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Spatial variation in the impact of dragonflies and debris on recreational ecosystem services in a floodplain wetland

Daniel R. Richards [a,c,*], Philip H. Warren [a], Helen L. Moggridge [b], Lorraine Maltby [a]

[a] Department of Animal and Plant Sciences, The University of Sheffield, Sheffield, UK
[b] Department of Geography, The University of Sheffield, Sheffield, UK
[c] Department of Geography, National University of Singapore, Singapore

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ABSTRACT

Recreation is an important ecosystem service. The interaction between people and habitat components is rarely considered in the analyses of recreational experiences, making it difficult to predict what people will experience. In this study we develop a modelling framework that describes three stages of interaction between people and habitats. This framework considers: (1) the distribution of habitat components in the environment, (2) the proportion of the available components that visitors notice, and (3) the net impact of multiple components on the quality of the recreational experience. The model was applied to a case study river floodplain, and was used to estimate visitor exposure to a combination of positive habitat components (dragonflies) and negative components (debris). The model provided an index of net impacts on experience quality that showed spatial variation across the floodplain, and this analysis highlighted areas that would deliver more positive experiences to visitors. The results of a sensitivity analysis indicated that neglecting the noticeability (observation rate) of habitat components resulted in different predictions. It is therefore important that the noticeability of habitat components is considered during analyses of recreational experiences, and recreational ecosystem service valuations.

1. Introduction

Habitats, with their abiotic and biotic components, provide key recreational ecosystem services (Hernández-Morcillo et al., 2013; Plieninger et al., 2013). It is therefore important to understand how recreational experiences may be affected by changes in habitat management (Arnberger and Haider, 2007; Christie et al., 2007; McCool, 2009; van Riper et al., 2011). Previous studies of recreational ecosystem services have focused on quantifying demand for components of habitats, for example by identifying the organisms and physical features that people want to experience (Westerberg et al., 2010). This understanding of people′s preferences can be used to suggest habitat components that could be enhanced to improve recreation (Bullock et al., 1998; Christie et al., 2007; Smyth et al., 2009), but knowing what people prefer is only the start; to manage habitats for recreation we also need to understand how likely it is that desirable habitat components will be supplied to visitors. In this study we quantify aspects of supply (abundance, spatial distribution, and noticeability) and recreational demand (public preference) in relation to two components of a floodplain habitat; debris items and odonates (dragonflies and damselflies). We integrate supply and demand information to provide an index of the net impact that these two habitat components have on a visitor′s recreational experience, in different locations within a restored floodplain habitat.

An individual′s recreational experience is affected by a range of factors including the physical environment, any activities that they undertake, their social interactions and individual psychology (Kaltenborn, 1997; Ballantyne et al., 2011). In this study we focus on the impacts of the physical and biological environment, by quantifying the presence and noticeability of habitat components that people experience (i.e. observe), and public preferences for these components. These data allowed us to create an index of the net impact of habitat components on the recreational experience, assuming that all other aspects of the recreational experience are held constant. While simplistic, this index of recreational impact may be useful in evaluating the potential outcomes of changes in habitat management, which commonly involve managing particular habitat components.

We outline a three-stage process that describes the impact that habitat components can have on visitor experience (referred to henceforth as the impact process). First, the potential impact is determined by the presence, abundance, and distribution of components in a habitat (Haines-Young and Potschin, 2007;

* Corresponding author.
E-mail address: d.r.richards@nus.edu.sg (D.R. Richards).

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Bastian et al., 2012). Second, a visitor will only observe a proportion of the potential habitat components, depending on the area that they visit, the timing and duration of their visit, their awareness of the habitat and the components that might be present in it, and the relative crypsis of the components that are present (Hull and Stewart, 1995; Hughes et al., 2005; Naidoo and Adamowicz, 2005). Third, particular habitat components will impact visitor experiences differently, depending on people′s preferences for them. Some habitat components will generally be positive (i.e. will enhance the quality of the experience), and some will be negative (i.e. will reduce it), and the net balance of all components that are noticed by the visitor will determine the impact on the overall quality of the recreational experience (Chenoweth and Gobster, 1990; Bullock et al., 1998; Dorwart et al., 2009).

Typically, previous research has not considered all three stages in our recreational impact framework and, in particular, has neglected the relationship between what is present in the environment and what people notice. Research has focused on characterising visitor preferences for habitat components (Hanley et al., 1998; Hoehn et al., 2003; Birol and Cox, 2007; Westerberg et al., 2010; Kenter et al., 2013), and has commonly used choice experiments to measure these preferences (Adamowicz et al., 1994; Hanley et al., 1998). Some studies have combined preference information with records of what people experience in the environment, through the use of on-site surveys, visitor employed photography (Dorwart et al., 2009; Nielsen et al., 2012) or stakeholder mapping exercises (Fagerholm et al., 2012; Plieninger et al., 2013), or by integrating preference studies with field data recorded from the perspective of a visitor (Naidoo, 2004; Naidoo and Adamowicz, 2005). Such combined methods can tell decision makers which habitat components people notice, and which are most desirable. However, these methods do not necessarily allow the desirable aspects of recreational experiences to be related to the state of the ecosystem. For example, in a study of forest recreational experiences (Nielsen et al., 2012) it is not clear whether participants took more photographs of “negative” dead wood items than “positive” dead wood because there were more examples present, because the examples were more noticeable, or because the items provoked a stronger participant response. To inform the management of recreational ecosystem services we need to be able to distinguish between the relative impacts of ecology (e.g. total species richness, abundance of key species) and aspects of human behaviour (e.g. trail routes, the presence of tour guides, hide infrastructure) in affecting visitor experiences (Naidoo and Adamowicz, 2005).

