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National Otter Survey of Ireland 2010/12

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National Otter Survey of Ireland 2010/12

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Executive Summary

The EC Habitats Directive requires that changes in the conservation status of designated species are monitored. Nocturnal and elusive species are difficult to count directly and thus population trajectories are inferred by variation in the incidence of field signs. Presence/absence techniques are, however, vulnerable to Type II errors (false negatives).

The Eurasian otter (*Lutra lutra*), listed by the IUCN as 'near threatened', is monitored throughout Europe using the 'Standard Otter Survey' method. We explored the reliability of this approach by analysing species incidence throughout Ireland.

Naïve species incidence (i.e. that recorded in the field) was 63.3% [95%CI 60.0 - 66.4%] with variation affected significantly by District Conservation Officer (DCO) survey teams and, at running freshwater sites, the number of bridges present and rainfall during the month, and most notably during the 7 days, prior to survey. Rainfall had no affect at static freshwater sites or the coast. After statistical correction for sources of bias and error, otter incidence was estimated at 93.6% [95%CI 79.0 – 97.1%].

The known range of the otter increased by 31% from 1993-2006 to 2007-11. The population estimate of 7,800 [95%CI 7,200 – 10,200] breeding females during 2010/11 was not significantly different from that established as a baseline. Modelling of species-habitat associations suggested that available habitat was not limiting and no putative pressures recorded at survey sites negatively impacted species occurrence. Thus, under the statutory parameters for assessing a species' conservation status, i.e. *range*, *population*, *habitat* and *future prospects*, the otter was judged to be in Favourable or 'Good' status. Any apparently improving trend from the previous 'Poor' status (NPWS, 2008) was due to improved knowledge and more accurate data rather than a real temporal trend.

Rapid Assessment Surveys conducted between National surveys provided greater survey effort within specific hydrometric areas (catchments). Neverthless, sample sizes were typically <100 sites which provided poor levels of statistical confidence (typically <20% power) in detecting a 10% decline over time whilst it was difficult to decern appreciable spatial variation between catchments.

We demonstrate that bias and error in binary wildlife surveys can have a major impact on conservation assessments. Our results provide empirical evidence for further criticisms of the Standard Otter Survey method calling into question its value in monitoring changes in otter populations throughout Europe.

We also examined the putative role of the otter as a bioindicator in Ireland and described its diet, using spraint contents, along rivers during 2010 whilst conducting a review and quantitative meta-analysis of the results of a further 21 studies. Otter diet did not vary with levels of productivity or availability of salmonids. There was distinct niche separation between riverine and lacustrine systems, the latter being dominated by Atlantic eel (*Anguilla anguilla*). Otters were opportunistic and took 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 was 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.

Two peer-reviewed papers have been published and another has been submitted for review as a direct consequence of this project:

a) Reid, N., Lundy, M.G., Hayden, B., Lynn, D., Marnell, F., McDonald, R.A. & Montgomery, W.I. (2013) Detecting detectability: identifying and correcting bias in binary wildlife surveys demonstrates their potential impact on conservation assessments. *European Journal of Wildlife Research*. DOI: 10.1007/s10344-013-0741-8

b) Reid, N., Thompson, D., Hayden, B., Marnell, F. & Montgomery, W.I. (2013) Review and meta-analysis suggests of diet suggests the Eurasian otter (*Lutra lutra*) is likely to be a poor bioindicator. *Ecological Indicators*, 26: 5-13. DOI: 10.1016/j.ecolind.2012.10.017.

c) Reid, N., Lundy, M.G., Hayden, B., Waterman, T., Looney, D., Lynn, D., Marnell, F., McDonald, R.A. & Montgomery, W.I. (*under review*) Covering over the cracks in conservation assessments at EU interfaces: a cross-jurisdictional ecoregion scale approach using the Eurasian otter (*Lutra lutra*). *Ecological Indicators*.

Recommendations for future monitoring protocols are discussed.

Acknowledgements

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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 & Mason, 1994). 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 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 & Wren, 2001). Consequently, otters have been suggested as a '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 & 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 & Reynolds, 1991; Ruiz-Olmo *et al*., 1998).

Molecular studies of Irish otter populations suggest a high level of genetic diversity in comparison with the rest of Europe, attributed to multiple colonization events and their comparatively stable demographic history i.e. no genetic bottlenecks caused by rapid population collapses (Finnegan & O'Neill 2009). Thus, Ireland remains a stronghold for the otter. Incidence of tracks and signs at survey sites was as high as 91.7% throughout Ireland during the early 1980s (Chapman & Chapman, 1982). Recent surveys in Northern Ireland suggest equally high levels of occurrence at 88.6% of sites surveyed during 2010 (Preston & 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 remained low.

1.1 Species biology and ecology

Freshwater and coastal habitats are used, but otters utilizing the marine environment apparently require access to freshwater habitats to drink and bathe. Local-scale habitat and broad-scale landscape parameters interact to influence site occupancy (Lundy & Montgomery, 2010). Previous studies suggest that otter occurrence is negatively associated with altitude, urbanization, bank height, water depth and bankside vegetation density whilst being positively associated with channel width leading to regional variation in occurrence between River Basin Districts (Bailey & Rochford, 2006). Whilst there is a general perception that otters are negatively affected by poor water quality, there has been little published evidence demonstrating any consistent relationship with pollution or human disturbance (Mason & Macdonald 1986; Delibes *et al.* 1991; Bailey & Rochford, 2006).

In Ireland, the territory of female otters in mesotrophic rivers (i.e. those with an intermediate level of productivity) is approximately 7.5 ± 1.5km in length (Ó Néill *et al.* 2008) and 6.5 ± 1.0km in coastal environments (de Jongh *et al*. 2010). The territory of male otters in mesotrophic and oligotrophic rivers (i.e. those with a low level of productivity), is approx. 13.2 ± 5.3km in length with a high degree of variability as territorial males respond quickly to social perturbation (O'Neill *et al.* 2008). Territorial marking typically occurs by means of sprainting or anal secretions. These marks are left mostly at features such as bridge footings, boulders, grass tussocks and stream confluences. An otter usually maintains numerous resting sites with its territory; these can be hidden refuges above ground (couches), or under-ground chambers (holts) (Kruuk 1995; Mason & McDonald 1986). The rearing of cubs occurs within 'natal holts', which are not marked by spraint. Although capable of breeding at any time of the year, a peak in breeding occurs during the summer and early autumn (Heggberget & Christensen 1994; Kruuk 1995). It is expected, therefore, that territories are likely to be more stable at this time of year in contrast to when young are dispersing and males are searching for females. Therefore, changes in sprainting behaviour may be seasonal (Kruuk *et al.* 1986).

Otters are principally piscivorous relying predominantly on salmonids (*Salmo trutta* and *Salmo salar*) but also eel (*Anguilla anguilla*). Otters, however, are not limited to fish and prey opportunistically on a range of prey sources where available (Gormally & Fairley 1982; Kruuk &

Moorhouse 1990; Carss 1995). Frogs are frequently eaten whilst invertebrates (crayfish), birds and small mammals are also taken (Chanin, 2003, cf. Bailey & Rochford, 2006).

1.2 Threats to otter populations

The National Parks & Wildlife Service's Threat Response Plan for the Otter (NPWS, 2009), a review of and response to the pressures and threats to otters in Ireland, categorized three principal risks: i) habitat destruction and degradation; ii) water pollution; and, iii) accidental death and/or persecution. Otters can be impacted by illegal snares, often set for foxes (*Vulpes vulpes*); for example, during a radio-tracking study of five male otters, two (40%) were caught and killed (Ó Néill, 2008). This has obvious, direct effects on individual otters but resulting territorial perturbation potentially impact populations locally, regionally and nationally. Conservation efforts should strive to minimize the further loss of semi-natural habitats at the landscape-scale, reduce the impacts of development and intensive agricultural practices and improve local-scale habitat diversity around riparian corridors (Lundy & Montgomery, 2010).

The historic decline of European otter populations coincided with the introduction and population expansion of invasive American mink (*Neovison vison*). Both species have been shown to utilise similar habitats (Green *et al.* 1984). Competition between otter and mink appears greatest at the northern extent of the otter's European range, where colder winters with snow cover, limit access to terrestrial prey by mink, inducing greater competition between the two species for aquatic prey (Erlinge 1972). However, initial suspicions that competition between the otter and mink was a primary cause of observed declines in otter occurrence throughout Europe, appear unfounded, given more recent evidence that the otter and mink can co-exist (Erlinge, 1972; Clode & Macdonald, 1995). Indeed, there is some evidence that strong and/or recovering populations of otter may limit mink populations (McDonald *et al.* 2007).

1.3 Associated habitats

The otter, being widespread, occurs in many habitats. Annex I of the Habitats Directive lists at least 19 habitat types or sub-types that occur in Ireland with which otters may be associated (Table 1).

Table 1 *EU Annex I habitats with which otters may be associated.*

#	EU Habitats Directive Code	Description
1	1130	Estuaries
2	1140	Tidal mudflats and sandflats
3	1150	Coastal lagoons
4	1160	Large shallow inlets and bats
5	1170	Reefs
6	1310	Saltmarsh habitats
	1320	*Spartina swards*
	1330	*Atlantic salt meadow*
	1410	*Mediterranean salt meadows*
	1420	*Halophilous scrub*
7	2100	Sand dune habitats
	2120	*Marram dunes*
	2130	*Fixed dunes*
	2140	*Decalcified empetrum dunes*
	2150	*Decalcified dune heath*
	2170	*Dunes with creeping willow*
	2190	*Humid dune slacks*
	21A0	*Machair*
8	3110	Lowland oligotrophic lakes
9	3130	Upland oligotrophic lakes
10	3140	Hard water lakes
11	3150	Natural euthrophic lakes
12	3160	Dystrophic lakes
13	3180	Turloughs
14	3260	Floating river vegetation
15	3270	Chenopodion rubri
16	7140	Transition mires
17	7210	Cladium fens
18	7230	Alkaline fens
19	91E0	Alluvial forests

1.4 Sources of bias and error in otter surveys

Surveillance of wild animal populations is notoriously problematic due to the difficulty in detecting individuals directly and the associated costs of surveying remote areas or rough terrain (Aing *et al.* 2011). For nocturnal and elusive species, researchers frequently sacrifice quantifying abundance and concentrate on determining patch occupancy (Gese 2001). Consequently, indirect survey methods that record species presence using tracks, faeces or scent markings have become standard protocol for many species (Heinemeyer *et al.* 2008). These have comparatively low costs and, therefore, are widely used not only for assessing distribution and abundance but also in studies of habitat selection, behaviour and diet (Humphrey & Zinn 1982; Ben-David *et al.* 1998; Heinemeyer *et al.* 2008; Reid *et al.* 2013a). However, binary presence/absence data are vulnerable to both Type I (false positive), and more significantly, Type II (false negative) errors (MacKenzie *et al.* 2005).

False positives occur when the target species is recorded erroneously, for example by the misidentification of scats or where transient individuals are detected but are not resident whilst false negatives occur when the target species goes undetected at a site at which it occurs due to the apparent absence of field signs (Wilson & Delahay 2001; Harrington *et al.* 2010). Such errors can result in highly biased estimates of site occupancy, population size and habitat use (MacKenzie & Nichols 2004; Mazerolle *et al.* 2005; Pagano & Arnold 2009). False positives can be avoided by surveyor training and testing as provided by the CyberTracker Certification used in the USA to quantify the skills of field observers (see http://trackercertification.com) or by independent verification, for example, DNA testing faeces to confirm the target species identity. One of the most commonly adopted solutions for false negatives is to use occupancy modelling techniques, for example, using software such as PRESENCE2 (Hines 2006), to estimate detection probabilities based on spatial or temporal resampling to allow correction factors to be applied, improving assessment of incidence independent of survey bias (MacKenzie *et al.* 2002). Conservation practitioners and wildlife surveyors typically resist the use of spatiotemporal resampling as it requires surveying transects typically longer than that perceived as the minimum necessary whilst multiple site visits are perceived as repetitious and expensive. Hence, methodologies are often based on a pragmatic trade-off between costs and effort. However, if standard surveys prove to be inadequate in providing robust estimates of species occupancy then all effort invested has been wasted.

Species detectability, and therefore reliability of ecological studies, may be influenced by a) sampling method, b) population densities and c) environmental factors (Nupp & Swihart 1996; Gu & Swihart 2004). Sampling methods include the use of multiple observers where the probability of detection may vary with levels of surveyor training, past experience or aptitude (Freilich & LaRue 1998; Evans *et al.* 2009; Pagano & Arnold 2009; Jeffress *et al.* 2011). Surveyor bias can be categorised as either: i) perception bias - which occurs when an observer fails to detect the signs of the target species despite them being visible due to failure in visual acuity or attention; or ii) availability bias - which occurs when an observer fails to see field signs directly, for example, where they are hidden behind a rock due to inadequate search time or thoroughness (Alpízar-Jara & Pollock 1996; Anderson 2001; Martin 2007). In addition to survey bias there is also survey error, for example, misidentification of field signs. There is an assumption that abundance and site occupancy are positively correlated (Lopez and Pfister 2001), but detectability may not exhibit a linear relationship with density as signs are more likely to be missed at low population densities (Kéry 2002). Bias in detectability may arise due to factors including weather, time of day and habitat structure. Despite variability in the likelihood of detection, the majority of studies that use field sign surveys do not account for differential detection probability (Mason & Macdonald 1987; Dubuc *et al.* 1990; Shackelford & Whitaker 1997).

The 'Standard Otter Survey' method, developed by Lenton *et al.* (1980), focuses on the detection of otter spraint (faeces) but may also include tracks (footprints) or holts (breeding dens) along river banks. The probability of detection may vary between signs with spraint being most readily detectable as it is usually deposited as territorial signposts on exposed boulders or sandy sidebars (Kruuk 1992). Substrate composition influences the detectability of otter tracks with soft wet substrates preserving tracks more readily than dry hard substrates (Murie & Elbroch 2005; Lowery 2006; Young & Morgan 2007). Holts are most difficult to locate and can be considerable distance from the river bank or concealed in vegetation. The Standard Otter Survey method is known to be vulnerable to false negatives (Ruiz-Olmo *et al.* 2001; Gallant *et al.* 2007; Evans *et al.* 2009; Marcelli & Fusillo 2009) as it is typically limited to short-distance, single-visit, presence-absence surveys (Long & Zielinski 2008). Indeed, the probability of false negatives is sufficiently high in some areas of its European range that up to three surveys are required to determine otter presence with any accuracy (Balestrieri *et al.* 2011; Fusillo *et al.* 2007). There is no direct relationship between otter sprainting activity (i.e. the mean numbers of spraints deposited) and otter abundance (Chanin 2003). Spraint surveys, however, are widely accepted as the best means by which to monitor changes in otter populations (Jefferies 1986). Indeed, the method has been adopted throughout Europe as the basis for species conservation assessments at the national-level (EIONET 2009), despite previous surveys failing to account for imperfect detection (e.g. Romanowski *et al.* 1996; Strachan & Jefferies, 1996, Crawford 2003; Jones & Jones 2004).

The effects of deploying multiple observers and transient or permanent variation in environmental conditions have not been examined with respect to implementing the Standard Otter Survey method. For example, anthropogenic structures including bridges may affect territorial sprainting behaviour and site use. Otters preferentially mark bridge plinths or avoid road or foot bridges due to disturbance (Reuther & Roy 2001; Elmeros & Bussenius 2002; Gallant *et al.* 2008). Moreover, they may also leave spraint disproportionately on exposed boulders at stream confluences. Variability in rainfall may be a major source of bias as this leads to flooding potentially washing away a large proportion of spraints and submerging marking sites for several days significantly reducing detectability (Ruiz-Olmo & Goslbez 1997).

