfare analysis or draw policy implications with respect to the scale of boaters' response to changes in water quality.

One quantitative finding that has policy relevance is that travel distance to water sites is an important factor in choosing between alternative locations for water based recreational activities. For each 10 km increase in distance to a site, the probability that it is visited declines by 7–10%. All else equal, water users are more likely engage in their boating activity at their 'local' waterway. This finding echoes the importance of achieving good water quality across all sites and ongoing efforts to improve the quality of the EU's waterways. However, it is notable that water quality monitoring for ecological status under the Water Framework Directive does not require monitoring for fecal coliforms, which is the pollutant that recreational users may be most responsive in terms of their boating activity and also immediately impacted health wise. Better information on how recreational users benefit from water quality improvements will enhance decision making with respect to investment priorities, especially when facing limited economic resources and competing priorities.

Declarations

Author contribution statement

John Curtis: Conceived and designed the experiments; Performed the experiments; Analysed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Stephen Hynes: Analysed and interpreted the data; Wrote the paper.

Benjamin Breen: Analysed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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Appendix B Trip Duration: Water Quality and Recreational Use of Public Waterways Quality

The research underpinning this project report has been published in peer-reviewed academic journals. This appendix includes the paper that examines how water quality affects the recreational users' trip duration at waterway sites. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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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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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

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

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

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

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
*Age*35 +	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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AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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Demand for Water-Based Leisure Activity: the Benefits of Good Water Quality

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Identifying pressures • Informing policy • Developing solutions

Authors: John Curtis and Stephen Hynes

Identify Pressures

The EPA's 2016 State of the Environment report notes that, while the quality of Ireland's surface waters is among the best in Europe improvements are still needed. Over the past six years there was no improvement in quality of river, transitional and coastal waters, while lake water quality has become slightly worse. The quality of Ireland's marine and freshwater resources is of direct importance to the public and especially those that participate in water based recreational activity.

Inform Policy

This research demonstrates that the quality of surface water impacts on the public's water based recreational activity. There is a higher likelihood that waterway users visit waterway locations with a high quality levels to undertake their recreational activity; and additionally, that recreational trips of longer duration are associated with waterway sites that have high water quality levels.

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