In this study we use the three-stage impact framework outlined above to model the relative impact of debris items and odonates on recreational experiences. The first stage in this framework is to model the spatial distribution of the habitat components that are of interest, in response to physical and ecological characteristics of the habitat. The second is to incorporate the noticeability of these habitat components to visitors. The third stage is to account for the relative preferences that people have for the habitat components. Combining these three stages allows us to estimate an index of impact on recreational experiences, and we apply this framework to model spatial variation in experience quality in a floodplain wetland case study.

Floodplain wetlands are an important recreational resource (Gren et al., 1995), and are commonly managed to enhance their recreational potential. Among the habitat components that can impact the visitor experience in wetlands, we analysed one positive and one negative component. Odonates (dragonflies and damselflies) and debris items (including both natural and man-made debris) were chosen as examples of positive and negative habitat components respectively, because they were expected to have contrasting impacts on visitor experiences and were known to be consistently present at the study site. Adult odonates are distinctive wetland organisms (Brooks and Lewington, 1997), and are attractive and popular, both with wildlife enthusiasts and in wider culture (Simaika and Samways, 2008; Lemelin, 2007, 2009). Debris accumulation is common in lowland river floodplains because buoyant items are carried in rivers and can be deposited during flooding (Williams and Simmons, 1999). Both natural (e.g. wood or vegetation) and man-made (e.g. food or drink containers) debris items are known to negatively impact the visitor experience in coastal (Tudor and Williams, 2003) and riverine (Williams and Simmons, 1999) habitats. These two habitat components, while not the only important aspects of visitor experience, provide relevant, contrasting, examples of components that people are likely to observe in floodplain wetland.

In this study we modelled spatial variation in the net impact of odonates and debris on recreational experience quality, to inform the management of visitors to the study floodplain. The net impact of odonates and debris on people′s experiences may be manipulated through the construction of footpaths or wildlife viewing sites, or improved signage to encourage people to visit particular areas. We applied the three-stage modelling framework described above to compare spatial variation in experience impact, and conducted a sensitivity analysis to assess the relative importance of each of the three stages of the framework in estimating the impact index.

2. Methods

2.1. Study site and chosen habitat components

The study site is located at Fishlake, near Doncaster in the United Kingdom (Fig. 1a; Latitude: 53.611239, Longitude: −1.002889). The curvilinear site is owned by the UK Environment Agency, and is bounded by the River Don to the south and a combined footpath and flood defence bank to the north (Fig. 1b). The floodplain receives inundation from the river through an engineered bank breach. The habitat in the study area is a mosaic of open water, marsh, and wet grassland. The standing water provides habitats for aquatic organisms, including dragonflies (Odonata: Anisoptera) and damselflies (Odonata: Zygoptera), while the periodical flood events bring debris items from the river and deposit them across the floodplain. Fishlake village has a population of less than 700, and visitors from further afield are rare (Richards, 2014). During more than 80 site visits between 2011 and 2013, it was common to encounter less than two people daily, with a high proportion of repeat visitors (Richards, 2014). Current visitors to the site are mainly dog walkers or people walking for personal exercise or relaxation. Despite the currently low number of visitors to the floodplain, recreation is a priority of the Environment Agency, and improvement works including car park construction have been carried out to attract visitors (Richards, 2014). Visitors can experience an open landscape with a wide field of view, and walking along the raised flood defence bank gives good views over surrounding agricultural land. Extensive mining waste heaps and several power station cooling towers are visible from the site, and a raised motorway runs within 500 m of the southern bank of the River Don (Richards, 2014). The floodplain provides habitat for common waterbird species and the site is grazed between April and November by a herd of cattle and ponies (Richards, 2014).

There is anecdotal local evidence to support the choice of odonates and debris as habitat components that impact recreation. Informal discussions with local visitors indicated that debris items were generally perceived negatively, and the Environment Agency routinely carry out debris collection to improve it for visitors

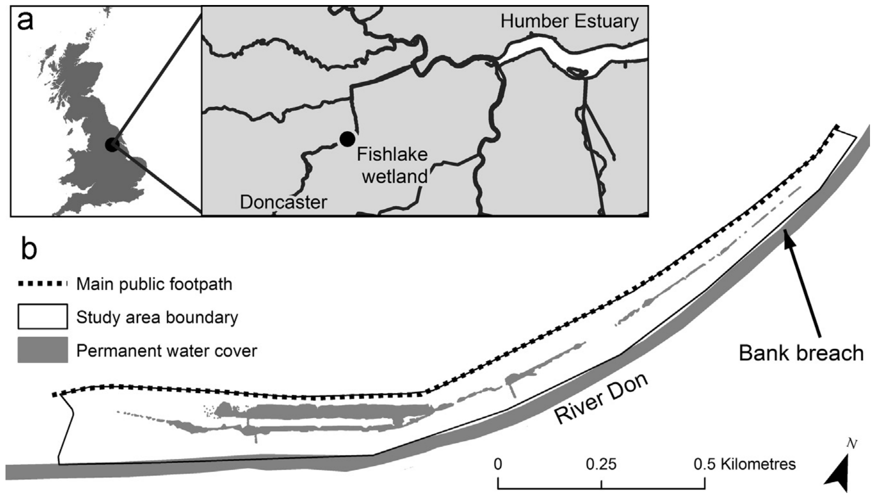

Fig. 1. Overview of study site: (a) location of Fishlake wetland in the Doncaster region and United Kingdom and (b) permanent water cover and location of footpath at the floodplain study area.