1.5 Current status

The previous Article 17 conservation assessment for otters in the Republic of Ireland under the Habitats Directive (NPWS, 2008) deemed the species as in Unfavourable or poor status (Fig. 1). This was principally due to a decline in species incidence from 92.5% (Chapman & Chapman, 1982) to 89.5% (Lunnon & Reynolds, 1991) to 70.5% (Bailey & Rochford, 2006) translating into a 24% overall decline in estimated numbers from 8,400 to 6,400 adult breeding females (Marnell *et al.* 2011). This apparent decline is also reflected in the Near Threatened assessment given to the species in the most recent Irish Red Data List for terrestrial mammals (Marnell *et al.*, 2009). In contrast, data for Northern Ireland was reported under a submission covering the United Kingdom, which judged the otter as favourable or good (JNCC, 2007) due to a 527% increase in species incidence in England and a 268% increase in Wales (due to recent recolonisation after local extripation) with concomitant increases in overall estimated abundance despite an apparent decline from 72.4% (Chapman & Chapman 1982) to 62.5% (Preston *et al.* 2006) in site occupancy throughout Northern Ireland. Great Britain and Northern Ireland, whilst forming the United Kingdom, represent distinct biogeographical ecoregions and thus the ecological relevance of changes in Northern Ireland otter numbers were lost by regional inclusion with Great Britain. Moreover, no formal comparative assessment of temporal trends in otter status has been made for the Republic of Ireland and Northern Ireland even though they are more comparable and more ecologically relevant to one another.

a) b)

OTTER *Lutra lutra* (1355)	
Range	Good
Population	Poor
Habitat	Good
Future prospects	Good
OVERALL	POOR

Estimated population (adults)	10,000 – 20,000 (2008)
Occurrence trends	Declining (-23.7%) (1980 – 2006)
Major threats	Habitat loss & disturbance Road casualties

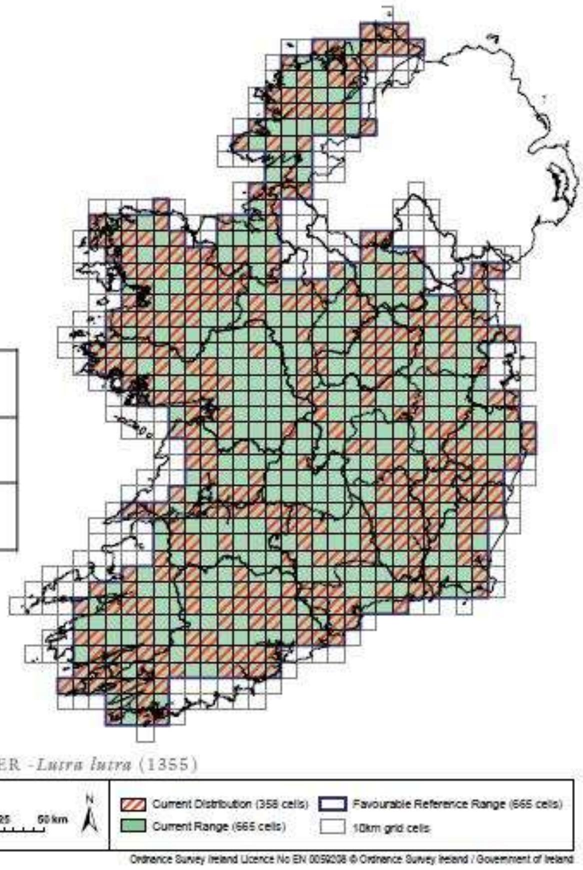


Fig. 1 (a) *summary of the last Article 17 conservation assessment for otter and* **(b)** *a 10km atlas of otter distribution in Ireland (2000 – 2006).* Source: [NPWS, 2008]

1.6 Aims of the current study

The current project aimed to develop a National Otter Survey that would:

1. *Provide an update of otter distribution*
2. *Estimate the adult population size*
3. *Assess population trends*
4. *Examine Rapid Assessment Surveys of individual catchments*
5. *Report on habitat usage*
6. *Assess otter diet nationally*
7. *Identify and report on significant pressures and threats*
8. *Make recommendations on potential improvements*

2. Methods

2.1 Study sites and survey methods

A total of 1,229 sites were surveyed for signs of Eurasian otters *Lutra lutra* (Linnaeus, 1758) from May 2010 to January 2011 throughout Ireland [852 in the Republic of Ireland (Fig. 2) and 377 in Northern Ireland]. Flowing freshwater (i.e. rivers, streams and canals) accounted for 999 sites (81.3%), static freshwater (i.e. lakes and reservoirs) accounted for 59 sites (4.8%) and the coast (i.e. the marine environment) accounted for 171 sites (13.9%). Where possible, sites were situated on separate rivers at least 5km apart to provide spatial independence. A total of 75 National Parks & Wildlife Service (NPWS) staff and 2 ecologists from Queen's University Belfast (Northern Ireland) participated in the survey. The current survey, like previous surveys in Ireland (Chapman & Chapman 1982; Lunnon & Reynolds 1991; Bailey & Rochford 2006) and those conducted since 1977 in England, Scotland and Wales was based on the 'Standard Otter Survey' method (Lenton *et al.* 1980). At each site a maximum distance of 600m was surveyed for spraint either along one river bank, around a lake or along a coastal shore. Three training days were organized for surveyors to standardize data collection including trial surveys to demonstrate methods *in situ* in the field.

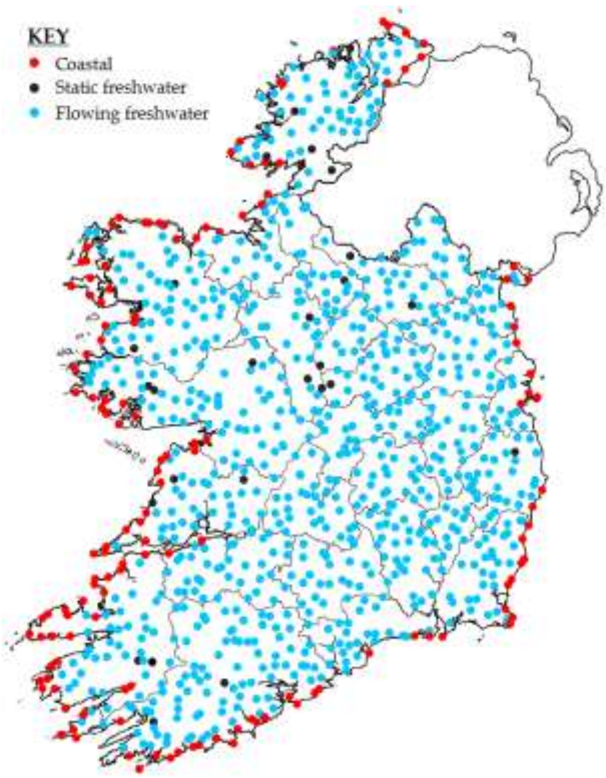


Fig. 2 *Location of 852 survey sites showing those classed as flowing freshwater (rivers, streams and canals), static freshwater (lakes and reservoirs) and those at the coast.*

2.1.1 Rapid Assessment Surveys

'Rapid Assessment Surveys' have been conducted by NPWS staff between 'National Surveys' and have focused on 8 hydrometric areas (hereafter referred to simply as catchments), namely the Boyne, Corrib, Lennan, Lough Derg, Munster Blackwater, Roaringwater Bay, Slaney and Upper Shannon (NPWS, 2009). These catchments were also covered during National Surveys but at a sampling effort much less than that deployed during Rapid Assessment Surveys. The Rapid Assessment Survey technique was based on the 'spot-check' approach advocated by Chanin & Smith (2003). They suggest that those sites which are otter positive using the Standard Otter Survey method of searching 600m of river bank are usually determined as positive within the first 100m if the survey starts at a bridge or other site favoured by otters as a territorial sprainting location. Thus, the Rapid Assessment Survey method is a 100m survey of river which usually starts at a bridge. Once a site was determined as otter positive the surveyor moved to the next site negating the time-consuming requirement of surveying a full 600m stretch *as per* the Standard Otter Survey method.

2.1.2 Estimating otter occurrence and change over space and time

Previous otter surveys used χ^2 tests of association to determine whether there was any change in otter occurrence (percentage of sites positive and negative) between two time frames (usually years). This provides a valid test of whether there was evidence that two years showed different levels of otter occurrence. However, it does not provide any indication of the level of uncertainty in estimated occurrence and, therefore, does not estimate uncertainty in the *change in incidence* over time. χ^2 tests are essentially a special case of a Generalized Linear Model (McCullagh & Nelder, 1992), and as such, we have adopted the latter approach to provide a means of estimating uncertainty in otter occurrence within past and current surveys whilst providing a measure of the variability in the estimate of the change in incidence over time. Estimating uncertainty in the change in otter incidence is relatively novel and provides details for the interpretation of past surveys that have hitherto been unavailable.

Multiple analyses were conducted at varying levels of spatio-temporal resolution. For example, estimates of incidence and change in incidence were produced for National Surveys in the Republic of Ireland for 1980/81, 2004/05 and 2010. Lunnon & Reynolds (1991) carried out a small scale survey of 246 sites throughout the Republic of Ireland but this represented only 12% of the 2,042 sites covered by Chapman & Chapman (1982) and was about half of the 525 sites covered by Bailey & Rochford (2006); therefore, we don't include their results for comparison here. Analyses were also conducted within River Basin Districts, Habitat types and SAC designation status (using only those 44 sites where otters were a designated feature; not all SACs) and were repeated for Rapid Assessment Surveys *within* catchments *between* years (temporal variation) and *between* catchments *within* years (spatial variation). Surveys were also conducted in Northern Ireland during 1980/81, 2001/02 and 2010 and the results of the latter two surveys have contrasted markedly with those reported previously from the Republic of Ireland. Otter incidence in both regions was similar during 1980/81 and declined markedly in both the Republic of Ireland and Northern Ireland by 2001/02 and 2004/05 respectively. Moreover, otter incidence subsequently increased significantly in Northern Ireland by 2010 returning to baseline levels. This raised the question of why otter occurrence and temporal trends in otter occurrence varied between jurisdictions. Consequently, it was necessary to include the three Northern Ireland surveys in our analysis (courtesy of Mark Wright, Northern Ireland Environment Agency).

In all cases, changes in otter incidence were examined using a Generalized Linear Model assuming a binomial error structure and a logit link function where otter occurrence (presence or absence) was fitted as the dependent variable. Survey (defined as the survey period - 1980/81, 2001/02, 2004/05 or 2010/11) and any spatial categories (River Basin Districts, Catchments, Habitat types or SAC designations) were fitted as fixed factors. This approach allowed us to test the null hypothesis (H_0) that '*all years within a particular spatial category e.g. a specific River Basin District showed the same level of otter incidence*'. If there was significant variation between surveys ($p<0.05$), *post-hoc* tests were conducted to establish which years differed from one another. Post-hoc tests compared differences between individual means (on the logit scale) to the corresponding least significant difference (at the 5% significance level). For each year, it was also possible to calculate the 95% confidence intervals (on the back-transformed scale), using the logit model estimates and standard errors. This provided levels of uncertainty in otter occurrence within each year at the appropriate spatial scale.

Bootstrap simulations were used to estimate the change in incidence between years as well as to produce a 95% confidence interval for that change in incidence allowing for the uncertainty in otter occurrence in those two years. For instance, for any two years of interest, this was done by selecting at random (with replacement) sites from each of the two years independently and estimating the corresponding change in incidence. A total of 500 iterations were employed to generate the 95% confidence intervals.

2.1.3 Power analyses

The sample size (i.e. numbers of sites) required to detect a 10% and 30% relative change in otter occurrence between two surveys was initially estimated using the Normal approximation to the binomial distribution assuming that occurrence was exactly that observed during the current survey (2010/11) without any associated level of uncertainty. The power analyses presented in this report were done to investigate whether a difference between incidence levels of X_1% and X_2% was detectable at a given statistical power (expressed as a percentage) where X_1 and X_2 are fixed. In other words, here, we investigated the power of detecting changes (in this case, declines) from the current survey to future surveys whilst accounting for the uncertainty in the latest observed otter occurrence. In this case, X_1 was taken as the observed occurrence during 2010/11 and X_2 was taken as a theoretical population that was 10% or 30% less than the observed occurrence during 2010/11 i.e. X_1*0.9 or X_1*0.7). X_1 was treated, not as a known probability, but rather a distribution of probabilities. This was performed using a Bayesian framework where beta distributions were the standard conjugate priors for binomial distributions. So, if p was the probability of observing signs of otters in the current survey, the Jeffreys prior for p was given by a beta distribution (Lee, 2004), specifically Beta(0.5,0.5). From this, it can be shown that the posterior probability density function for p was another distribution, specifically, Beta(x+0.5,n-x+0.5), where x was the number of sites with signs of otters and n was the number of sites visited in the latest available year (so that $X_1=x/n*100$).

Instead of simply using the latest observed proportion of sites with signs of otters for the current incidence level, a probability of presence of signs (say Y_1) was drawn at random from the posterior distribution described above (i.e. beta distribution). Then, a corresponding probability of presence was calculated for the second year (e.g. $Y_2=Y_1*0.9$ or $Y_1*0.7$). Then, assuming that as many sites were sampled in the two years, a number (e.g. 1000) of observations (0/1, i.e. signs/no sign) were simulated from binomial distributions with respective probabilities of presence Y_1 and Y_2. A Generalized Linear Model, as described above, was then run to test for differences between the two survey years. The process of generating the observations from the two binomial distributions (with respective probabilities of presence of Y_1 and Y_2) was then repeated for 500 iterations and the proportion of times where the model detected a significant difference between the two survey years was taken as the power.

This approach did not account for the uncertainty in the initial estimate of incidence. To do so, it was necessary to repeat the whole process (using 100 iterations), starting from the selection of the current probability Y_1 of signs of otters. This provided a range of power estimates, as a result of the uncertainty in the latest estimates. The "median power", "2.5% percentile power" and "97.5% percentile power" were calculated. The objective was to highlight the fact that because the baseline incidence levels were uncertain, there was uncertainty in the power of future sampling strategies.

This approach was taken for National Surveys as a whole, within River Basin Districts, habitat types and SAC designations. The sample size required to detect a 10% or 30% relative decline in otter occurrence at 80% power was determined using the theoretical framework described. However, due to levels of uncertainty in incidence the actual power associated with survey data using this theoretically derived sample size was generally below the 80% threshold. Thus, the actual power was determined at a sample size both above and below the theoretically derived threshold and where 80% power was not achieved this was extrapolated forward using linear regression. Finally, a number of samples was added as a contingency to account for the likely level of survey failure, derived from the observed level of survey failure during 2010/11.

In contrast to the power analysis for National Surveys which estimated the sample size (i.e. numbers of sites) required to detect a 10% and 30% relative change in otter occurrence between two surveys, the power associated with each Rapid Assessment Survey within catchments was calculated at various sample sizes (n=30-200) with the observed occurrence of otters in each of 8 catchments during the last survey available from 2006 to 2010. This was done following the same Bayesian approach as described above. Levels of power were then averaged across catchments to make generalisations about the level of power typically achieved.

It is important to note that the power analyses presented in this report investigated changes in naive species incidence between two survey periods only and not long-term trends. All analyses were done using Genstat 14.1.

2.2 Survey bias and error

Individual surveyors (who normally worked in pairs or trios) could not be attributed to individual data returns. However, small groups of surveyors (usually 4-5 people) were managed as 17 survey teams (under District Conservation Officers or DCOs) whose identity could be attributed to survey sites. Thus, DCO (analogous to survey team) was taken as a proxy for variance in ability between groups of surveyors. Surveys should not be conducted within 5 days of heavy rain or flooding but it has been shown that even modest amounts of rain in the days preceding a survey can introduce negative bias (Preston & Reid 2010). To this end, the cumulative rainfall (mm) was calculated for 1-5, 7, 14, 21 and 28 days prior to each survey. Data were extracted from the geographically closest weather station (n=10) to each survey site, namely, the Met Éireann stations in the Republic of Ireland at Belmullet, Casement, Claremorris, Cork Airport, Dublin Airport, Malin Head, Shannon Airport and Valentia Observatory and the Met Office stations in Northern Ireland at Aldergrove and Armagh Observatory. The number of bridges that occurred on each 600m stretch of river was recorded and reduced to a 3-level factor; no bridge, 1 bridges and ≥2 bridges. Similarly, the number of confluences was also recorded and reduced to a 3-level factor; 1 confluence, 2 confluence and >2 confluences.

2.2.1 Spatial variation

Two levels of spatial variation in species incidence were examined; i) Hydrometric areas of which there were 43 drainage catchments identified throughout Ireland and ii) River Basin Districts of which there were 8 regions representing large-scale amalgamations of Hydrometric areas.

2.2.2 Landscape parameters

Each survey site was buffered to 7 candidate spatial scales of increasing radii: 500m, 1.5km, 2.5km, 4.5km, 6.5km, 10.5km and 20.5km. A total of 4 parameters were used to describe landscape composition relevant to otters including the area (measured in hectares) of i) bog, marsh, moor & heath, ii) pasture, iii) broad-leaved woodland and iv) standing freshwater as derived from the CORINE land cover map (EEA 2010). The total length of riparian corridor (measured in kilometres) was extracted from each buffer and taken as the sum of all linear features (i.e. rivers, canals and streams). A measure of human population density, rail networks, major roads, navigable rivers, coastal shore lines, night-time stable light emissions, urban landcover and agriculture was captured using the 'Human Influence Index' (downloaded from http://sedac.ciesin.columbia.edu) and averaged within each buffer. The altitude of each survey site was recorded by handheld GPS units in the field. Each survey site was attributed a value for water quality described by levels of orthophosphate derived from 2,177 sites throughout Ireland from 2008 to 2010 collected by the Environmental Protection Agency (EPA) in the Republic of Ireland and the Water Management Unit (WMU), Northern Ireland Environment Agency (NIEA). Values were interpolated for areas with no measurements using the Kriging tool in Spatial Analyst for ArcGIS (ESRI, California, USA) and attributed to each site.

