Ecological Indicators 26 (2013) 5–13

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Review and quantitative meta-analysis of diet suggests the Eurasian otter (*Lutra lutra*) is likely to be a poor bioindicator

Neil Reid[a,*], Danielle Thompson[a], Brian Hayden[a,b], Ferdia Marnell[c], W. Ian Montgomery[d]

[a] Quercus, School of Biological Sciences, Queen's University Belfast, Belfast BT9 7BL, UK
[b] University of Helsinki, Kilpisjärvi Biological Station, Faculty of Biological and Environmental Sciences, Viikinkaari 9, Helsinki, Finland
[c] National Parks & Wildlife Service, Department of Arts, Heritage and the Gaeltacht, 7 Ely Place, Dublin 2, Ireland
[d] School of Biological Sciences, Queen's University Belfast, Belfast BT9 7BL, UK

ARTICLE INFO

Article history:
Received 21 June 2012
Received in revised form 12 October 2012
Accepted 17 October 2012

Keywords:
Dietary analysis
Percentage frequency and occurrence
Aquatic ecosystems
Eutrophication
Salmonids
White-clawed crayfish

ABSTRACT

The Eurasian otter (*Lutra lutra* L.) is a top predator in aquatic systems and plays an important role in ecosystem functioning. However, it has undergone dramatic declines throughout Europe as a result of environmental degradation. We examine the putative role of the otter as a bioindicator in Ireland which remains a stronghold for the species and affords a unique opportunity to examine variation in its ecological niche. We describe diet, using spraint contents, along rivers during 2010 and conduct a review and quantitative meta-analysis of the results of a further 21 studies. We aimed to assess variation in otter diet in relation to river productivity, a proxy for natural nutrification and anthropogenic eutrophication, and availability of salmonid prey (*Salmo trutta* and *Salmo salar*), to test the hypothesis that otter diet is related to environmental quality. Otter diet did not vary with levels of productivity or availability of salmonids whilst Compositional Analysis suggested there was no selection of salmonid over non-salmonid fish. There was a distinct niche separation between riverine and lacustrine systems, the latter being dominated by Atlantic eel (*Anguilla anguilla*). Otters are opportunistic and may take insects, freshwater mussels, birds, mammals and even fruit. Otters living along coasts have a greatest niche breath than those in freshwater systems which encompasses a wide variety of intertidal prey though pelagic fish are rarely taken. It is concluded that the ability of the otter to feed on a wide diversity of prey taxa and the strong influence of habitat type, renders it a poor bioindicator of environmental water quality. It seems likely that the plasticity of the habitat and dietary niche of otters, and the extent of suitable habitat, may have sustained populations in Ireland despite intensification of agriculture during the 20th century.

1. Introduction

The Eurasian otter is a species of conservation concern and high priority having suffered major declines in its range and population throughout Europe since the 1950s (Macdonald and Mason, 1986). It is classified as 'near threatened' by the IUCN Red List with a decreasing population trend and, as such, is listed in Appendix 1 of CITES, Appendix II of the Bern Convention (Council of Europe, 1979) and Annexes II and IV of the 'EC Habitats & Species Directive' (92/43/EEC). The otter is a top predator in many European freshwater systems and thus has an important role in ecosystem functioning. Otter population density, seasonality of breeding, reproductive success, carrying capacity, foraging behaviour and local rates of mortality may be linked to prey availability (Ruiz-Olmo et al., 2001) and, hence, reflect the overall status of an ecosystem (DETR, 2001).

Otter population declines in continental Europe and Great Britain were linked to the bioaccumulation of pesticides, namely polychlorinated biphenyl or PCBs (Mason and Wren, 2001). Consequently, otters have been suggested as 'sentinel species' for the diversity and dynamics of pesticides in aquatic food webs (Lemarchand et al., 2011). River habitats also underwent major changes during the 20th century due to landscape-scale intensification of surrounding agriculture resulting in the alteration of water chemistry (eutrophication), destruction of riparian habitat (Gutleb and Kranz, 1998; Kruuk, 1995) and introduction of alien invasive species (Leppakoski et al., 2002). More widely the otter has been suggested as a 'bioindicator' of water quality reflecting the diversity of macroinvertebrate and fish communities due their perceived susceptibility to pollution (Lunnon and Reynolds, 1991; Ruiz-Olmo et al., 1998).

Ireland is a stronghold for the otter in Europe. Incidence of tracks and signs at survey sites was as high as 91.7% throughout Ireland

* Corresponding author. Tel.: +44 028 9097 2281.
E-mail address: neil.reid@qub.ac.uk (N. Reid).

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http://dx.doi.org/10.1016/j.ecolind.2012.10.017

during the early 1980s (Chapman and Chapman, 1982). Recent surveys in Northern Ireland suggest equally high levels of occurrence at 88.6% of sites surveyed during 2010 (Preston and Reid, 2011). It remains unclear why otters in Ireland have been largely unaffected by changes in water quality and landscape ecology compared to those in other parts of Europe which have declined substantially and remain low. This paper provides recent data on the diet of otters living along rivers in Ireland during 2010 and combines these with published data in a meta-analysis examining between- and within-habitat variation. We aimed to assess variation in otter diet in relation to river productivity, a proxy for natural nutrification and anthropogenic eutrophication, and availability of salmonids and other prey, to explicitly test the hypothesis that otter diet is related to environmental quality.