(Richard Jennings, Environment Agency; personal communication). Local visitors were aware of, and felt positive about, the occurrence of odonates at the site, and the cultural significance of their presence is recognised in the use of a dragonfly as the logo of a walking route that passes through the site (Richards, 2014). Odonates and debris items are appropriate indicators to use for analysis of experience over relatively small spatial scales, such as the within-site scale used here. They typically do not move rapidly over large distances, and exhibit small scale spatial variation in density (on the scale of a few metres) in response to local environmental factors. Visitor exposure to these habitat components was thus likely to vary in relation to their location in the site; this is less likely to be true of highly visible and mobile taxa such as cattle and waterbirds.

2.2. Three stage modelling framework

2.2.1. Spatial distribution of odonates and debris

The study floodplain was divided into 825 grid squares ("quadrats"), each of 400 m^2. The abundance of odonates and debris items was measured in a subset of one hundred quadrats that were chosen randomly with stratification across a gradient of flood exposure (these measurements are referred to as "quadrat surveys"). Odonates were sampled by a visual search conducted by one experienced surveyor at each quadrat on three days in August 2012 and three days during July–August 2013. Searches for odonates were limited in duration to one minute. Debris items (including both man-made and natural items) were counted on three occasions interspersed by periods of flooding: June 2012, August 2012 and May 2013.

Environmental data were collected over the entire floodplain area, so data were available for each of the quadrats. Hydrological and topographic variables were derived from a detailed site topographic map and time series of water level measurements that were collected over two years (between May 2011 and 2013), using the methodology described in detail in Richards et al. (2014). Under this methodology a high resolution (1 pixel $= 0.0625\ m^2$) topographic map was cross-referenced with measurements of the height of the standing water level (collected in the field using a global positioning system), to create a map of the extent of standing water on a given occasion. This sampling was conducted on 52 occasions over two years, providing an index of the frequency of inundation at every location in the floodplain. The hydrological dataset provided four environmental variables: the mean proportion of time that the area within the quadrat was flooded (flood exposure), whether or not there was a permanent area of standing water inside the quadrat (water body permanence), the distance from the water's edge at the highest recorded water level (distance from the high water mark), and mean topographic slope. In addition to these four variables, an index of the connectivity (flow distance) between each quadrat and the river (the closest flood entry point) was developed to estimate the likelihood of debris items being moved in by flowing water. A least-cost distance method was used to calculate this index; the minimum distance was calculated from the flood bank breach, and the cost surface was the proportional dryness of the floodplain over the survey period described above. The least cost distance of a quadrat is the minimum cumulative cost value that would be required to reach it from either of the bank breaches, with larger numbers indicating quadrats that were less connected to the river. An ordinal classification of vegetation height (vegetation height) was visually estimated for each quadrat using 5 categories (0 cm, 1–20 cm, 21–40 cm, 41–75 cm, 76+ cm).

To estimate the distribution of odonates and debris items across the whole floodplain, the environmental datasets were used as explanatory variables to model the abundance of odonates and quantity of debris in the 100 quadrats. The abundance of odonates and debris was modelled in response to different environmental predictor variables, depending on prior expectation of the environmental factors that might be important in determining their distribution. Odonate abundance was modelled in response to flood exposure, water body permanence and vegetation height. Debris quantity was modelled in response to flood exposure, flow distance, distance from the high water mark, vegetation height, and slope. Odonate abundance and quantity of debris were modelled as negative binomial responses using generalised linear mixed-effects models (GLMMs), with survey occasion included as a random effect to take account of temporal pseudoreplication (categorical variable, six occasions for odonate abundance, three occasions for debris quantity) (Skaug et al., 2006). These models were simplified following a stepwise procedure to minimise the Akaike Information Criterion (AIC) (Burnham and Anderson, 2002; Crawley, 2007). The resulting models of odonate abundance and debris quantity were then applied across the whole floodplain, to predict the distribution and density of odonates and debris across each of the 825 grid squares.

2.2.2. Observation rate of odonates and debris

At the same time as each quadrat survey for odonates or debris, the noticeability of the respective habitat components to visitors was measured by matched surveys from the nearest point of the main public footpath ("remote surveys"). The number of odonates or debris items that were observed from the footpath was recorded. The footpath surveyor searched by eye and focused entirely on the survey quadrat in which the quadrat surveyor was present.