2.2.3 Statistical analysis of survey bias and error

First, the relationship of naïve otter occurrence to rainfall at varying temporal scales was assessed. The impact of rainfall was likely to vary between running water sites liable to flooding (rivers) and static water sites at which inundation was less likely (lakes and the coast). Univariate General Linear Models (GLMs) were constructed for each environment in which cumulative rainfall was the independent variable with a separate model for each of the 9 temporal lags described above (i.e. 1 day to 4 weeks). In the case of rivers, survey team, number of bridges and number of confluences were fitted as fixed factors in all candidate models. In the case of lakes and the coast, only survey team was fitted as a fixed factor as the numbers of bridges and confluences were irrelevant. Univariate models were compared using the Akaike Information Criterion (AIC) with the lowest value within each set of temporal scales indicating the best descriptor of otter detectability. Rainfall at its optimum temporal scale was only retained for inclusion in a subsequent global variance partitioning analysis if significant at $p<0.05$ (see below).

Second, the response of naïve otter occurrence to landscape parameters at varying spatial scales was assessed. Univariate GLMs were constructed in which a single independent variable was fitted i.e. each landscape parameter measured at each of the seven spatial scales. Models were compared using the AIC value as before with the lowest value within each set of spatial scales indicating the best descriptor of otter occurrence for each landscape parameter. Univariate selection procedures for different spatial scales prior to inclusion in multiscale models is well established (e.g. McAlpine *et al.* 2006a; Lundy *et al.* 2012) and has been used in modelling otter occurrence previously (Lundy & Montgomery 2010). Landscape variables at their respective selected scales were further reduced using Principal Components Analysis (PCA) to describe landscapes most relevant to the occurrence of otters. These were then included, along with rainfall at its optimum temporal scale, in a subsequent global variance partitioning analysis (see below).

Once the most appropriate scales for landscape parameters (spatial variation) and rainfall (temporal variation) were selected, variance in otter occurrence was analysed using separate GLMs for each of the three habitats. On rivers, otter occurrence was fitted as the dependent variable and survey team, River Basin District, hydrometric area, number of bridges and number of confluences were fitted as fixed factors whilst cumulative rainfall (at the appropriate temporal lag), landscape principal component scores, altitude and levels of orthophosphate were fitted as covariates. Identical GLMs were constructed for lakes and the coast except that number of bridges and confluences were excluded as explanatory variables. All predictor variables were tested for multicollinearity to ensure that all tolerance values were >0.2 and all variance inflation factor values were <10.0 (Quinn & Keough 2002). To allow the direct comparison of regression coefficients, variables were standardized to have a $\bar{x} = 0$ and a $\sigma = 1$ prior to analysis. All possible model permutations were created and ranked using AIC values. The Akaike weight (ω_i) of each model was calculated within the top set of *N* models defined as those with a value of ΔAIC ≤2 units (Burnham and Anderson 2002). The Akaike weight of each model is the relative likelihood of that model being the best within a set of *N* models. To calculate the importance of each variable relative to all other variables, the $\sum\omega_i$ of all models within the top set of models that contained the variable of interest was calculated and the variables ranked by $\sum\omega_i$ (McAlpine *et al.* 2006b); the larger the value of $\sum\omega_i$ (which varies between 0 and 1), the more important the variable. Multimodel inference and model averaging was used to determine the effect size (β coefficient) of each variable across the top set of models (Burnham & Anderson 2002). Variables that had equal $\sum\omega_i$ values were ranked in order of the magnitude of their model averaged regression coefficients.

To neutralise the potential effect of sources of bias or error on observed levels of otter incidence, the predicted values (marginal estimated mean occurrence) from the final GLM models were adjusted. A total of eight adjustments were made in a sequential manner to disentangle the effects of each source of bias or error. Specifically: a) fitting mean rainfall during the 7 days prior to survey (i.e. 14.64mm), b) fitting the mean number of bridges (1 bridge), c) fitting the mean survey team detectability (i.e. mean β coefficient), d) fitting no rainfall (i.e. 0mm), e) fitting multiple bridges (i.e. ≥2 bridges), f) fitting the maximum survey team detectability (i.e. β coefficient of the DCO survey team associated with the highest level of species incidence) and g) fitting no rainfall, multiple bridges and maximum DCO survey team detectability. This was done for rivers whilst marginal estimated mean occurrence in lakes and coasts was adjusted by fitting maximum DCO survey team detectability only as rainfall and the number of bridges was irrelevant at these sites. Predicted values were combined for river, lakes and coasts and mean values expressed within River Basin Districts to examine spatial variance in otter occurrence independent of sources of bias or error.

2.3 EC Habitats Directive Conservation Assessment

Methods for assessing conservation status have been devised by the European Topic Centre for Nature Conservation (ETCNC) in conjunction with EU member states represented on the Scientific Working Group of the Habitats Directive (Evans & Arvela, 2011). The conservation status of a species is assessed on four parameters scored objectively: i) range; ii) population; iii) habitat; and iv) future prospects. Conservation status is defined as "*the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations*". A standard format for reporting was agreed at a European level during 2006 (European Comission, 2006). The format involves the application of a traffic-light system and brings together information on the four parameters to be assessed. Each parameter is classified as being 'favourable FV' or 'good' (green); 'unfavourable inadequate U1' or 'poor' (amber); 'unfavourable U2' or 'bad' (red); or 'unknown' (grey). A species is taken as being in favourable conservation status only when: i) population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats; ii) the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future; and, iii) there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis. Favourable reference values for range and population are set as targets against which future values can be judged. These reference values have to be at least equal to the value when the Habitats Directive came into force i.e. in 1994. The 'Favourable Reference Range' for a species is the geographic range within which it occurs and which is sufficiently large to allow its long-term persistence. The major pressures and threats preceived to be affecting the species are listed during each assessment. Their status, projected status and observed impacts are used to determine the species' likely future prospects. If any one of the four parameters are assessed as unfavourable, then the overall assessment for the species is also unfavourable.

2.3.1 Range

The previous Article 17 report under the Habitats Directive established a baseline Favourable Reference Range for the otter between the implementation of the Directive and the submission of the first report covering the 13 year period from 1993 to 2006. The species range was described at a 10-km square scale consistent with methods adopted by species atlases. The Directive requires reporting every 6 years constraining the period during which the current distribution (i.e. occupied 10-km grid cells) could be assessed, that is, *for this report* the 4 year period from 2007 to 2011. This necessarily constrained the methodology that could be employed to describe changes in the distribution of the otter. Species records from the current survey were augmented with those from multiple sources including the Centre for Environmental Data and Recording (CEDaR), the National Biodiversity Data Centre, the Environmental Protection Agency (EPA), National Parks and Wildlife Service (NPWS), Northern Ireland Environment Agency (NIEA), members of the public and www.biology.ie (courtesy of Paul Whelan). Otter distribution during 2007-2011 was compared to that recorded at baseline during 1993-2006 using a 2 x 2 contingency χ^2 test of association and the difference expressed as percentage change. Power analysis based on a χ^2 distribution, was used to calculate the number of occupied squares needed during future surveys so as to demonstrate no significant decline from the current survey.

2.3.2 Population

Breeding female otters have more stable home ranges than males or juveniles (Kruuk, 1995; 2006). Thus, estimating adult female abundance was deemed more reliable than estimating total abundance. Methods for doing so have been outlined in detail by Ó Néill (2008) and Marnell *et al.* (2011) and were followed as closely as possible for comparability with previous estimates. Specifically, female otter abundance was estimated based on habitat- and productivity-specific density (individuals.km^{-1}) described in Table 2. The total length of riparian corridor (streams, rivers, lake edge) and coastline was calculated using line shapefiles and ArcGIS 10.1 (ESRI, California, USA). Data for Northern Ireland were obtained from Ordnance Survey Northern Ireland (OSNI) and streams categorised as <2m and 2-5m whilst rivers were categorised as 5-10m, 10-20m, 20-40m and >40m. Linear data for riparian length for the Republic of Ireland were obtained from Ordnance Survey Ireland (OSI) but width had to be based on mean estimates from ground-truthed data gathered during previous otter surveys (Chapman & Chapman, 1982; Bailey & Rochford, 2006) where streams were estimated to be on average 4.2m wide and rivers 12.9m wide. Typically, otters do not forage >80m from river banks or lake or coastal shores (Kruuk & Moorhouse, 1991). Consequently, rivers >80m wide were taken as representing two banks rather than one (as assumed for all rivers <80m). Similarly, lake or coastal lines were mapped with a 80m line length resolution, whereby edge habitats were treated as coincident when they were within 80m of each other as they gave access to the same foraging habitat.

Streams, rivers, and lakes were further classified according to their trophic status, as defined by their levels of orthophosphate (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 in water were derived from 2,177 sites throughout Ireland from 2008 to 2010 collected by the Environmental Protection Agency (EPA) in the Republic of Ireland and the Water Management Unit (WMU), Northern Ireland Environment Agency (NIEA) in Northern Ireland. Values were interpolated for areas with no measurements using the Kriging tool in Spatial Analyst for ArcGIS. Densities were subsequently adjusted according to altitude following the methods of Ruiz-Olmo (1998). Coastal density was classified according to the underlying geology derived from the All Ireland Bedrock Map obtained from the Geological Survey of Ireland and was assumed to be independent of productivity (Ó Néill, 2008). Mean density of otters (adult females.km^{2}) was calculated per River Basin District and plotted using ArcGIS to demonstrate regional variation.

Table 2 Adult female otter density (individuals.km^{-1}) with 95% confidence intervals in parentheses for various habitats throughout Ireland at three levels of landscape productivity.

Country (source)	**Habitat category**	**Productivity (orthophosphate)**		
		Low[I] (0.00 - 0.02 mg.l^{-1})	**Intermediate**[†] (0.02 - 0.04 mg.l^{-1})	**High**[II] (>0.04 mg.l^{-1})
Republic of Ireland (OSI)	Streams ~ 4.2m	0.05 [0.05 - 0.06]	0.06 [0.05 - 0.10]	0.07 [0.05 - 0.10]
	Rivers ~ 12.9m	0.05 [0.05 - 0.06]	0.08 [0.05 - 0.14]	0.12 [0.11 - 0.14]
	Lakes	0.05 [0.05 - 0.06]	0.09 [0.05 - 0.21]	0.17 [0.15 - 0.21]
Northern Ireland (OSNI)	Streams <2m	0.05 [0.05 - 0.05]	0.05 [0.05 - 0.05]	0.05 [0.05 - 0.05]
	Streams 2-5m	0.06 [0.05 - 0.08]	0.07 [0.05 - 0.10]	0.08 [0.05 - 0.12]
	Rivers 5-10m	0.08 [0.05 - 0.12]	0.09 [0.07 - 0.12]	0.10 [0.08 - 0.14]
	Rivers 10-20m	0.10 [0.08 - 0.14]	0.11 [0.09 - 0.14]	0.12 [0.11 - 0.15]
	Rivers 20-40m	0.12 [0.11 - 0.15]	0.13 [0.11 - 0.15]	0.13 [0.11 - 0.16]
	Rivers >40m	0.13 [0.11 - 0.16]	0.14 [0.12 - 0.16]	0.15 [0.13 - 0.17]
	Lakes	0.05 [0.05 - 0.06]	0.09 [0.05 - 0.21]	0.17 [0.15 - 0.21]
Coastlines (Geological Survey of Ireland)	Paleozoic[III]		0.43 [0.38 - 0.49]	
	Carboniferous[††]		0.43 [0.38 - 0.49]	
	Devonian[‡]		0.10 [0.09 - 0.11]	
	Igneous[III]		0.10 [0.09 - 0.11]	
	Mesozoic[III]		0.66 [0.58 - 0.75]	
	Pre-Cambrian[III]		0.18 [0.16 - 0.20]	

Density estimates were derived from [I]Green *et al.* 1984, Kruuk *et al.* 1993, Durbin 1996, Kruuk 2006; [II]O'Néill, 2008; [†]intermediate between low and high trophic status with most extreme confidence intervals; [III]Yoxon 1999; [††]Carboniferous limestone was assumed to be similar to Cambrian rock (Yoxon 1999) and [‡]otter density on Devonian rock was assumed similar to that on Igneous rock (Kruuk 1995, Yoxon 1999, H. Kruuk *pers. comms.*). Note the effect of geology was assumed independent of productivity (Ó Néill, 2008).

2.3.3 Habitats and future prospects

Twenty-eight variables were listed as perceived pressures extracted and modified from O'Sullivan (1996) and Foster-Turley (1990) who listed major and specific threats to otters as recorded in 29 European countries/regions (Table 3). Only 10 such pressures were recorded at >10% of sites and retained for inclusion in analysis. A further 69 habitat (both aquatic and terrestrial) variables were recorded during the survey describing river size, flow regime, substrate, prey availability, bank type and management, vegetation, water use and adjacent landcover (see Appendix I for an example of the otter survey recording form). Of these, 9 were deemed ecologically relevant enough for inclusion in analysis without modification (Table 4a), whilst the remaining 60 were reduced by a series of Principal Components Analyses (PCA) to 28 variables (Table 4b) yielding a final total of 37 candidate explanatory variables.

Variance in otter occurrence was examined within each habitat type (rivers, lakes and the coast) using Generalized Linear Models (GLMs) assuming a binomial error structure and a logit link function where otter occurrence (presence or absence) was fitted as the dependent variable. An information theoretic approach was used in which all sub-set regressions were created and evaluating using the AIC value with subsequent multimodel inference and averaging of regression coefficients (see *Section 2.2.3* above for full description).

Table 3 List of perceived pressures on otter populations extracted and modified from O'Sullivan (1996) and Foster-Turley (1990) who listed major and specific threats to otters as recorded in 29 European countries/regions. These have been translated into their corresponding Habitats & Species Directive threat codes.

		EU pressure & threat	
Type	**Name**	**Code**	**Description**
Adjacent land use	Farm livestock	A04	Grazing
	Arable	A02.01	Agricultural intensification
Water use	Abstraction	J02.06	Water abstractions from surface waters
	Wetland drainage	J02.07.01	Groundwater abstractions for agriculture
	Boating	G01.01	Nautical sports (motorized and non-motorised)
	Bank angling	F02.03	Leisure fishing
	Shooting	F05.05	Shooting
	Game keepering	F06.01	Game/bird breeding station
	Aquaculture/fisheries	F01	Marine or freshwater aquaculture
	Fyke netting	F02.01.02	Netting
	Illegal killing	F03 .01	Hunting
	Hydroelectric scheme	J02.05.05	Small hydropower projects, weirs
Weed control	Mechanical	A10.01	Removal of hedges and copses or scrub
	Chemical	H01.09	Diffuse pollution to surface waters (not listed)
Bank management	Canalised	J02.03.02	Canalisation
	Resectioned	J02.05.02	Modifying structures of inland water courses
Pollution	Agricultural	H01.05	Diffuse pollution to surface waters (agricultural/forestry)
	Domestic	H01.08	Diffuse pollution to surface waters (household)
	Industrial	H01.01	Pollution to surface waters by industrial plants
	Oil spillages	H03.01	Oil spills in the sea
Construction	Piers	D03.01.02	Piers/tourist harbours or recreational piers
	Moorings	D03.01.03	Fishing harbours
	Slipways	D03.01.01	Slipways
	Fishing stands	E04	Structures, buildings in the landscape
	Road traffic	D01.02	Roads & motorways
	Development	E01	Urbanisation areas, human habitation
Invasive species	American mink	I01	Invasive non-native species
	Giant Hogweed	I01	Invasive non-native species

Table 4 Explanatory variables selected for inclusion in models of otter occurrence. **a)** Nine variables were retained without modification; however, **b)** the remaining 60 were reduced to 28 variables using Principal Components Analysis (PCA) yielding at total of 37 candidate explanatory variables.