2. Methods

2.1. Spraint collection and analysis

The National Otter Survey of Ireland 2010/12 involved an assessment of otter incidence at 872 sites throughout the Republic of Ireland (Reid et al., 2012). Otter spraints were recorded using the 'Standard Otter Survey' method (Lenton et al., 1980). Where present, spraints were collected and stored. A subsample of 192 spraints was selected at random from sites on rivers and their contents analysed for comparison with previous studies. Spraint analysis followed the standard methodology described by Conroy and Chanin (2005).

2.2. Productivity and fish biomass

The productivity or trophic status of rivers throughout Ireland was defined by their levels of orthophosphate following the methods of O'Neill (2008). Rivers were defined as low productivity = 0.00–0.02 mg l^{-1}; intermediate productivity = 0.02–0.04 mg l^{-1} and high productivity >0.04 mg l^{-1}. Measurements of orthophosphate were derived from 1459 sites throughout Ireland from 2008 to 2010 monitored by the Environmental Protection Agency (EPA) in the Republic of Ireland.

Fish biomass data were obtained from Inland Fisheries Ireland at 77 electrofishing sites throughout the Republic of Ireland. Stretches of riffle habitat were surveyed from 2008 to 2010 and the biomass of each species of fish recorded. Electrofishing of riffle habitat is designed for monitoring salmonid abundance (most notably Atlantic salmon *Salmo salar*) and is likely to underrepresent many species associated with cover, for example, pike *Esox lucius*. Therefore, only Salmonid and non-Salmonid biomass were retained for analysis rather than individual species-level data.

2.3. Literature review

All previous studies published on otter diet in Ireland were reviewed ($n = 21$). Publications were located using the search term "otter diet and Ireland" on the Web of Knowledge (http://wok.mimas.ac.uk). Studies described diet using a variety of well-established metrics. Total weight or bulk (usually dry mass of remains) or estimated biomass (extrapolated wet weight) were reported by very few studies. Percentage *frequency* (% of identified prey items) and percentage *occurrence* (% of spraints containing prey) were the most commonly reported descriptors. Percentage frequency data are vulnerable to bias as the incidence of small bony species, such as the three-spined stickleback *Gaterosteus aculeatus*, is likely to be over-represented compared to large fleshy fish, such as salmonids of which fewer bones are likely to be ingested (Wise et al., 1981; Ward et al., 1986). Therefore, most authors advocate percentage occurrence data as the most useful metric as this produces an accurate rank order for prey categories and is the most utilitarian metric for the purposes of comparison (Carss and Parkinson, 1996; Jacobsen and Hansen, 1996; Wise et al., 1981). Studies typically reported results in tabular form summarised by 'Site' (rivers, catchments, River Basin Districts or, in some cases entire regions, for example Northern Ireland). Variance in the metadata, therefore, was constrained by the varying definition of 'Site'.

2.4. Statistical analyses

Descriptive statistics were used to summarise percentage frequency ±95% confidence limits of each prey category for those studies that were predominately riverine. The mean percentage frequency of each prey category was compared to that obtained from spraints analysed during 2010 using a *G*-test of association.

Spatial data that were missing for productivity (orthophosphate mg l^{-1}) and salmonid biomass (kg/m^2) were interpolated throughout the Republic of Ireland using the Kriging tool in Spatial Analyst for ArcGIS (ESRI, CA, USA). A Multiple Analysis of Variance (MANOVA) was used to examine variation in percentage frequency from spraints analysed during 2010 by fitting all prey categories as a group of dependent variables, River Basin District (describing regionality) as a fixed factor, and productivity and salmonid biomass as covariates. Compositional analysis (Aebischer et al., 1993) was conducted using the 'Compositional Analysis Add-In Tool' for Excel 2002 (Version 4.1; Peter Smith, Wales, UK) to assess the degree of prey selectivity by otters by comparing the proportion of salmonid and non-salmonid fish available (expressed as percentage of biomass) and the proportion used (expressed as percentage frequency in spraints). Wilk's lambda (Λ) was used in both the MANOVA and compositional analysis to test significance ($p < 0.05$).

A meta-analysis was performed on percentage occurrence data reported by previous studies using Discriminant Function Analysis (DFA). Prey categories were fitted as a single group of independent variables and habitat (riverine, lacustrine and coastal) as a fixed factor. Niche separation between freshwater habitats (riverine and lacustrine) was illustrated by plotting the frequency distribution of values on the Discriminant Function Axis that partitioned variance between these habitats most clearly. Descriptive statistics were used to summarise the percentage occurrence ±95% confidence limits of each prey items within each habitat.

3. Results and discussion

3.1. Riverine diet

Eleven studies (52.4%) out of the 21 reviewed provided percentage *frequency* data which summarised the analysis of 4854 spraints from 48 river sites throughout Ireland when combined with the results from the current study during 2010. Generally, the otter is considered as a 'fish specialist' (Mason and Macdonald, 1986) and the composition of spraints from previous studies in Ireland typically consisted of 69.1% fish of which salmonid fragments were most abundant, accounting for 24.5% of items identified (Table 1). Eel *Anguilla anguilla* (14.8%) and three-spined stickleback (10.5%) also represented substantial quantities of the fragments in spraint. Some studies suggest that sticklebacks may be overlooked as an important part of the diet but in some cases their remains can be found in up to 50% of spraints accounting for almost a quarter of dietary fragments identified (Preston et al., 2006a). However, stickleback abundance shows substantial spatio-temporal variation and they may also be ingested incidentally when consuming the stomachs of salmonids rather than being preyed upon directly (O'Neill, 1995).