The data from the remote surveys were used, in combination with those from the quadrat surveys, to model the noticeability of odonates and debris. The noticeability of debris items was modelled as the proportion of items present in a quadrat that were observed from the footpath. This was modelled as a binomial response within a GLMM, using vegetation height, distance between the quadrat and the footpath, and quantity of debris present in the quadrat as explanatory fixed effects, and survey occasion (categorical, three occasions) as a random effect (Skaug et al., 2006). The maximal model was then simplified stepwise using AIC as the criterion (Crawley, 2007). The data from the remote surveys indicated that the observation rate of odonates reduced rapidly with distance, to such an extent that it was practical to assume that the probability of observing an odonate from a distance greater than one quadrat (i.e. a 28 m diagonal length) was zero (see Section 3.1). It was therefore assumed that a visitor within a quadrat would experience all of the odonates that were present within it.

2.2.3. Public preferences for odonates and debris

The net experience provided by odonates and debris at a viewing site location was analysed using preference data from a choice experiment that was completed by The University of Sheffield staff and students. The survey was targeted at over 10,000 staff and students using an official electronic mailing list for volunteers. The targeted population included all undergraduate and postgraduate students, and all academic and support staff, excluding any who had previously unsubscribed from the list. Choice experiments are commonly used to evaluate people preferences for different habitat components (Adamowicz et al., 1994; Hanley et al., 1998), as they allow preferences for individual components to be measured and compared quantitatively. Quantitative measurements of preferences are a flexible tool for prediction because the impacts of multiple components, and different combinations of components, can be assessed and reported in terms of a net preference. Choice experiments are often used in economic analyses of recreational ecosystem services (Hanley et al., 1998), and are effective in describing trade-offs between different services (van Riper et al., 2011). This approach can also be applied to compare preferences in either dimensionless or non-monetary units.

In the choice experiment used in this study, participants were presented with pairs of hypothetical scenarios and were asked to choose the one which they would prefer to visit in each case. Each floodplain scenario varied in two characteristics: the quantity of debris present and the abundance of odonates present. Factor levels for both debris quantity and odonate abundance were based on the results of the quadrat surveys. Factor levels for debris quantity were 0, 30, 50 and 150 debris items, and for each photograph a realistic mixture of natural and man-made debris was used (4:1 natural to man-made). Factor levels for odonate abundance were 0, 1, 3, 5, 7 and 10 individuals. We used a simple design with only two choices per question to reduce participant fatigue, this is similar to many choice experiment studies in the ecosystem services valuation literature (Bullock et al., 1998; Christie et al., 2007). The factor levels were therefore arranged in a fully factorial design, resulting in 24 different sets of choices. No explicit opt-out option was given, but participants were informed that they were able to leave questions unanswered if desired. Participants were randomly assigned to one of two blocks of choice sets, so each participant answered 12 questions.

In the survey, debris quantity was represented as a fixed-view photograph of part of the study site in which the quantity of debris had been experimentally manipulated. Odonate abundance was represented separately as a numerical value shown below each question image, alongside a greyscale drawing of a damselfly (see Fig. 2 for an example choice set). A greyscale image was used to reduce the potential positive bias that may be encountered if a close-up colour photograph was used, as it is unlikely that a visitor in the field would experience odonates in such detail. Prior to beginning the survey participants were also shown some example photographs of debris aggregations at the study site. To give context, visitors were shown an introductory video that presented individuals of a common odonate species at the site (*Ischnura elegans*) as they would likely be viewed in the field.

The choice experiment survey was sent to over 10,000 potential participants via email, but it is not possible to gauge how many people noticed or read the message. The online survey was viewed by 532 people and was completed by 308 people, giving a

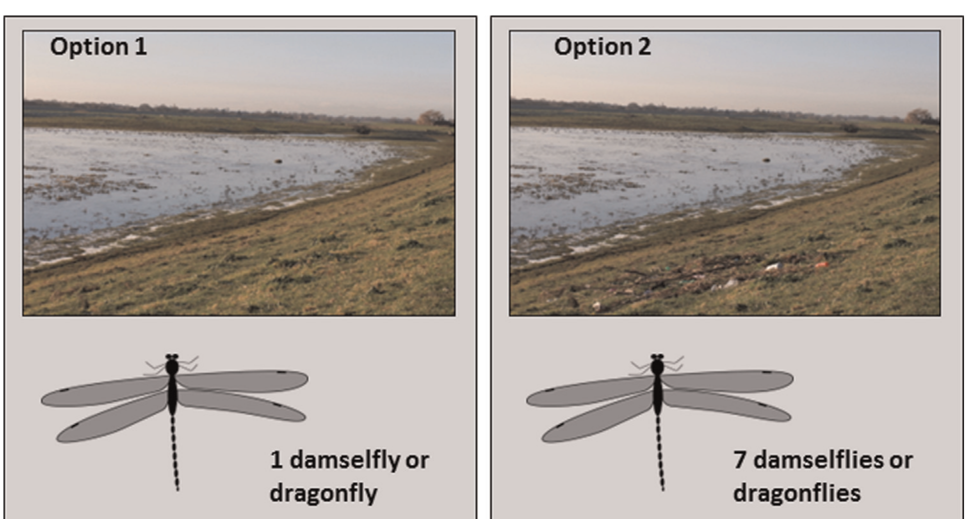

Fig. 2. Example choice set used in the online survey. Participants were asked to select whether they preferred Option 1 or Option 2. Please see the online version of this article for a colour version of this image.

completion rate of 58%. People with these biases are of greatest interest for this study, as they may be more likely to visit floodplains for recreation.