Variable type	Explanatory variable	Description
a) Unmodified variables		
Survey bias	Surveyor	There were a total of 17 survey teams throughout Ireland. Sixteen consisted of 75 conservation rangers from the National Parks & Wildlife Service (NPWS), Department of Arts, Heritage and the Gaeltacht, Republic of Ireland (ROI) whilst the sites in Northern Ireland (NI) were covered by one team consisting of two ecologists from Queen's University Belfast.
	Rainfall	Cumulative volume of rainfall (mm) during the 7 days prior to the survey extracted from the geographically closest weather station, namely, Aldergrove and Armagh Observatory (NI) or Met Éireann stations at Belmullet, Casement, Claremorris, Cork Airport, Dublin Airport, Malin Head, Shannon Airport and Valentia Observatory (ROI).
	No. of bridges	Number of bridges on each 600m survey stretch of river or 300m radius of the survey points at lakes and on the coast determined as the number of intersections between a river, stream, canal GIS shapefile and road shapefile.
Water quality	Q-values	Ecological Quality Ratings or Q-values measured at the closest Environmental Protection Agency (EPA) monitoring site to each otter survey site. The last period during which measurements were available varied from 2004 to 2010 but were typically recent. See http://www.epa.ie
Mink	Mink occurrence	Presence or absence of mink scat at each otter survey site (see Appendix VI)
Disturbance	Disturbance	Categorical 6-level factor for perceived disturbance ranging from no disturbance present (0) to high levels of disturbance present (5)
	Livestock	Presence or absence of domestic stock that had access to the river bank
Prey availability	Salmonid biomass	Biomass of salmonid species including brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), sea trout (*S. trutta* morpha *trutta*) and Atlantic salmon (*Salmo salar*) interpolated for all sites using the Kriging tool in Spatial Analyst of ArcGIS derived from 77 locations from which electofishing data were available from Inland Fisheries Ireland. See http://www.fisheriesireland.ie
Tidal state (coastal sites only)	Tide	Categorical 3-level factor including low, intermediate and high tidal states.
b) Variables derived from Principal Components Analysis of data collected in the field		
River size PCA	River size	Principal Component (PC) Axis 1 accounted for 72.3% of variance in river size (eigenvalue = 1.446) and was positively correlated with channel width (r= +0.850) and channel depth (r= +0.850)
Flow regime PCA	Slow flowing water	PC1 accounted for 26.5% of variance in flow regime (eigenvalue = 1.327) and was positively correlated with slow flowing water (r= +0.828) and negatively correlated with fast flowing water (r= -0.796)
	Fast flowing water	PC2 accounted for 21.9% of variance in flow regime (eigenvalue = 1.093) and was positively correlated with rapidly flowing water (r= +0.951)
Substrate PCA	Cobble & gravel substrate	PC1 accounted for 21.5% of variance in substrate (eigenvalue = 1.293) and was positively correlated with cobbles (r= +0.751) and gravel (r= +0.640)
	Exposed bedrock & boulders	PC2 accounted for 20.4% of variance in substrate (eigenvalue = 1.224) and was positively correlated with exposed bedrock (r= +0.630) and boulders (r= +0.585)
	Sandy substrate	PC3 accounted for 17.4% of variance in bankside vegetation (eigenvalue = 1.045) and was positively correlated with sand (r= +0.935)
Channel feature PCA	Channel & side bars	PC1 accounted for 44.7% of variance in channel features (eigenvalue = 1.341) and was positively correlated with in-channel bars (r= +0.795) and side bars (r= +0.701)
Aquatic vegetation PCA	Aquatic plants	PC1 accounted for 35.1% of variance in aquatic vegetation (eigenvalue = 1.405) and was positively correlated with submerged plants (r= +0.718) and emergent vegetation (r= +0.767)
Bankside vegetation PCA	Trees providing shade	PC1 accounted for 35.6% of variance in bankside vegetation (eigenvalue = 3.207) and was positively correlated with trees (r= +0.766) including hawthorn (r= +0.610), sycamore (r= +0.618) and ash (r= +0.686) with overhanding boughs (r= +0.788) providing shade (r= +0.716)
	Tall herbaceous plants & shrubs	PC2 accounted for 16.1% of variance in bankside vegetation (Eigenvalue = 1.446) and was positively correlated with tall herbs (r= +0.824) and shrubs (r= +0.708)

Table 4 (continued)

Variable type	Explanatory variable	Description
Bank type PCA	Low shallow banks	PC1 accounted for 22.8% of variance in bank type (eigenvalue = 1.596) and was positively correlated with banks <1m high (r= +0.837) with slopes <30° (r= +0.741)
	Moderately high sloping banks	PC2 accounted for 18.1% of variance in bank type (eigenvalue = 1.266) and was positively correlated with banks 1-2m high (r= +0.690) with slopes 30-60° (r= +0.656)
	High banks	PC3 accounted for 16.1% of variance in bank type (eigenvalue = 1.128) and was positively correlated with banks 2-3m high (r= +0.703) which did not slope steeply i.e. 60-90° (r= -0.518)
Bank management PCA	Wild unmaintained banks	PC1 accounted for 17.9% of variance in bank management (eigenvalue = 1.434) and was positively correlated with wild banks (r= +0.729) with no management (r= +0.885)
	Chemical control of giant hog weed	PC2 accounted for 17.1% of variance in bank management (eigenvalue = 1.364) and was positively correlated with giant hogweed (r= +0.777) and chemical control (r= +0.775)
	Canalisation with mechanical weed control	PC3 accounted for 15.2% of variance in bank management (eigenvalue = 1.218) and was positively correlated with canalisation (r= +0.916) and mechanical weed control (r= +0.560)
	Resectioned and maintained	PC4 accounted for 15.0% of variance in bank management (eigenvalue = 1.201) and was positively correlated with resectioned (r= +0.792) and maintained banks (r= +0.509)
Water use PCA	Boating and harbours	PC1 accounted for 24.9% of variance in water use (eigenvalue = 1.181) and was positively correlated with boating activity (r= +0.775) and harbours or moorings (r= +0.837)
	Hunting activities	PC2 accounted for 23.7% of variance in water use (eigenvalue = 1.419) and was positively correlated with game keepering (r= +0.709), shooting (r= +0.562) and angling (r= +0.577)
Adjacent landcover PCA	Urban areas	PC1 accounted for 26.8% of variance in landcover (eigenvalue = 1.343) and was positively correlated with urban (r= +0.752) and parks (r= +0.803)
	Woodland	PC2 accounted for 25.5% of variance in landcover (eigenvalue = 1.276) and was positively correlated with broad-leaved woodland (r= +0.675) and coniferous plantations (r= +0.807)
Fish eating birds PCA	Fish eating birds	PC1 accounted for 52.2% of variance in fish eating bird presence (eigenvalue = 1.566) and was positively correlated with cormorants (r= +0.822), gulls (r= +0.734) and herons (r= +0.592)
Shoreline PCA (lakes & coasts only)	Low shallow shores	PC1 accounted for 28.9% of variance in shoreline type (eigenvalue = 1.733) and was positively correlated with shorelines <5m high (r= +0.931) which sloped gently at 0-30° (r= +0.907)
	Intermediately high sloping shores	PC2 accounted for 23.2% of variance in shoreline type (eigenvalue = 1.394) and was positively correlated with shorelines 5-20m high (r= +0.801) which sloped at 30-60° (r= +0.844)
	High steep shores	PC3 accounted for 21.4% of variance in shoreline type (eigenvalue = 1.284) and was positively correlated with shorelines >20m high (r= +0.745) which sloped steeply at 60-90° (r= +0.829)
Coastal habitat PCA (coasts only)	Rocky shores	PC1 accounted for 26.1% of variance in coastal habitat (eigenvalue = 1.321) and was positively correlated with rocky shores (r= +0.740) and cliffs (r= +0.691)
	Beeches & saltmarsh	PC2 accounted for 25.2% of variance in coastal habitat (eigenvalue = 1.242) and was positively correlated with saltmarsh (r= +0.750) and negative correlated with beeches (r= -0.771)
Shellfish PCA (coasts only)	Shellfish	PC1 accounted for 59.5% of variance in shellfish and mollusc presence (eigenvalue = 1.786) and was positively correlated with shellfish (r= +0.905) and crabs (r= +0.885)

2.4 Review and meta-analysis of otter diet

2.4.1 Spraint collection and analysis

A subsample of 192 spraints were collected from randomly chosen survey sites and stored. Their contents were analyzed for comparison with previous studies. Spraint analysis followed the standard methodology described by Conroy & Chanin (2005).

2.4.2 Productivity and fish biomass

The productivity or trophic status of rivers throughout Ireland was defined by their levels of orthophosphate (see *Section 2.3.2* above for full description). 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 was 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 was retained for analysis rather than individual species-level data.

2.4.3 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 (Ward *et al.*, 1986; Wise *et al*., 1981). 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 & Parkinson, 1996; Jacobsen & Hansen, 1996; Wise *et al.*, 1981). Studies typically reported results in tabular form summarized by 'Site' (rivers, catchments, River Basin Districts or, in some cases entire regions, for example Northern Ireland). Variance in the meta-data, therefore, was constrained by the varying definition of 'Site'.

2.4.4 Statistical analysis of diet

Descriptive statistics were used to summarize 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 analyzed 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, California, 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) and used 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 summarize the percentage occurrence ± 95% confidence limits of each prey items within each habitat.

3. Results

3.1 National Otter Survey 2010/11

A total of 852 sites were successfully surveyed throughout the Republic of Ireland during 2010/11. Flowing freshwater (i.e. rivers, streams and canals) accounted for 694 sites of which 450 (64.8%) had signs of otters. Static freshwater (i.e. lakes and reservoirs) accounted for 24 sites of which 13 (54.2%) had signs of otters and the coast (i.e. the marine environment) accounted for 134 sites of which 76 (56.7%) had signs of otters. Special Areas of Conservation (SACs) accounted for 237 sites of which 159 (67.1%) had signs of otters (Fig. 3). Otters were widespread (Fig. 4).

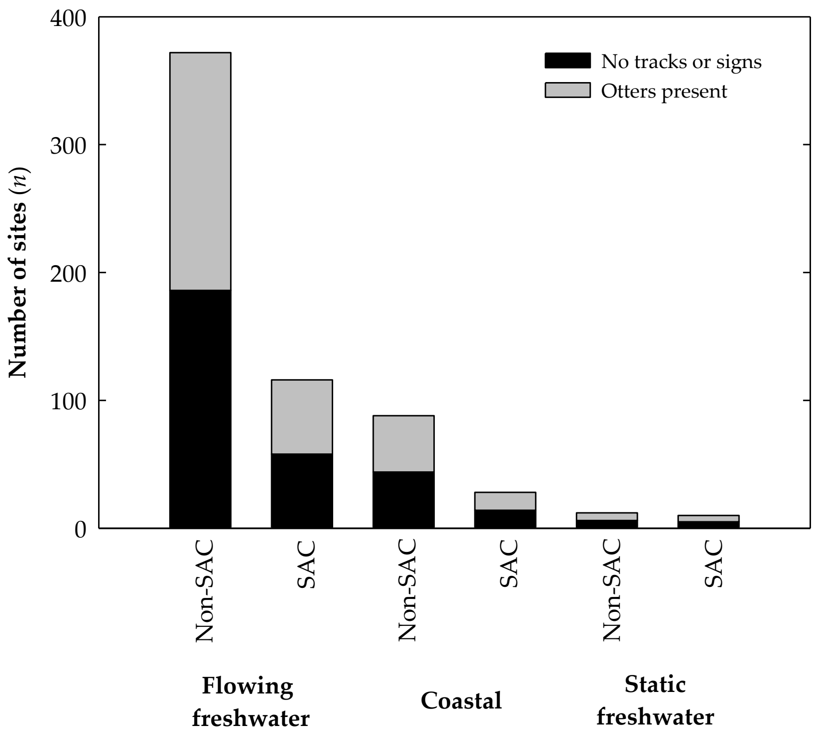


Fig. 3 Descriptive summary of the sample sizes in each category of survey site and the number of sites where otters were present or where no signs were found.

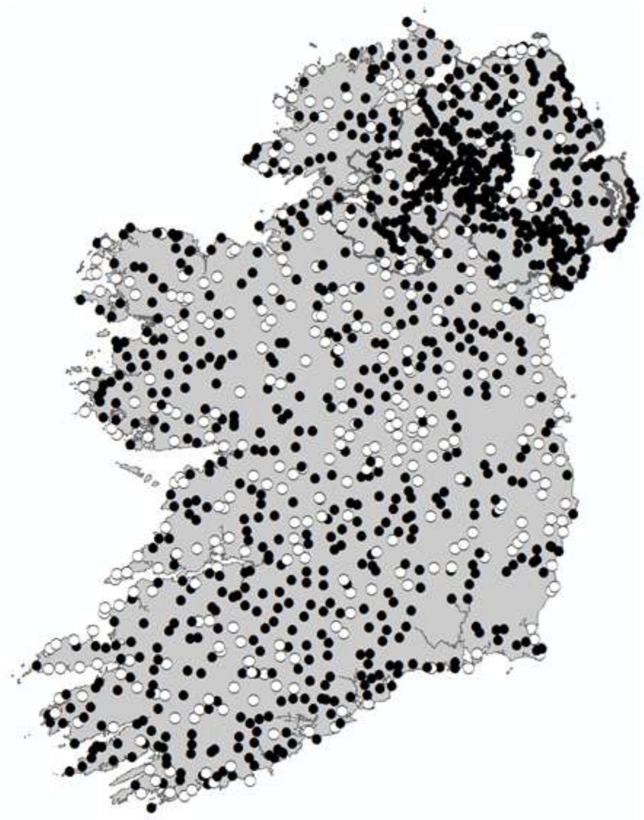


Fig. 4 Otter survey sites in the Republic of Ireland (during 2010/11) augmented by those surveyed Northern Ireland in 2010 showing otter occurrence as closed circles and absence of tracks or signs as open circles. [Data for Northern Ireland were extracted from Preston & Reid, 2011 with the written permission of the Northern Ireland Environment Agency (NIEA)]. Note that the density of survey sites was greater in NI than ROI.

3.1.1 *Spatio-temporal context*

The current survey was placed in context by comparing it to past surveys in the Republic of Ireland (1980/81, 2004/05 and 2010/11), excluding Lunnon & Reynolds (1991) due to small sample size, and comparable surveys in Northern Ireland. Historically, sample sizes varied markedly between River Basin Districts within surveys, for example, in the Republic of Ireland from 9 sites in the Neagh-Bann River Basin District during 2004/05 to 529 sites in the Shannon River Basin District during 1980/81 (Table 5).

Sample sizes varied markedly between habitat types (flowing freshwater, static freshwater and coastal) within surveys; for example, sample size in the Republic of Ireland ranged from 24 sites at static freshwater during 2010/11 to 1,495 at running freshwater during 1980/81 (Table 6). Samples sizes also varied between SACs and the wider countryside (non-SAC) within surveys;

for example, there were 237 sites within SACs during 2010/11 but 1,566 sites within the wider countryside (non-SACs) during 1980/81 (Table 7).

Table 5 Descriptive summary of River Basin Districts showing the number of sites where otter tracks and signs were recorded (*+ve*) compared to the total sample size of sites surveyed (*n*) with otter occurrence expressed as a percentage (%) for three National Surveys in the Republic of Ireland and Northern Ireland from 1980/81 - 2010/11.

Country	**River Basin District**	**1980/81**		**2004/05**		**2010/11**	
		+ve / n	***%***	***+ve / n***	***%***	***+ve / n***	***%***
Republic of Ireland	Eastern	154 / 190	81.1	22 / 35	62.9	34 / 65	52.3
	Neagh Bann	28 / 33	84.8	8 / 9	88.9	12 / 26	46.2
	North-Western	203 / 214	94.9	43 / 66	65.2	63 / 101	62.4
	Shannon	515 / 529	97.4	70 / 100	70.0	128 / 216	59.3
	South-Eastern	305 / 351	86.9	77 / 108	71.3	92 / 130	70.8
	South-Western	367 / 398	92.2	71 / 95	74.7	110 / 161	68.3
	Western	309 / 319	96.9	79 / 112	70.5	100 / 153	65.4
	Sub-total	**1,881 / 2,034**	**92.5**	**370 / 525**	**70.5**	**539 / 852**	**63.3**
		1980/81		**2001/02**		**2010**	
Northern Ireland	Neagh Bann	135 / 158	85.4	182 / 282	64.5	151 / 162	93.2
	North-East	89 / 110	80.9	89 / 142	62.7	70 / 80	87.5
	North-West	57 / 63	90.5	230 / 318	72.3	113 / 135	83.7
	Sub-total	**281 / 331**	**84.9**	**501 / 742**	**67.5**	**334 / 377**	**88.6**
	TOTAL	**2162 / 2,365**	**91.4**	**871 / 1,267**	**68.7**	**873 / 1,229**	**71.0**

Table 6 Descriptive summary of habitat types showing the number of sites where otter tracks and signs were recorded (*+ve*) compared to the total sample size of sites surveyed (*n*) with otter occurrence expressed as a percentage (%) for three National Surveys in the Republic of Ireland and Northern Ireland from 1980/81 - 2010/11.

		1980/81		**2004/05**		**2010/11**	
Country	**Habitat type**	***+ve / n***	***%***	***+ve / n***	***%***	***+ve / n***	***%***
Republic of Ireland	Flowing freshwater	1,400 / 1,495	93.6	329 / 462	71.2	450 / 694	64.8
	Static freshwater	284 / 315	90.2	19 / 29	65.5	13 / 24	54.2
	Coastal	197 / 224	87.9	22 / 34	64.7	76 / 134	56.7
	Sub-total	**1,881 / 2,034**	**92.5**	**370 / 525**	**70.5**	**539 / 852**	**63.3**
		1980/81		**2001/02**		**2010**	
Northern Ireland	Flowing freshwater	221 / 255	86.7	365 / 551	66.2	267 / 305	87.5
	Static freshwater	33 / 37	89.2	107 / 135	79.3	32 / 35	91.4
	Coastal	27 / 39	69.2	29 / 56	51.8	35 / 37	94.6
	Sub-total	**281 / 331**	**84.9**	**501 / 742**	**67.5**	**334 / 377**	**88.6**
	TOTAL	**2,162 / 2,365**	**91.4**	**871 / 1,267**	**68.7**	**873 / 1,229**	**71.0**

Table 7 Descriptive summary of designation (SAC) status showing the number of sites where otter tracks and signs were recorded (*+ve*) compared to the total sample size of sites surveyed (*n*) with otter occurrence expressed as a percentage (%) for three National Surveys in the Republic of Ireland and Northern Ireland from 1980/81 - 2010/11.

		1980/81		**2004/05**		**2010/11**	
Country	**Designation**	***+ve / n***	**%**	***+ve / n***	**%**	***+ve / n***	**%**
Republic of Ireland	Non-SACs	1,423 / 1,566	90.9	177 / 263	67.3	380 / 615	61.8
	SACs	458 / 468	97.9	193 / 262	73.7	159 / 237	67.1
	Sub-total	**1,881 / 2,034**	**92.5**	**370 / 525**	**70.5**	**539 / 852**	**63.3**
		1980/81		**2001/02**		**2010**	
Northern Ireland	Non-SACs	274 / 324	84.6	437 / 660	66.2	318 / 358	88.8
	SACs	7 / 7	100.0	64 / 82	78.0	16 / 19	84.2
	Sub-total	**281 / 331**	**84.9**	**501 / 742**	**67.5**	**334 / 377**	**88.6**
	TOTAL	**2,162 / 2,365**	**91.4**	**871 / 1,267**	**68.7**	**873 / 1,229**	**71.0**

3.*1.2 Estimates of occurrence and change in occurrence*

In the Republic of Ireland, otter occurrence significantly differed between surveys (Table 8). Pairwise comparisons of change in occurrence exhibited a significant decline ($p<0.05$) between 1980/81 (baseline) and 2010/11 (current survey) of 31.6% in the incidence of tracks and signs. The magnitude of the decline between 1980/81 and 2004/05 (-24.0%) was more than twice that exhibited between 2004/05 and 2010/11 (-10.3%). However, the periods between the surveys were of different lengths. Thus, the *rate* of change was approximately 1.0% per annum between 1980/81 and 2004/05 but 1.5 - 2.0% per annum between 2004/05 and 2010/11. A similar trend was observed within River Basin Districts (Table 9); however, at this spatial scale declines between 2004/05 and 2010/11 were generally not significant (at $p<0.05$) except for the Neagh-Bann and Shannon River Basin Districts. Although statistically significant, the decline within the latter was "borderline" (upper limit of the 95% confidence interval of -1.6%). The general trend also held across each of the three habitat types (flowing freshwater, static freshwater and coastal sites), but flowing freshwater sites showed continuous statistically significant decline from 1980/81 (baseline) to 2004/05 and 2010/11 (current survey) whilst only the first decline in static freshwater and coastal sites (between the first two surveys from 1980/81 and 2004/05) was statistically significant.

Declines observed at static freshwater and coastal sites were not statistically significant at $p<0.05$ between 2004/05 and 2010/11 but it should be noted that sample sizes in these habitats were considerably lower than those in flowing freshwater sites (Table 10). Temporal trends did not differ between SAC designated sites and those in the wider countryside (Table 11).

The observed temporal trend in otter occurrence in Northern Ireland differed markedly from that observed in the Republic of Ireland (Table 8). In common with the latter region, otter occurrence initially demonstrated a significant overall decline between 1980/81 and 2001/02 (-20.5%) but subsequently increased significantly between 2001/02 and 2010 (+31.6%) resulting in no statistically significant change between 1980/81 (baseline) and 2010 (current survey). A similar trend was observed within River Basin Districts in Northern Ireland (Table 9); however, the Neagh-Bann River Basin District exhibited a significant 9.1% increase in otter occurrence between 1980/81 and 2010. Temporal trends at flowing freshwater and coastal sites mirrored those observed at larger scales declining markedly between 1980/81 and 2001/02 before increasing between 2001/02 and 2010 (Table 10). Changes in occurrence were not significant within static freshwater or coastal sites most probably due to the effect of small sample sizes. The change in occurrence could not be examined within SAC sites between 1980/81 and 2001/02 as there was 100% occurrence in all SAC sites during the first survey i.e. it was not possible to perform bootstrapping resampling due to lack of variability.

Table 8 Temporal changes in otter occurrence (% ± 95%CI) for three National Surveys in the Republic of Ireland and Northern Ireland from 1980/81 - 2010/11.

Country	Change of deviance (df)	*p*	Survey and % occurrence ± 95%CI		Relative % change in occurrence ± 95%CI	
Republic of Ireland	393.56 (df=2)	< 0.001	1980/81[c]	92.48% [91.25%, 93.54%]	1980/81 – 2004/05	-24.0% [-29.0%, -19.8%]
			2004/05[b]	70.48% [66.43%, 74.22%]	2004/05 – 2010/11	-10.3% [-17.0%, -2.9%]
			2010/11[a]	63.26% [59.97%, 66.44%]	1980/81 – 2010/11	-31.6% [-35.6%, -27.8%]
Northern Ireland	80.89 (df=2)	< 0.001	1980/81[b]	84.89% [80.62%, 88.36%]	1980/81 – 2001/02	-20.5% [-25.8%, -14.7%]
			2001/02[a]	67.52% [64.06%, 70.80%]	2001/02 – 2010	31.6% [23.8%, 39.6%]
			2010[b]	88.59% [84.97%, 91.43%]	1980/81 – 2010	4.3% [-1.5%, 11.0%]

[a] Changes shown in red have 95% confidence intervals that do not include zero and for which the decrease or increase in occurrence was therefore significant.

[b] Means separating groups have been calculated from a Generalized Linear Model. Two years with the same letter are not significantly different from each other.

Table 9 Temporal changes in otter occurrence (% ± 95%CI) within River Basin Districts for three National Surveys in the Republic of Ireland and Northern Ireland from 1980/81 - 2010/11.

Country	River Basin District	Change of deviance (df)	*p*	Survey and % occurrence ± 95%CI		Relative % change in occurrence ± 95%CI	
Republic of Ireland	Eastern	21.00 (df=2)	<0.001	1980/81[b]	81.05% [74.82%, 86.03%]	1980/81 – 2004/05	-22.3% [-42.7%, -1.0%]
				2004/05[a]	62.86% [45.99%, 77.08%]	2004/05 – 2010/11	-16.2% [-43.7%, 16.7%]
				2010/11[a]	52.31% [40.22%, 64.13%]	1980/81 – 2010/11	-35.0% [-51.3%, -19.5%]
	Neagh Bann	12.15 (df=2)	0.002	1980/81[b]	84.85% [68.06%, 93.64%]	1980/81 – 2004/05	5.7% [-24.1%, 32.0%]
				2004/05[b]	88.88% [50.13%, 98.45%]	2004/05 – 2010/11	-47.3% [-69.7%, -16.9%]
				2010/11[a]	46.15% [28.09%, 65.29%]	1980/81 – 2010/11	-45.1% [-68.3%, -20.1%]
	North-Western	63.54 (df=2)	<0.001	1980/81[b]	94.86% [91.04%, 97.10%]	1980/81 – 2004/05	-31.5% [-44.6%, -18.5%]
				2004/05[a]	65.15% [52.94%, 75.65%]	2004/05 – 2010/11	-3.4% [-24.0%, 19.5%]
				2010/11[a]	62.38% [52.54%, 71.29%]	1980/81 – 2010/11	-33.9% [-44.2%, -24.5%]
	Shannon	188.86 (df=2)	<0.001	1980/81[b]	97.35% [95.60%, 98.42%]	1980/81 – 2004/05	-27.7% [-36.6%, -18.3%]
				2004/05[a]	70.00% [60.32%, 78.17%]	2004/05 – 2010/11	-15.1% [-28.2%, -1.6%]
				2010/11[a]	59.26% [52.57%, 65.62%]	1980/81 – 2010/11	-39.2% [-46.9%, -31.9%]
	South-Eastern	22.40 (df=2)	<0.001	1980/81[b]	86.89% [82.97%, 90.02%]	1980/81 – 2004/05	-18.1% [-28.7%, -7.3%]
				2004/05[a]	71.30% [62.08%, 79.03%]	2004/05 – 2010/11	-0.3% [-13.9%, 17.9%]
				2010/11[a]	70.77% [62.40%, 77.93%]	1980/81 – 2010/11	-18.1% [-26.8%, -8.2%]
	South-Western	53.35 (df=2)	<0.001	1980/81[b]	92.21% [89.14%, 94.46%]	1980/81 – 2004/05	-18.8% [-29.0%, -8.9%]
				2004/05[a]	74.74% [65.04%, 82.47%]	2004/05 – 2010/11	-8.6% [-22.6%, 6.4%]
				2010/11[a]	68.32% [60.73%, 75.05%]	1980/81 – 2010/11	-25.9% [-33.9%, -17.6%]
	Western	99.78 (df=2)	<0.001	1980/81[b]	96.87% [94.28%, 98.30%]	1980/81 – 2004/05	-27.1% [-36.4%, -18.4%]
				2004/05[a]	70.54% [61.44%, 78.25%]	2004/05 – 2010/11	-6.6% [-20.3%, 9.3%]
				2010/11[a]	65.36% [57.47%, 72.48%]	1980/81 – 2010/11	-32.7% [-40.5%, -25.0%]
Northern Ireland	Neagh Bann	60.04 (df=2)	<0.001	1980/81[b]	85.44% [79.03%, 90.14%]	1980/81 – 2001/02	-24.6% [-33.0%, -14.0%]
				2001/02[a]	64.54% [58.77%, 69.92%]	2001/02 – 2010	43.8% [29.9%, 57.7%]
				2010[c]	93.21% [88.19%, 96.19%]	1980/81 – 2010	9.1% [1.0%, 18.7%]
	North-East	20.40 (df=2)	<0.001	1980/81[b]	80.91% [72.45%, 87.23%]	1980/81 – 2001/02	-21.9% [-33.0%, -9.5%]
				2001/02[a]	62.67% [54.44%, 70.24%]	2001/02 – 2010	40.4% [21.7%, 63.7%]
				2010[b]	87.50% [78.40%, 93.10%]	1980/81 – 2010	8.4% [-4.0%, 21.6%]
	North-West	15.19 (df=2)	<0.001	1980/81[b]	90.48% [80.36%, 95.66%]	1980/81 – 2001/02	-19.8% [-26.7%, -10.3%]
				2001/02[a]	72.33% [67.14%, 76.98%]	2001/02 – 2010	16.3% [5.5%, 28.8%]
				2010[b]	83.70% [76.47%, 89.03%]	1980/81 – 2010	-7.1% [-16.2%, 3.7%]

[a] Changes shown in red have 95% confidence intervals that do not include zero and for which the decrease or increase in occurrence was therefore significant.

[b] Means separating groups have been calculated from a Generalized Linear Model. Two years with the same letter are not significantly different from each other.

Table 10 Temporal changes in otter occurrence (% ± 95%CI) within habitat types for three National Surveys in the Republic of Ireland and Northern Ireland from 1980/81 - 2010/11.

Country	Habitat	Change of deviance (df)	*p*	Survey and % occurrence ± 95%CI		Relative % change in occurrence ± 95%CI	
Republic of Ireland	Running freshwater	321.44 (df=2)	< 0.001	1980/81[c]	93.64% [92.30%, 94.76%]	1980/81 – 2004/05	-23.9% [-28.8%, -19.3%]
				2004/05[b]	71.21% [66.91%, 75.16%]	2004/05 – 2010/11	-9.1% [-15.8%, -2.1%]
				2010/11[a]	64.84% [61.21%, 68.31%]	1980/81 – 2010/11	-30.8% [-34.7%, -26.9%]
	Static freshwater	26.73 (df=2)	< 0.001	1980/81[b]	90.16% [86.34%, 93.00%]	1980/81 – 2004/05	-27.0% [-47.0%, -7.2%]
				2004/05[a]	65.52% [52.94%, 80.38%]	2004/05 – 2010/11	-14.9% [-49.1%, 29.5%]
				2010/11[a]	54.17% [52.54%, 72.57%]	1980/81 – 2010/11	-40.5% [-63.2%, -17.1%]
	Coastal	46.31 (df=2)	< 0.001	1980/81[b]	87.95% [82.98%, 91.61%]	1980/81 – 2004/05	-26.5% [-45.4%, -7.8%]
				2004/05[a]	64.71% [47.52%, 78.78%]	2004/05 – 2010/11	-10.8% [-31.7%, 22.1%]
				2010/11[a]	56.72% [48.19%, 64.86%]	1980/81 – 2010/11	-35.1% [-45.7%, -24.8%]
Northern Ireland	Running freshwater	69.97 (df=2)	< 0.001	1980/81[b]	86.66% [81.96%, 90.29%]	1980/81 – 2001/02	-23.6% [-29.9%, -17.4%]
				2001/02[a]	66.24% [62.20%, 70.06%]	2001/02 – 2010	32.5% [23.3%, 42.6%]
				2010[b]	87.54% [83.39%, 90.76%]	1980/81 – 2010	1.1% [-5.8%, 7.6%]
	Static freshwater	4.47 (df=2)	0.110	1980/81	89.19% [74.40%, 95.90%]	1980/81 – 2001/02	-11.0% [-22.2%, 2.3%]
				2001/02	79.26% [71.55%, 85.31%]	2001/02 – 2010	15.3% [-0.9%, 29.9%]
				2010	91.43% [76.49%, 97.22%]	1980/81 – 2010	3.0% [-12.4%, 20.3%]
	Coastal	22.30 (df=2)	< 0.001	1980/81[a]	69.23% [53.11%, 81.72%]	1980/81 – 2001/02	-24.2% [-47.2%, 4.5%]
				2001/02[a]	51.79% [38.75%, 64.58%]	2001/02 – 2010	85.9% [46.8%, 143.5%]
				2010[b]	94.59% [80.97%, 98.63%]	1980/81 – 2010	38.6% [8.8%, 80.7%]

[a] Changes shown in red have 95% confidence intervals that do not include zero and for which the decrease or increase in occurrence was therefore significant.

[b] Means separating groups have been calculated from a Generalized Linear Model. Two years with the same letter are not significantly different from each other.

Table 11 Temporal changes in otter occurrence (% ± 95%CI) within designated SACs for three National Surveys in the Republic of Ireland and Northern Ireland from 1980/81 - 2010/11.

Country	Habitat	Change of deviance (df)	*p*	Survey and % occurrence ± 95%CI		Relative % change in occurrence ± 95%CI	
Republic of Ireland	Wider countryside (non-SACs)	268.06 (df=2)	< 0.001	1980/81[b]	90.87% [89.34%, 92.20%]	1980/81 – 2004/05	-26.0% [-32.4%, -19.5%]
				2004/05[a]	67.30% [61.40%, 72.70%]	2004/05 – 2010/11	-8.2% [-17.2%, 2.0%]
				2010/11[a]	61.79% [57.88%, 65.55%]	1980/81 – 2010/11	-31.9% [-36.2%, -27.5%]
	SACs	158.73 (df=2)	< 0.001	1980/81[b]	97.86% [96.11%, 98.83%]	1980/81 – 2004/05	-24.6% [-30.2%, -19.5%]
				2004/05[a]	73.66% [67.99%, 78.65%]	2004/05 – 2010/11	-8.9% [-19.7%, 2.0%]
				2010/11[a]	67.09% [60.85%, 72.78%]	1980/81 – 2010/11	-31.6% [-37.5%, -25.4%]
Northern Ireland	Wider countryside (non-SACs)	84.12 (df=2)	< 0.001	1980/81[b]	84.57% [80.21%, 88.11%]	1980/81 – 2001/02	-21.7% [-27.1%, -15.9%]
				2001/02[a]	66.21% [62.51%, 69.72%]	2001/02 – 2010	34.2% [25.5%, 44.5%]
				2010[b]	88.83% [85.12%, 91.70%]	1980/81 – 2010	5.2% [-1.7%, 12.4%]
	SACs (ignoring 1980/81 with 100% incidence)	0.37 (df=1)	0.54	2001/02	78.05% [67.88%, 85.79%]	2001/02 – 2010	6.8% [-21.5%, 31.7%]
				2010	84.21% [60.56%, 94.88%]		

3.1.3 Power Analysis of the National Survey

It was assumed that otter occurrence across the Republic of Ireland was **exactly** 539 positive sites out of 852 sites surveyed or 63.3% (Table 8). A 10% relative decline, therefore, was taken as 56.9%. In this case, a Normal approximation of a simulated binomial distribution suggested that a sample size of 740 sites would be required to detect a 10% decline with 80% statistical power.

However, as previously described, observed otter occurrence was associated with an estimate of uncertainty. Specifically during 2010/11, the 95% confidence interval around the observed level of occurrence was 59.97 - 66.44% (Table 8). Thus, incorporating this level of uncertainty into the power analysis simulations suggested that the 'actual' statistical power using 740 sites would be less than 80.0% (in this case, 70.2% power). Extrapolating upward to 80.0% power whilst accounting for this observed level of uncertainty suggested that 892 sites would be needed to detect a 10% decline assuming otter occurrence was **exactly** 63.3% (Fig. 5a and Appendix II; Table S1).