The relative preferences of participants for debris and odonates were modelled using a conditional logistic model (Therneau, 2013). Debris quantity, odonate abundance, and a quadratic term for odonate abundance were used as explanatory variables. A quadratic term for odonate abundance was used because the recreational benefits provided by habitat components commonly do not scale linearly but show diminishing returns (Rambonilaza and Dachary-Bernard, 2007). Relative preference was expressed using a "willingness-to-pay" index, but the aim was to characterise the net value of recreation in terms of odonates and debris, rather than in monetary terms. It was expected that the beneficial impact of odonates would be offset by the negative "cost" of seeing debris. In this case, the impact on recreational experience of seeing one odonate could be characterised as the number of debris items that a participant was willing to tolerate seeing. The number of debris items that a participant was willing to see in order to observe an odonate (referred to henceforth as the willingness to see debris) was calculated as the negative counterpart of the ratio $-n/m$ where n was the estimated coefficient of odonate preference (as estimated by the conditional logit model), and m was the estimated coefficient of debris preference (Aizaki, 2012). The negative n term was necessary to give a positive estimate of the number of debris items.

The willingness to see debris was used to calculate an "impact balance" for locations in the floodplain. The impact balance indicates the net impact of the odonates and debris observed, in units of debris. A more positive impact balance indicates an excess of odonates and therefore a more positive net visitor experience, while a more negative balance indicates a less positive impact on experience. To calculate the impact balance it was first necessary to know the maximum number of debris items that a visitor was willing to see, in order to see the number of odonates present in the grid square. This was calculated using

$$W = o \times m_o + o^2 \times m_p \tag{1}$$

where W was the willingness to see debris, o was the number of odonates present, m_o was the marginal willingness to see debris value for odonates, and m_p was the marginal willingness to see debris value for the odonate quadratic term. To calculate the net balance, this willingness to see debris was compared to the number of debris items that the visitor actually saw. The impact balance was thus quantified using

$$b = W - d \tag{2}$$

where b was impact balance, W was the willingness to see debris items, and d was the quantity of debris present.

The presence of odonates and debris items is temporally and spatially variable, so stochasticity was incorporated into the recreational impact model through a bootstrap method. For each bootstrap replicate, the odonate and debris abundance GLMMs were bootstrapped using a model-based (fixed –X) technique, with resampling stratified across survey dates (Fox, 2008). This created variability in the model coefficients, and therefore in the estimate of odonates and debris items on the floodplain. Stochasticity was not incorporated into the noticeability models because it was not possible to quantify temporal variability in odonate noticeability, so noticeability for both odonates and debris was assumed to be fixed across bootstrap replicates. The number of odonates and debris items present, and the number noticed at each viewing location were calculated for each of 300 bootstrap replicates, and the mean values of the 300 replicates were used to calculate impact balances when comparing different viewing sites.

2.3. Sensitivity analysis: the importance of considering all three stages in the experience process

The series of statistical models described above were combined to form an impact model that was used to simulate the relative quality of recreational experiences in different parts of the floodplain. We simulated experience impact at 200 locations which were spaced across a regular grid within the floodplain area. The model incorporated all three stages in the impact process, and is referred to throughout as the complete model. To compare the relative importance of each of the three stages in the experience process, three additional indicators that included only parts of the complete model were calculated. The first indicator only considered the spatial distribution of positive and negative components, and was quantified as the ratio of odonates to debris (odonates/debris) that were present within the same quadrat as the visitor (the distribution model). The second indicator combined distribution data with the relative preferences of visitors for odonates and debris, and was quantified as the debris balance of the odonates and debris that were present in the same quadrat as the visitor (the distribution and preference model). The final indicator considered the presence and noticeability of positive and negative components, but not the relative preferences of visitors for them. This was quantified as the ratio of odonates to debris (odonates/debris) that were noticed by the visitor from a given location (the distribution and noticeability model). These partial models of impact on recreational experience were run over the same set of bootstrap replicates as the complete model, so the same number of odonates and debris were always present on the simulated floodplain. The difference in relative performance between each of the partial indicators and the complete model indicator was analysed as the Spearman′s rank correlation coefficient (Spearman′s rho) between the two resulting impact balances. The statistical significance of this coefficient was not assessed because the number of test locations in the sample, and therefore the number of degrees of freedom available, was arbitrary.

2.4. Methodological limitations

The remote survey method may over-estimate the amount of debris noticed from the footpath by the average visitor, as it is likely that a member of the public would not observe the survey area in as much detail as the remote surveyor (Dallimer et al., 2012). However, the survey effort expended when sampling odonates and debris items was comparable, so this method can be applied to indicate the relative noticeability of these components. Alternative methods such as visitor surveys could have been used to more realistically quantify the numbers of odonates and debris that were observed from the footpath. However, such methods would not have allowed the actual number of odonates and debris present to be measured, because it would not have been possible to simultaneously survey the entire area within the visitor′s line of sight. It would therefore not have been possible to quantify the observation rate of these components. At some case study sites it may be possible to carry out an additional field survey of visitors to validate our method, but this was not feasible at Fishlake due to the low numbers of visitors to the site. Informal discussions with visitors suggested that qualitatively the patterns observed in the choice experiment were realistic; visitors perceived odonates and other wildlife positively, and the quantity of debris at the site was a common complaint.

The choice experiment sampled a population of University staff and students, including administrative, cleaning, and other support staff. This population is unlikely to be proportionally representative of the general public in terms of class, income, and education level. However, not all members of the public are equally likely to visit wetlands; the English Monitor of Engagement with the Natural Environment Survey indicates that members of the working and subsistence classes are less likely to frequently visit nature than members of the middle classes (Burt et al., 2013). We surveyed a University population due to practical constraints: choice experiments require large numbers of participants but there were few visitors to the site, and a large database of email addresses from the general public was not available.

3. Results

3.1. Distribution, noticeability, and preferences for odonates and debris items

Of the 100 quadrats surveyed, debris was present on at least one occasion at 95 quadrats, and odonates were present on at least one occasion at 79 quadrats. Odonate abundance was marginally significantly greater in quadrats that had more frequent flood exposure, and was significantly greater in quadrats that contained some permanent standing water, and that had taller vegetation (Table 1). The quantity of debris present within a quadrat decreased significantly with increasing flood exposure and vegetation height, and flow distance from the bank breach (Table 2). The majority of odonates (more than 95%) recorded within the quadrats were damselflies, most commonly *Ischnura elegans* and *Coenagrion puella*. Occasional *Calopteryx splendens*, and the dragonflies *Sympetrum striolatum* and *Anax imperator* were also observed. Approximately three quarters of the debris present in the quadrats was natural; mainly wood or riparian vegetation. The man-made debris that was observed comprised mainly plastic bottles, pieces of polystyrene or food wrappers.

Debris was observed from the footpath at least once at 87 of the 100 quadrats, and odonates were observed from the footpath at only two quadrats. The quantity of debris recorded as observed from the footpath was slightly greater than the actual quantity recorded within the quadrat on four occasions. This occurred at low levels of debris, and was likely due to misidentification of bare ground or floating foam as debris. In these instances the observed debris was recorded as the actual amount present in the quadrat, i.e. noticeability was recorded as perfect. The observation rate of debris increased significantly when there was a larger amount of debris present in a quadrat, and decreased significantly as the observer was further away (Table 3). It was not possible to model the noticeability of odonates statistically due to their very low observation rate, but odonates were unlikely to be visible from distances much greater than the 28 m diagonal length of a quadrat. The two recorded odonate sightings occurred at quadrats that were 3 and 30 m from the footpath, and were both sightings of *Anax imperator*, a large, rare, dragonfly species.

The choice experiment survey had 308 respondents. These participants showed a significant negative preference for floodplain scenarios with greater debris quantities (Table 4), and preference for odonates showed a significant quadratic relationship with increasing odonate abundance (Table 4). The willingness to see debris showed a concave quadratic relationship, plateauing at around eight odonates (Fig. 3). The observation of a single odonate was valued at 27 debris items (Fig. 3), which corresponds to an aggregation covering approximately 2.5 m^2.

Table 1
GLMM of odonate abundance in floodplain quadrats.

	Estimate	Std. error	*z*	*p*
Intercept	−1.231	0.328	−3.74	< 0.001
Flood exposure	0.011	0.005	1.89	0.058
Water body permanence	0.807	0.188	4.30	< 0.001
Vegetation height	0.230	0.064	3.59	< 0.001

Table 2
GLMM of debris quantity in floodplain quadrats.

	Estimate	Std. error	*z*	*p*
Intercept	2.993	0.330	9.04	< 0.001
Flood exposure	−0.031	0.004	−6.47	< 0.001
Flow distance from flood entry point	−0.007	0.002	−2.51	0.012
Vegetation height	−0.130	0.063	−2.06	0.038
Distance from high water mark	0.009	0.005	1.77	0.076

Table 3
GLMM of noticeability of debris items from the bank.

	Estimate	Std. error	*z*	*p*
Intercept	1.95	3.364	0.58	0.56
Distance from footpath	−0.146	0.028	−5.16	< 0.001
Number of debris items present	0.072	0.012	6.2	< 0.001

Table 4
Conditional logit model of relative preferences of survey participants for debris and odonates.

	Estimate	Std. error	*z*	*p*
Alternative specific constant	−0.43	0.058	−7.49	< 0.001
Debris quantity	-0.03	< 0.01	−29.40	< 0.001
Odonate abundance	0.87	0.04	19.93	< 0.001
Odonate abundance squared	−0.05	< 0.01	−12.56	< 0.001

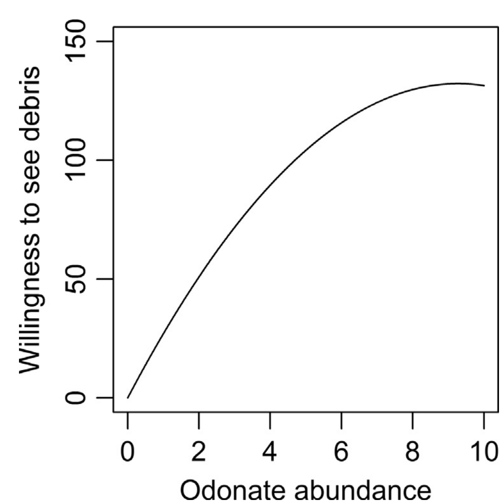

Fig. 3. Willingness to see debris for increasing abundances of odonates (units are number of debris items that participants were willing to see).