If we adopt a conservative approach and assuming that otter occurrence during the current survey may have been as low as 59.97% (our lower 95% confidence interval) then extrapolating upwards to 80.0% power suggested that 998 sites would be needed to detect a 10% decline (Fig. 5b).

It is necessary in every survey to incorporate a contingency for survey failure. For example, in the current survey a total of 980 sites were actually allocated for survey but data were successfully returned for only 852 sites (86.9%). Assuming that future surveys have a similar level of failure we might suggest that a 13.1% contingency is required. Thus, the most conservative approach for future surveys would be to allocate at least 1,148 sites i.e. 998 sites plus a 13.1% contingency of 150 sites (Fig. 5b).

This analysis was repeated on the basis of detecting a 30% relative change in otter occurrence. In this case, a simulated distribution suggested that 85 sites were required when otter occurrence was assumed to be **exactly** 63.3% (Fig. 6a and Appendix II; Table S1). Again, due to levels of uncertainty in occurrence, actual power was below the 80% threshold. Thus extrapolating to 80% and accounting for observed levels of uncertainty a total of 101 sites would be required to detect a 30% decline in real terms. However, adopting a conservative approach assuming that otter occurrence may have been as low as 59.97% suggested that 110 sites would be required. Thus, adding a 13.1% contingency for failure resulted in a total of 127 sites being required for allocation during the next survey if a 30% decline is to be detected (Fig. 6b).

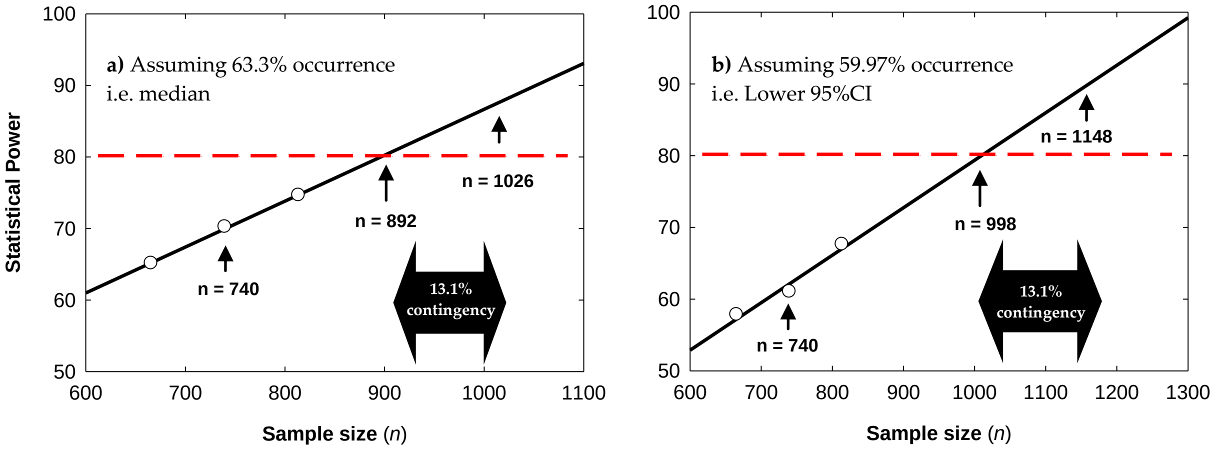


Fig. 5 Statistical power (%) to detect a **10% relative decline** in otter occurrence between two 'National Surveys' where 80% power is achieved using 740 sites based on a Normal approximation of the binomial distribution. Actual power is lower due to observed levels of uncertainty in occurrence and was extrapolated forward to achieve 80% power in real terms. **a)** Assumed otter occurrence was exactly 63.3% as observed; and, **b)** assumed otter occurrence was 59.97% (i.e. our lower 95% confidence interval). More detailed analyses are present in Appendix II. Note that in each case a 13.1% contingency was added to be consistent with the level of survey failure during 2010.

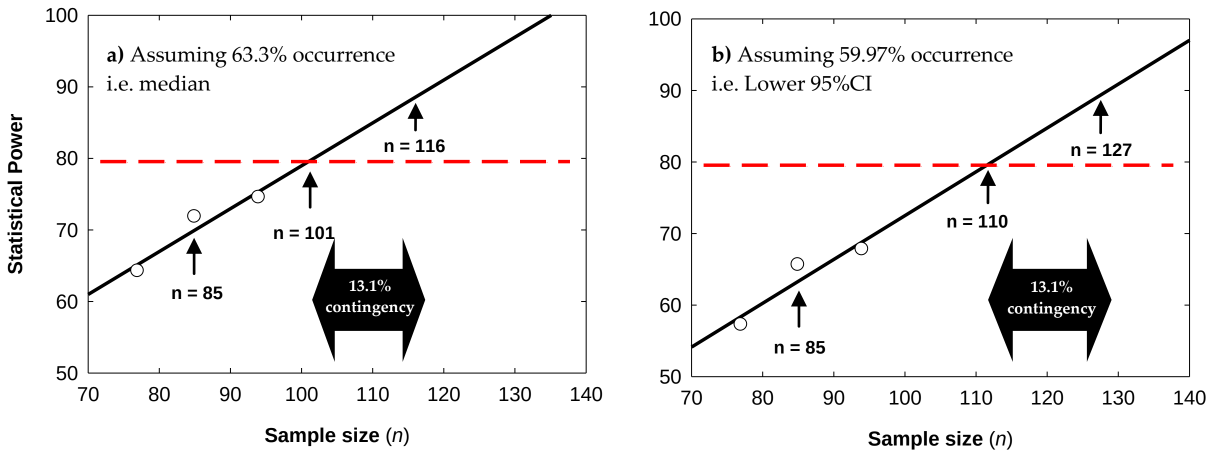


Fig. 6 Statistical power (%) to detect a **30% relative decline** in otter occurrence between two 'National Surveys' where 80% power is achieved using 85 sites based on a Normal approximation of the binomial distribution. Actual power is lower due to observed levels of uncertainty in occurrence and was extrapolated forward to achieve 80% power in real terms. **a)** Assumed otter occurrence was exactly 63.3% as observed; and, **b)** assumed otter occurrence was 59.97% (i.e. our lower 95% confidence interval). More detailed analyses are present in Appendix II. Note that in each case a 13.1% contingency was added to be consistent with the level of survey failure during 2010.

Power analyses were repeated using River Basin Districts (Appendix II; Table S2), Habitat types (Appendix II; Table S3) and SAC designation (Appendix II; Table S4). In all cases many hundreds of sites (up to 1500 sites) may be required within River Basin Districts to detect a 10% decline; far more than is practical or spatially independent. Similar results were obtained for habitat types and SAC designation status suggesting that the only feasible spatial scale on which to detect a 10% decline was the National scale.

In contrast, current sample sizes within River Basin Districts, Habitat types and SAC designation, generally appeared to be within the predicted values required to detect a 30% decline in occurrence. Exceptions included the Eastern River Basin District which required 123 samples but had 65 sites in the current survey; the Neagh-Bann River Basin District which required 153 samples but had 26 in the current survey and static freshwater sites that required 116 samples but had 24 sites in the current survey.

3.2 Rapid Assessment Surveys

'Rapid Assessment Surveys' focused on 8 hydrometric areas (hereafter referred to simply as catchments), namely the Boyne, Corrib, Lennan, Lough Derg, Munster Blackwater, Roaringwater Bay, Slaney and Upper Shannon. These catchments were also covered during National Surveys but at a sampling effort much less than that deployed during Rapid Assessment Surveys (Table 12). Taking all surveys together, the Munster Blackwater catchment had the highest level of otter occurrence (92.8%) whilst Upper Shannon, Corrib and Roaringwater Bay had the lowest levels of otter occurrence (54.4, 64.5 and 65.6% respectively).

Analysis of temporal trends within specific catchments comparing results from the appropriate sub-sample of each National Survey with Rapid Assessment Survey produced a mixed picture of temporal trends and power to detect change:

3.2.1 Boyne Catchment

A total of 5 surveys have been conducted in the Boyne Catchment from 1980/81 to 2010/11 with sample sizes varying from 12 to 84 sites (Table 12). Otter incidence declined significantly by 37.3% from 1980/81 to 2004/05 and subsequently increased by an estimated 42.8% (though this was not statistically significant) by 2010/11 (Table 13). Rapid Assessment Surveys also demonstrated a recent increase of 17.7% from 2008 to 2010 although this was also not statistically significant (Table 14).

Table 12 Descriptive summary contrasting National Surveys (black text) with Rapid Assessment Surveys (red text) within Hydrometric areas showing the number of sites where otter tracks and signs were recorded (*+ve*) compared to the total sample size of sites surveyed (*n*) with otter occurrence expressed as a percentage (%) for the Republic of Ireland from 1980/81 – 2010/11.

	Catchment															
	Boyne		**Corrib**		**Lennan**		**Lough Derg**		**Munster Blackwater**		**Roaringwater Bay**		**Slaney**		**Upper Shannon**	
	+ve / n	%	*+ve / n*	%	*+ve / n*	%	*+ve / n*	%	*+ve / n*	%	*+ve / n*	%	*+ve / n*	%	*+ve / n*	%
1980/81	78 / 84	92.9	29 / 29	100.0	15 / 15	100.0	67 / 67	100.0	19 / 29	65.5	7 / 7	100.0	55 / 57	96.5	73 / 74	98.6
2004/05	7 / 12	58.3	5 / 6	83.3			5 / 6	83.3	6 / 8	75.0	3 / 4	75.0	15 / 17	88.2	7 / 13	53.8
2006					30 / 38	78.9							46 / 73	63.0		
2007			30 / 63	47.6							46 / 67	68.7				
2008	44 / 76	57.9			30 / 39	76.9			70 / 85	87.1			51 / 72	70.8		
2009							59 / 109	54.1			40 / 67	59.7			20 / 96	20.8
2010/11	13 / 17	76.5	7 / 12	58.3	1 / 2	50.0	13 / 22	59.1	14 / 16	87.5	3 / 6	50.0	3 / 7	42.9	19 / 34	55.9
2010	51 / 76	67.1			21 / 39	53.8			74 / 85	82.4			46 / 71	64.8	24 / 46	52.2
2011											53 / 67	79.1				
TOTAL	193 / 265	**72.8**	71 / 110	**64.5**	97 / 133	**72.9**	144 / 204	**70.6**	207 / 223	**92.8**	99 / 151	**65.6**	216 / 297	**72.7**	143 / 263	**54.4**

Table 13 Temporal changes in otter occurrence (% ± 95%CI) within 'National Surveys' within catchments in the Republic of Ireland from 1980/81 – 2010/11.

Catchment	Change of deviance (df)	*p*	Survey and % occurrence ± 95%CI		Relative % change in occurrence ± 95%CI	
Boyne	10.41 (df=2)	0.005	1980/81[b]	92.86% [84.95%, 96.77%]	1980/81 – 2004/05	-37.3% [-64.6%, -6.7%]
			2004/05[a]	58.33% [30.49%, 81.71%]	2004/05 – 2010/11	42.8% [-22.4%, 164.7%]
			2010/11[a,b]	76.47% [51.14%, 90.98%]	1980/81 – 2010/11	-17.3% [-42.2%, 4.0%]
Corrib (ignoring 1980/81 with 100% occurrence)	1.21 (df=1)	0.270	2004/05	83.33% [32.97%, 98.07%]		
			2010/11	58.33% [28.85%, 82.86%]	2004/05 – 2010/11	-28.4% [-66.7%, 25.0%]
Lennan (ignoring 1980/81 with 100% occurrence)	Only one year with 'National Survey' data during 2010					
Lough Derg (ignoring 1980/81 with 100% occurrence)	1.32 (df=1)	0.250	2004/05	83.33% [34.54%, 97.93%]		
			2010/11	59.09% [37.24%, 77.85%]	2004/05 – 2010/11	-26.4% [-59.1%, 27.3%]
Munster Blackwater	2.78 (df=2)	0.250	1980/81	65.52% [46.50%, 80.60%]	1980/81 – 2004/05	16.6% [-37.0%, 81.2%]
			2004/05	75.00% [36.84%, 93.91%]	2004/05 – 2010/11	21.7% [-21.4%, 116.7%]
			2010/11	87.50% [60.98%, 96.91%]	1980/81 – 2010/11	37.6% [-1.8%, 95.2%]
Roaringwater Bay	0.64 (df=1)	0.420	2004/05	75.00% [17.36%, 97.72%]		
			2010/11	50.00% [13.21%, 86.79%]	2004/05 – 2010/11	-25.3% [-83.3%, 66.7%]
Slaney	13.02 (df=2)	0.001	1980/81[b]	96.49% [86.82%, 99.14%]	1980/81 – 2004/05	-8.2% [-28.2%, 5.6%]
			2004/05[b]	88.24% [62.63%, 97.11%]	2004/05 – 2010/11	-51.5% [-84.8%, -2.9%]
			2010/11[a]	42.86% [14.09%, 77.43%]	1980/81 – 2010/11	-56.4% [-85.7%, -21.7%]
Upper Shannon	39.54 (df=2)	<0.001	1980/81[b]	98.65% [90.91%, 99.81%]	1980/81 – 2004/05	-46.3% [-69.2%, 22.0%]
			2004/05[a]	53.85% [27.94%, 77.83%]	2004/05 – 2010/11	13.1% [-38.8%, 139.0%]
			2010/11[a]	55.88% [38.99%, 71.51%]	1980/81 – 2010/11	-43.3% [-60.7%, -26.4%]

[a] Changes shown in red have 95% confidence intervals that do not include zero and for which the decrease or increase in occurrence was therefore significant.
[b] Means separating groups have been calculated from a Generalized Linear Model. Two years with the same letter are not significantly different from each other.

Table 14 Temporal changes in otter occurrence (% ± 95%CI) within 'Rapid Assessment Surveys' within catchments in the Republic of Ireland from 2006 - 2010.

Catchment	**Change of deviance** (df)	***p***	**Survey and % occurrence ± 95%CI**		**Relative % change in occurrence ± 95%CI**	
Boyne	1.38 (df=1)	0.240	2008	57.89% [46.51%, 68.50%]	2008 – 2010	17.7% [-8.3%, 51.4%]
			2010	67.10% [55.77%, 76.74%]		
Corrib	Only one year with "Rapid Assessment Survey" data (2007)					
Lennan	6.97 (df=2)	0.030	2006[b]	78.95% [63.03%, 89.19%]	2006 – 2008	-0.9% [-22.7%, 25.9%]
			2008[b]	76.92% [61.10%, 87.61%]	2008 – 2010	-29.7% [-51.6%, -6.9%]
			2010[a]	53.85% [38.18%, 68.78%]	2006 – 2010	-31.1% [-52.7%, -6.5%]
Lough Derg	Only one year with "Rapid Assessment Survey" data (2010)					
Munster Blackwater	No change in incidence between the two years with data (2008 and 2010)					
Roaringwater Bay	1.17 (df=1)	0.280	2007	68.66% [56.58%, 78.64%]	2007 – 2009	-12.6% [-32.7%, 13.5%]
			2009	59.70% [47.54%, 70.78%]		
Slaney	1.10 (df=2)	0.580	2006	63.01% [51.41%, 73.29%]	2006 – 2008	14.0% [-10.3%, 42.5%]
			2008	70.83% [59.33%, 80.17%]	2008 – 2010	-7.6% [-27.6%, 14.9%]
			2010	64.79% [53.03%, 74.99%]	2006 – 2010	2.7% [-21.4%, 29.7%]
Upper Shannon	Only one year with "Rapid Assessment Survey" data (2009)					

[a] Changes shown in red have 95% confidence intervals that do not include zero and for which the decrease in incidence is therefore significant.

3.2.2 *Corrib Catchment*

A total of 4 surveys have been conducted in the Corrib Catchment from 1980/81 to 2010/11 with sample sizes varying from 6 to 63 sites (Table 12). Otter incidence appeared to decline from 100% occurrence during the National Survey in 1980/81 (n=29) to 47.6% during the Rapid Assessment Survey in 2007 (n=63) with a subsequent increase to 58.3% during the National Survey in 2010/11 (n=12). However, such was the variation in survey methods and sample sizes that we cannot be confident that such a change was genuine (Tables 13 & 14).

3.2.3 *Lennan Catchment*

A total of 5 surveys have been conducted in the Lennan Catchment from 1980/81 to 2010/11 with sample sizes varying from 2 to 39 sites (Table 12). Otter incidence appeared to decline from 100% occurrence during the National Survey in 1980/81 (n=15) to 53.8% during the Rapid Assessment Survey in 2010 (n=39). This catchment was not covered in the 2004/05 survey and a lack of variation in the 1980/81 survey (which had 100% occurrence) meant that no statistical analysis could be undertaken within the National Surveys (Table 13). However, Rapid Assessment Surveys suggested that otter occurrence remained stable between 2006 and 2008 (at 79 and 77% respectively) but declined by a significant 29.7% between 2008 and 2010 leading to an overall decline of 31.1% from 2006 to 2010 (Table 14) .