3.2. Spatial variation in the impact of odonates and debris on recreational experiences

The bootstrap simulations estimated the abundance of odonates and quantity of debris that were present across the whole study area, and using this method an average of 868 odonates and 6674 debris items were estimated to be present in the study floodplain during any one visit by a member of the public. The complete model of impact on recreational experiences estimated that the net impact balance experienced at the 150 locations

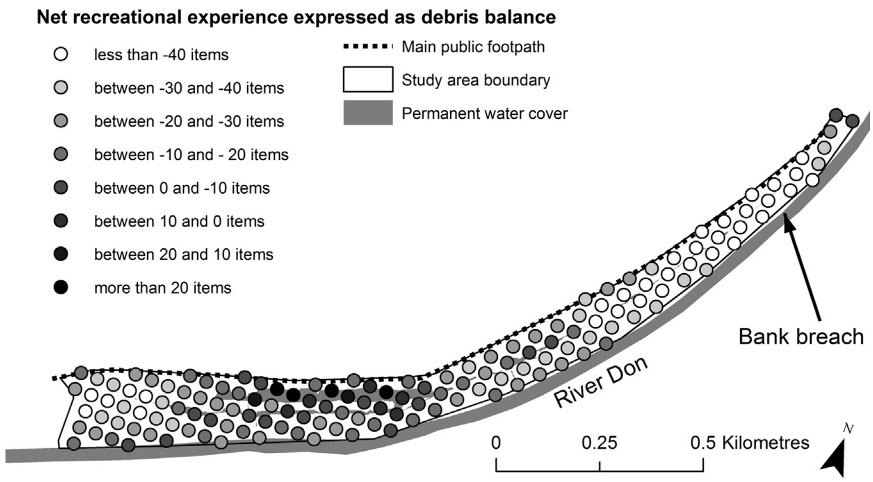

Fig. 4. Net visitor recreational experience expressed as debris balance for each of 150 floodplain locations. More positive values indicate more positive recreational experiences.

would vary between approximately −57 and 27 items, with a mean of −21 items (negative numbers indicate net negative impacts, and positive numbers indicate net positive impacts). The most positive impacts on recreational experiences were delivered in areas that were within or close to larger water bodies, and were distant from the flood entry point (Fig. 4).

3.3. Sensitivity analysis

The performance of the partial models of impacts on recreational experience was assessed by comparison with the complete model. The predictions from the distribution model were the most different from those of the complete model (Spearman′s rho = 0.57). The distribution and preference model also gave considerably different results to the complete model (Spearman′s rho=0.65), and the predictions from the distribution and noticeability model best matched those made by the complete model (Spearman′s rho=0.95).

4. Discussion

This study analysed the relative impacts that two habitat components can have on recreational experiences. It integrated an understanding of the physical and ecological factors that explained the distribution of odonates and debris, the noticeability of these components to visitors, and visitor preferences for the two components. This framework enabled the net impact on recreational experience delivered by odonates and debris to be predicted at a high spatial resolution within the study floodplain. The net impact balance is not an absolute measure of recreational quality, but an index that allows a number of management options to be compared objectively. In the study site, the most positive impacts on experiences were delivered in wetter areas which were further from the bank breach, because in these areas interaction with odonates was most likely, and exposure to debris was reduced. This detailed knowledge could inform management, as visitor behaviour could be manipulated to encourage interaction with optimal areas of the site (Orams, 1996; Reynolds and Braithwaite, 2001; McCool, 2009), for example through the construction of a series of viewing platforms or alteration of the footpath route (Reynolds and Braithwaite, 2001; Suh and Samways, 2001). To make spatially detailed estimates of the impacts on experiences provided by a habitat, an understanding of all three stages of the impact process is required. This study provides a novel framework for considering the interaction between people and the environment when analysing the provision of recreational experiences.

The noticeability of habitat components impacts visitor recreational experiences, because noticeability affects the interaction between visitors and the environment. Odonates were rarely observed from the footpath because of their small size and cryptic behaviour (Brooks and Lewington, 1997) and, as a result, the interaction between visitors and odonates was limited. In contrast, debris items were noticeable from the footpath even at considerable distances, probably because they formed aggregations (Storrier et al., 2007) that contrasted in colour with the background landscape (Bishop and Miller, 2007). The differential observation rate of odonates and debris had an impact on the habitat components that a visitor was likely to interact with, and therefore on the quality of recreational experiences.

The partial models of recreational impact that did not consider the noticeability of habitat components (the distribution model, and the distribution and preference model) gave very different results when compared to the complete model. This suggests that the different observation rate of odonates and debris had a relatively large impact on visitor recreational experiences. When the noticeability of habitat components is not considered explicitly during analysis then it is assumed to be equal, and in the case of the distribution and preference model it was assumed that the noticeability of both odonates and debris was very low. This assumption resulted in an underestimate of the quantity of debris that visitors were exposed to. The error in estimating recreational experience quality based on habitat component distribution data and preference information indicates that there is a risk in combining preference data with habitat descriptions of sites or regions, as is commonly done in benefit transfer valuations of ecosystem services (Troy and Wilson, 2006; Liu et al., 2010). Valuations derived through applications of benefit transfer that use the occurrence, rather than experience, of habitat components may not accurately represent the true recreational value because while habitat components have some existence value (Sutherland and Walsh, 1985; Pate and Loomis, 1997), much of their recreational value comes from being directly experienced by people (Green and Elmberg, 2014). In studies of benefits that accrue through direct experience, it is important to use data that represent the likely experiences of actual visitors, rather than the potential of the components present in the habitat, in order to minimise the chance of under- or overestimating recreational value. It may be possible to ignore noticeability when comparing habitat components that are similarly noticeable to visitors, because the ratio of what is present will be similar to the ratio of what people will experience. However, cases like the example presented here, where the noticeability of habitat components was very different, are likely to be common.

Although the combined distribution and noticeability model of recreational experience performed well in relation to the complete model, there were subtle differences in its predictions. These differences were a result of the nonlinear relationship between people's preferences for these components (Fig. 3). When the preference relationship between positive and negative habitat components is nonlinear, the actual visitor experience must be estimated as accurately as possible, because the absolute quantity of the habitat components will affect the balance between them. For example, the net impact balance if one odonate and one item of debris were experienced would be 26 (a net positive experience). This is very different to the net balance if 10 odonates and debris items were experienced, which would be 121. The net recreational impact of odonates and debris would thus be different; even though the ratio of odonates to debris in each case would be the same. Such nonlinear preference relationships are likely to be common between different habitat components because many habitat components are perceived more positively because of their rarity; they have a novelty value (Moscardo and Saltzer, 2004; Hughes et al., 2005). Increasing numbers of similar habitat components can give diminishing aesthetic returns as people become accustomed to seeing them (Rambonilaza and Dachary-Bernard, 2007), although variation within the habitat components (e.g. different species of odonates) may help to maintain visitor interest. There are advantages to using a preference relationship to estimate the net impact of habitat components on recreational experience in cases where more than two habitat components are compared simultaneously. For example, the relative preference for different habitat components can be used to summarise the impact of multiple, positive and negative habitat features as a net recreational experience balance. Preference relationship methods can additionally be used to calculate an economic value for the recreational value of habitats or habitat improvements, if desired (Carson and Mitchell, 1993; Hanley et al., 1998; Westerberg et al., 2010).

The three stage framework outlined in this study does not represent the entire complexity of recreational experiences, such as the longer-term emotional, behavioural and cultural impacts of experiences in nature (Kaltenborn, 1997; Ballantyne et al., 2011). However, the net impact balance of habitat components provides an objective indicator of recreational quality that is suitable for application to habitat management decision making at local spatial scales. The framework applied in this case study is flexible and could be applied to management problems that consider larger numbers of habitat components in any habitat type, or that involve physical or ecological habitat modification. Additionally, human variation in awareness or preferences for habitat components could be incorporated, to assess the recreational experiences of different socioeconomic or visitor groups (Birol et al., 2006; Kenter et al., 2013).

A potential constraint with the framework presented in this study is that it required a large amount of data, as it combined a traditional choice experiment with field sampling that was more intensive than a visitor participation exercise. However, future applications of the three stage framework may be able to utilise existing data. The habitat preferences of some taxa that are of interest to the public have previously been described in detail (Buckton and Ormerod, 1997; Besnard et al. 2013), and at many sites the distributions of key species are known (Ross-Smith et al., 2011). The noticeability of organisms and landscape features is relatively straightforward to quantify through field surveys, and when data collection is not feasible it may be possible to make assumptions about noticeability, as was necessarily done for odonates in this study. At larger spatial scales, the interaction of visitors with larger habitat or landscape components such as mountains or woodlands can be estimated using viewshed analyses (van der Horst, 2006). Quantification of the relative preferences of the public for a range of habitat components is a considerable challenge, as designing and conducting choice experiments, particularly for complex designs involving large numbers of habitat components, requires a large participant base and can be time consuming (Johnson et al., 2013). However, such choice experiments have previously been conducted in a range of habitat types including wetlands (Hoehn et al., 2003; Westerberg et al., 2010), and forests (Hanley et al., 1998; Naidoo and Adamowicz, 2005), so applicable preference data may already be available in the literature. Alternatively, other indices of popularity, such as Google search volume (Żmihorski et al., 2013) taxa rarity (Tournant et al., 2012), or qualitative methods such as focus group studies (Moran et al., 2007) or expert knowledge (Strager and Rosenberger, 2006) could be used to estimate the relative preference of the public for habitat components.

5. Conclusions

To manage habitats for recreational ecosystem services we should not only maintain and protect habitat components that are of interest, but also provide opportunities for visitors to interact with them (McCool, 2009). To predict the impacts of the environment on recreation, and inform management at fine spatial scales, it is necessary to understand the interaction between visitors and habitat components. It is important to consider the noticeability of habitat components when considering the supply of habitat components to visitors, because noticeability plays a key role in determining the subset of available components that visitors interact with, and consequently their net recreational experience. Noticeability should therefore be considered during analyses of recreational ecosystem services. The three stage framework for analysing impacts on recreational experiences presented in this paper considered the noticeability of habitat components to visitors, and this allowed estimates of their net impact on visitor experience to be made. These estimates were made at a sufficiently detailed spatial scale to allow on-site management planning, such as the design of footpath routes or signage to create wildlife viewing areas. Future studies of recreational experiences should consider the noticeability of habitat components, and could utilise the modelling framework outlined in this study. This framework is applicable to other habitat types and management problems, and could be extended to include more complex combinations of habitat components and variability among visitors.

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