3.2.4 *Lough Derg Catchment*

A total of 4 surveys have been conducted in the Lough Derg Catchment from 1980/81 to 2010/11 with sample sizes varying from 6 to 109 sites (Table 12). Otter incidence appeared to decline from 100% occurrence during the National Survey in 1980/81 (n=67) to 54.1% during the Rapid Assessment Survey in 2009 (n=109). Because there was 100% occurrence in the 1980/81 survey, it was not possible to undertake any statistical analysis between the 1980/81 National Survey and any of the other two National Surveys (Table 13). However, despite a 26.4% decline in recorded occurrence there was no statistically significant change in occurrence between the 2004/05 and 2010/11 National Surveys. Only one Rapid Assessment Survey was completed in 2010 when otter occurrence was 54.1% (n=109).

3.2.5 Muntster Blackwater Catchment

A total of 5 surveys have been conducted in the Munster Blackwater Catchment from 1980/81 to 2010/11 with sample sizes varying from 8 to 85 sites (Table 12). Otter incidence appeared to increase from 65.5% occurrence during the National Survey in 1980/81 (n=29) to 98.8% during the Rapid Assessment Survey in 2010 (n=85). Despite an apparent 37.6% increase in otter occurrence between 1980/81 and 2010/11 during National Surveys, sample sizes were small and therefore no significant change could be detected (Table 13). Moreover, there was no change in incidence between the Rapid Assessment Surveys during 2008 and 2010 suggesting a stable population (Table 12).

3.2.6 Roaringwater Bay Catchment

A total of 5 surveys have been conducted in the Roaringwater Bay Catchment from 1980/81 to 2010/11 with sample sizes varying from 4 to 67 sites (Table 12). Otter incidence appeared to decline from 100.0% occurrence during the National Surveys in 1980/81 (n=7) to 50.0% during 2010/11 (n=6). Due to sample sizes there was no significant difference between National Surveys (Table 13). Occurrence within Rapid Assessment Surveys in 2007 and 2009 declined by 12.6% but again there was no significant difference in occurrence (Table 14).

3.2.7 Slaney Catchment

A total of 6 surveys have been conducted in the Slaney Catchment from 1980/81 to 2010/11 with sample sizes varying from 7 to 73 sites (Table 12). Otter incidence varied from 96.5% occurrence during the National Survey in 1980/81 (n=57) to 42.9% occurrence during the Rapid Assessment Survey in 2010 (n=7). There was no significant change in occurrence between the National Surveys during 1980/81 and 2004/05 but incidence dropped by a significant 51.4% from 2004/05 and 2010/11 leading to an overall significant decline from the 1980/81 baseline of 56.4% (Table 13). However, in contrast, Rapid Assessment Surveys in 2006, 2008 and 2010 (n = 71-73) suggested that levels of incidence were stable during this period of time (Table 14).

3.2.8 Upper Shannon Catchment

A total of 5 surveys have been conducted in the Upper Shannon Catchment from 1980/81 to 2010/11 with sample sizes varying from 13 to 96 sites (Table 12). Otter incidence varied from 98.6% occurrence during the National Survey in 1980/81 (n=74) to 20.8% occurrence during the Rapid Assessment Survey in 2009 (n=96). Analysis of the National Surveys suggested a significant 43.3% decline from 1980/81 to 2010/11; however, the majority of this decline occurred between 1980/81 and 2004/05 (Table 13). Rapid Assessment Surveys suggested an increase in incidence from 20.8% during 2009 to 52.2% during 2010 (the latter year was not included in formal analyses as the data were not returned until March 2012).

3.2.9 Spatial variation in Rapid Assessment Surveys

Temporal variation in Rapid Assessment Survey results (reported above) was the result of comparing otter incidence with associated confidence limits *within* the same Catchment during *different* years. Spatial variation was examined by comparing otter incidence *between* Catchment during the *same* year. Otter incidence did not generally vary significantly (p<0.05) between Catchments *within* years (Fig. 7). However, during 2008 otter incidence in the Boyne was 57.9% [95%CI 46.8-69.0] which was significantly lower than that within the Munster Blackwater at 87.1% [95%CI 79.9-94.2]. During 2010, otter incidence was also lower in the Boyne than the Munster Blackwater but not at p<0.05 despite their being no significant temporal change within either Catchment. During 2009, otter incidence in the Derg was 54.1% [95%CI 44.8-63.5] and in Roaringwater Bay was 60.6% [95%CI 48.8-72.4]; both being significantly higher than the Upper Shannon at 20.8% [95%CI 12.7-29.0]. However, otter incidence in the Upper Shannon during 2010 (just 12 months later) was significantly higher at 52.1% [95%CI 38.0-66.2] and not significantly different from values for both the Derg and Roaringwater Bay during 2009 suggesting that values for the Upper Shannon during 2009 may have been erroneous. Nevertheless, otter incidence in the Upper Shannon during 2010 was significantly lower than that within the Munster Blackwater at 82.4% [95%CI 74.2-90.5]. In summary, such was the width of the 95% confidence intervals associated with otter incidence due to relative small sample sizes that despite 17 Rapid Assessment Surveys in 8 Catchments over 6 years, we can only be confident that otter incidence was generally higher in the Munster Blackwater than both the Boyne during 2009 but not 2010 and the Upper Shannon during 2010.

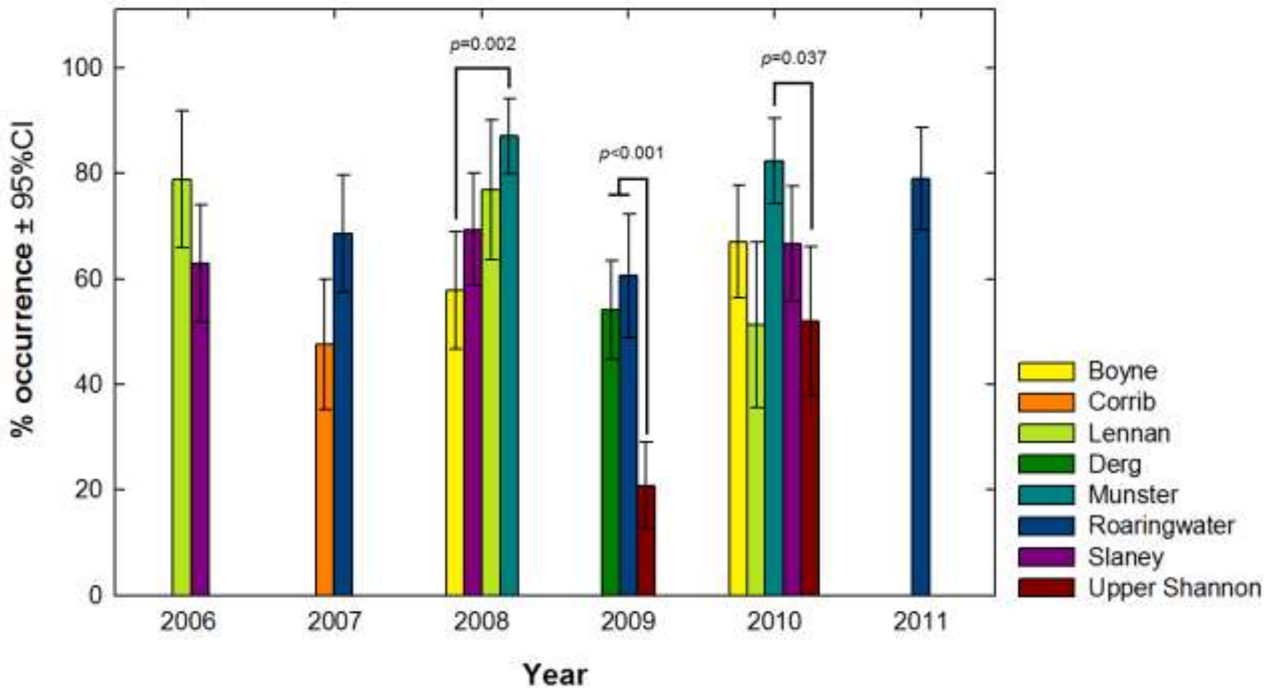


Fig. 7 Observed percentage occurrence (%) ± 95% confidence intervals of Rapid Assessment Surveys showing significant (p<0.05) differences between Catchments within the same year (indicated by brackets above bars and associated p-values) derived from *post-hoc* pairwise Least Significant Differences (LSDs).

3.2.10 Power Analysis of Rapid Assessment Surveys

In contrast to the analysis provided for National Surveys which estimated the sample size (i.e. numbers of sites) required to detect a 10% relative change in otter occurrence between the two surveys, we estimated the power provided by each Rapid Assessment Survey assuming various sample sizes (n=30-200) with the observed occurrence of otters in each of 8 catchments during their last survey between 2006 to 2010 (Appendix II; Table S5). As before, we used the Normal approximation to the binomial distribution. Taken together, the average power of Rapid Assessment Surveys ranged from approximately 10% in the Lennan Catchment (which had sample size of 39 sites) up to approximately 18% power in the Lough Derg catchment (which had a sample size of 109 sites; see Fig. 8).

Again, many hundreds of samples would be required within each catchment to ensure detection of a 10% decline with 80% power and certainly far more than is practical or spatially independent. However, our analyses of temporal trends within Rapid Assessment Surveys suggested that we could detect a 30% decline in occurrence within the Lennan Catchment between 2008 and 2010 (Table 14). Thus, our Power Analysis of individual catchments is largely consistent with that obtained at the National Survey scale.

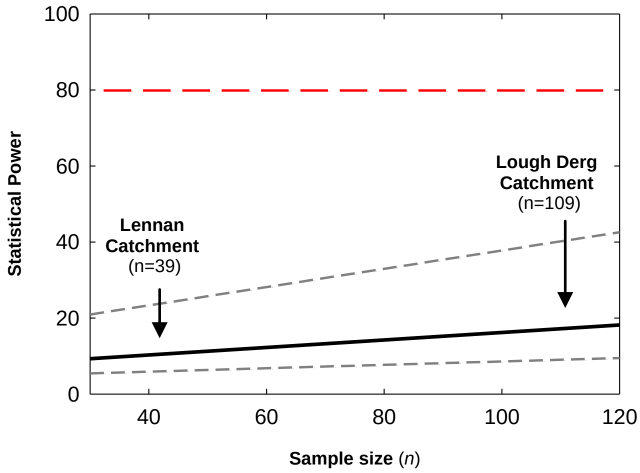


Fig. 8 Statistical power (%) to detect a **10% relative decline** in otter occurrence between two Rapid Assessment Surveys. Mean values (bold black line) and 2.5th and 97.5th percentiles (dash grey lines) were derived from the observed occurrence of otters during the last survey within the Boyne, Corrib, Lennan, Lough Berg, Munster Blackwater, Roaringwater Bay, Slaney and Upper Shannon catchments (for individual catchment results see Appendix II; Table S5). The statistical power in the catchments with the lowest and highest sample sizes is shown. The minimum acceptable level of 80% power is shown as a dashed red line.

3.3 Survey bias and error

Cumulative rainfall had a significant negative impact on the detection of otter tracks and signs along rivers at every temporal lag examined from 1 day i.e. the day of the survey to 28 days i.e. 1 month before the survey (Table 15). The greatest effect was shown at a lag of 7 days (1 week). Rainfall, regardless of the temporal lag examined, had no effect on the detection of tracks and signs at either static freshwater or coastal sites (Table 15). There was a high degree of variation in rainfall during the week prior to the survey in relation to spraint age ($F_{df=2,267}$ = 2.140, p=0.120). Nevertheless, there was a strong trend for sites where old spraints were found to have been drier prior to survey than sites where new spraints were found (Fig. 9).

Table 15 GLM results for the effect of rainfall at various temporal lags (shown in subscript) at **a)** rivers where survey team, number of bridges and number of confluences were fitted as fixed factors, and **b)** coastal and **c)** lake sites, where survey team only was fitted as a fixed factor. The single best approximating model that was statistically significant at *p*<0.05 is shown in bold.

						Effect of rainfall			
Environment	**Fixed factors**	**Covariate**	**AIC**	**ΔAIC**	w_i	$\beta \pm s.e.$	***F***	**df**	***P***
a) Rivers (n=999)	Survey team + bridges + confluences +	Rainfall $_{1\ day}$	1028.1	12.5	0.00	-0.056 ± 0.028	4.08	1,977	0.044
	Survey team + bridges + confluences +	Rainfall $_{2\ days}$	1022.6	7.0	0.02	-0.088 ± 0.029	9.13	1,977	0.003
	Survey team + bridges + confluences +	Rainfall $_{3\ days}$	1021.8	6.2	0.03	-0.093 ± 0.030	9.86	1,977	0.002
	Survey team + bridges + confluences +	Rainfall $_{4\ days}$	1021.5	5.9	0.04	-0.094 ± 0.030	10.18	1,977	0.001
	Survey team + bridges + confluences +	Rainfall $_{5\ days}$	1018.9	3.3	0.14	-0.106 ± 0.030	12.63	1,977	<0.001
	Survey team + bridges + confluences +	**Rainfall $_{7\ days}$**	**1015.6**	**0.0**	**0.74**	**-0.118 ± 0.030**	**15.92**	**1,977**	**<0.001**
	Survey team + bridges + confluences +	Rainfall $_{14\ days}$	1023.4	7.8	0.01	-0.085 ± 0.029	8.79	1,977	0.003
	Survey team + bridges + confluences +	Rainfall $_{21\ days}$	1025.6	10.0	0.00	-0.074 ± 0.028	6.71	1,977	0.010
	Survey team + bridges + confluences +	Rainfall $_{28\ days}$	1027.2	11.6	0.00	-0.064 ± 0.028	5.20	1,977	0.023
b) Coast (n=171)	Survey team +	Rainfall $_{1\ day}$	189.6	1.8	0.40	-0.135 ± 0.112	1.45	1,156	0.231
	Survey team +	Rainfall $_{2\ days}$	190.9	3.1	0.21	-0.057 ± 0.096	0.35	1,156	0.555
	Survey team +	Rainfall $_{3\ days}$	191.1	3.3	0.19	-0.032 ± 0.086	0.14	1,156	0.712
	Survey team +	Rainfall $_{4\ days}$	191.0	3.2	0.20	-0.037 ± 0.083	0.20	1,156	0.656
	Survey team +	Rainfall $_{5\ days}$	190.1	2.4	0.31	-0.086 ± 0.085	1.01	1,156	0.317
	Survey team +	Rainfall $_{7\ days}$	190.7	2.9	0.23	-0.059 ± 0.083	0.51	1,156	0.475
	Survey team +	Rainfall $_{14\ days}$	190.6	2.9	0.24	0.061 ± 0.079	0.59	1,156	0.443
	Survey team +	Rainfall $_{21\ days}$	190.1	2.3	0.32	0.086 ± 0.081	1.14	1,156	0.287
	Survey team +	Rainfall $_{28\ days}$	187.8	<0.1	1.00	0.153 ± 0.081	3.58	1,156	0.060
c) Lakes (n=59)	Survey team +	Rainfall $_{1\ day}$	69.6	0.5	0.77	0.029 ± 0.080	0.13	1,47	0.717
	Survey team +	Rainfall $_{2\ days}$	69.4	0.4	0.83	0.045 ± 0.080	0.31	1,47	0.574
	Survey team +	Rainfall $_{3\ days}$	69.7	0.6	0.73	0.044 ± 0.090	0.23	1,47	0.632
	Survey team +	Rainfall $_{4\ days}$	69.6	0.5	0.79	0.017 ± 0.095	0.03	1,47	0.862
	Survey team +	Rainfall $_{5\ days}$	69.7	0.7	0.72	-0.002 ± 0.094	<0.01	1,47	0.979
	Survey team +	Rainfall $_{7\ days}$	69.1	<0.1	1.00	0.039 ± 0.092	0.18	1,47	0.674
	Survey team +	Rainfall $_{14\ days}$	69.2	0.1	0.95	0.078 ± 0.093	0.70	1,47	0.408
	Survey team +	Rainfall $_{21\ days}$	69.7	0.6	0.73	0.072 ± 0.094	0.60	1,47	0.444
	Survey team +	Rainfall $_{28\ days}$	69.5	0.4	0.80	0.011 ± 0.094	0.01	1,47	0.907

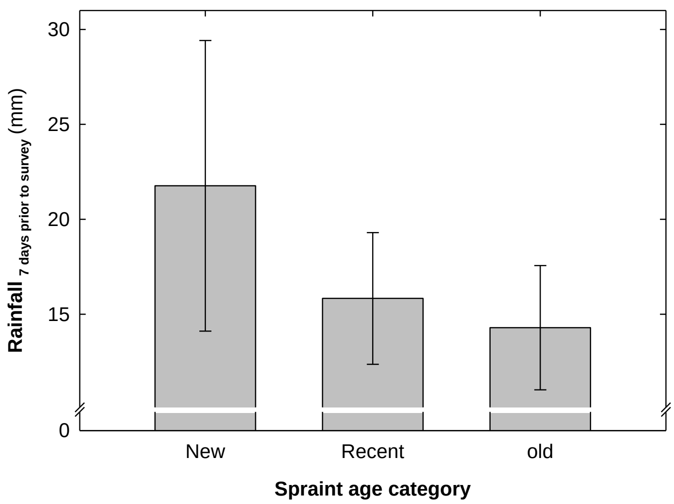


Table 9 Rainfall $_{7\ days}$ ± 95%CI at sites on rivers in relation to the age of spraint found (only sites where all spraints were of the same age were included).

Principal Components Analysis provided two axes describing landscapes relevant to otters. Axis 1 (PC1) accounted for 31% of variance in land cover (eigenvalue = 1.8) and described human-dominated landscapes being positively correlated with Pasture$_{20.5km}$ (r= 0.8) and Human Influence Index (r= 0.7) and negatively correlated with Bog & marsh$_{4.5km}$ (r= -0.8). Axis 2 (PC2) accounted for 22% of variance in land cover (eigenvalue = 1.3) and described aquatic landscapes being positively correlated with Riparian corridor$_{4.5km}$ (r= 0.8), Standing freshwater$_{20.5km}$ (r= 0.5) and Broad-leaved woodland$_{4.5km}$ (r= 0.5). At flowing freshwater sites, detection of otter tracks and signs was significantly affected by DCO survey team, rainfall$_{7days}$, the number of bridges and Landscape PC1 describing 'human-dominated landscapes' (Fig. 10a). Detection of otters varied from 47 to 88% of sites depending on the DCO survey team (Fig. 11a). Otter signs were detected at 61% of sites that had no bridges, 72% of sites with one bridge and 78% of sites with ≥2 bridges (Fig. 11b). Sites where otters were detected typically had 7.0 to 7.5mm less rainfall during the week prior to the survey than those sites where otters were not detected (Fig. 11c).

Neither Hydrometric area or River Basin District, were retained in the top models of otter occurrence (Table 10). Survey team was the only variable retained in the top model for static freshwater sites but was not significant at $p<0.05$ (Fig. 10b). At coastal sites, otter detection was affected principally by survey team and positively related to Landscape PC2 describing 'aquatic landscapes' (Fig.10c).

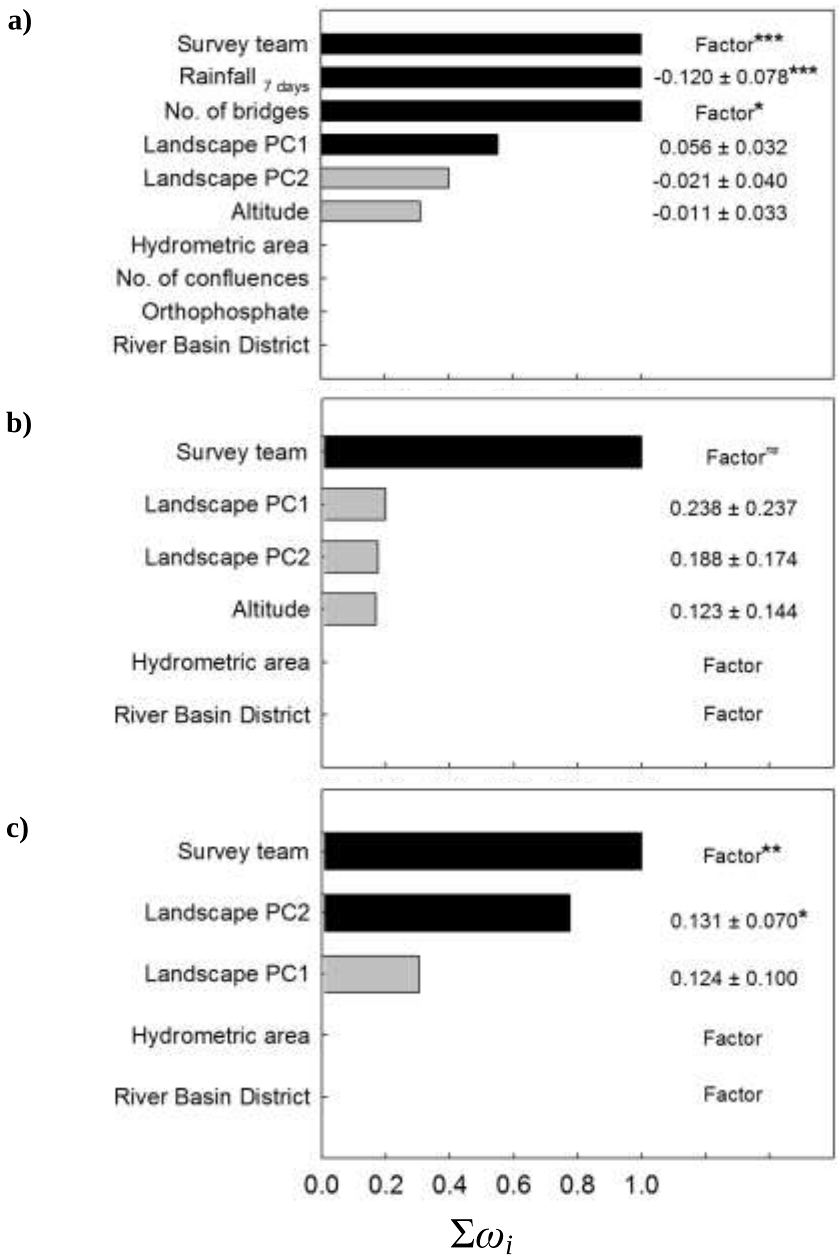
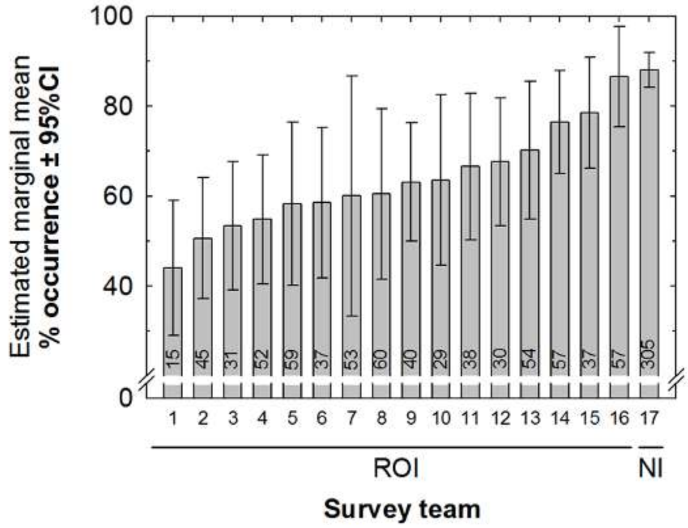
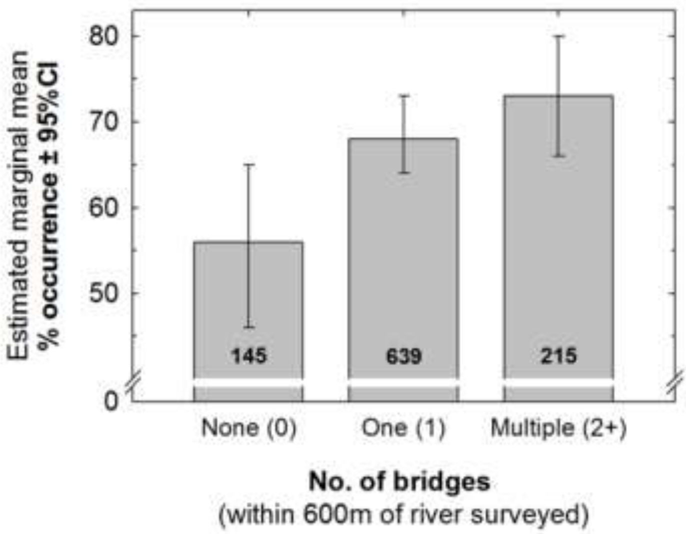


Fig. 10 Relative importance of explanatory variables in explaining variation in otter occurrence at **a)** flowing freshwater, **b)** static freshwater and **c)** coastal sites. Variables are ranked in order of the sum of their Akaike weights ($\Sigma\omega_i$) within the top set of models i.e. models with $\Delta AIC \leq 2$. Black bars indicate those variables that were retained in the best single approximating model (i.e. that with the lowest AIC value) and grey bars indicate variables included in all other models within the top set. Model averaged β coefficents for each covariate are shown to the right of each bar. Statistical significance, in the traditional sense, is indicated as *** $p<0.001$, ** $p<0.01$, * $p<0.05$ and ^{ns} $p>0.05$ (i.e. not significant). Landscape PC1 = "Human-dominated pastoral landscapes" and Landscape PC2 = "Freshwater landscapes" (riparian corridors and standing freshwater fringed with broad-leaved woodland).

a)



b)



c)

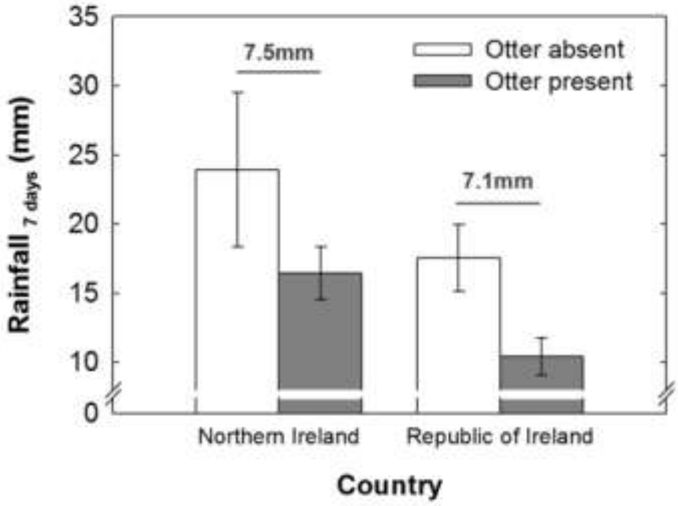


Fig. 11 Variance in otter incidence ± 95%CI between **a)** survey teams and **b)** number of bridges at rivers. **c)** Variation in rainfall during the 7 days prior to survey ± standard error at sites where otter tracks and signs were detected compared to sites where they were not detected (showing the mean difference above the bars).

Naïve species occupancy was 72% throughout Ireland including ROI and NI (Fig. 12). The marginal estimate mean assuming 0mm of rainfall in the week prior to survey was 78% suggesting that paritioning the effects of rainfall accounted for 6% of variance (Fig. 12d). The marginal estimate mean assuming the presence of >2 bridges was 77% suggesting that paritioning the effects of bridges accounted for 5% of variance (Fig. 12e). However, accounting for the β value of the best surveyor yielded a marginal estimated mean of 88% suggesting that paritioning the effects of surveyor accounted for 16% of variance (Fig. 12f) implying that surveyor detectability had approximately 3 times the effect of either rainfall or bridges alone. Accounting for the compound effects of all three sources of bias and error yielded an estimated marginal mean of 94% suggesting that taken together throughout Ireland, these negative biases accounted for a 22% under-estimation of otter incidence (Fig. 12g). Once adjusted, otter incidence appeared highly comparable between River Basin Districts and between the Republic of Ireland and Northern Ireland (Table 16) suggesting that any disparity between River Basin Districts or jurisdictions in naïve otter incidence (report in *Section 3.1* and *3.2* above) were entirely attributable to sources of bias or error.

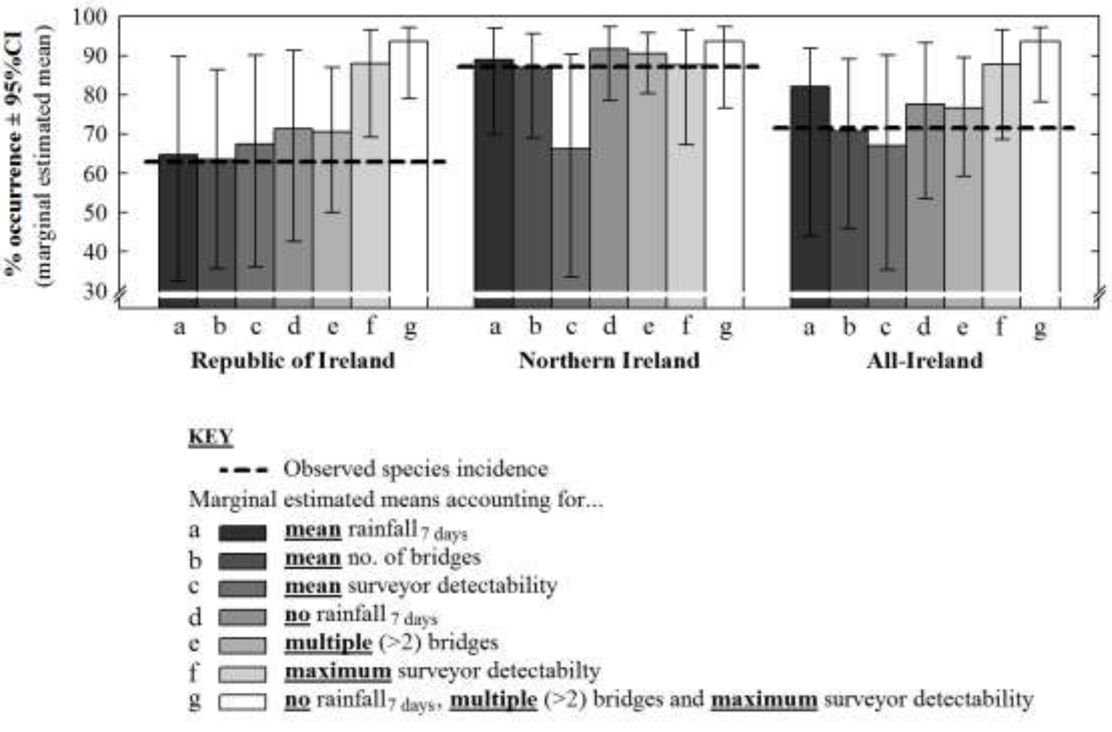


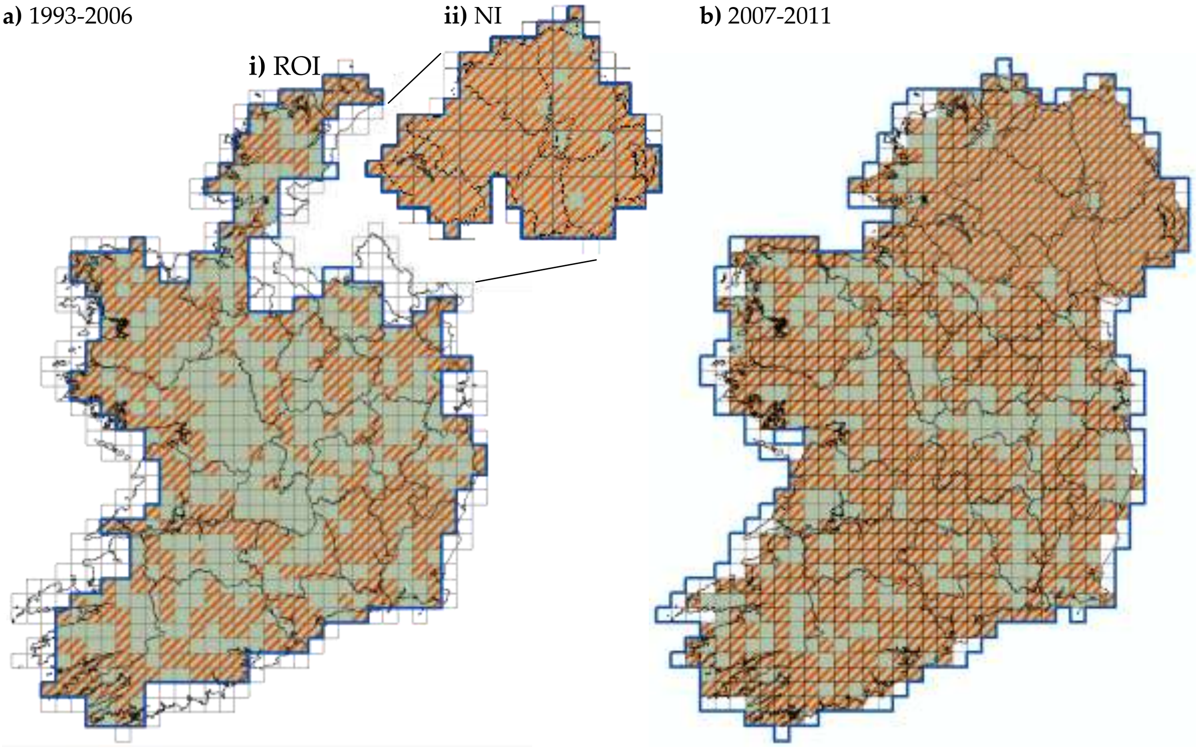
Fig. 12 Marginal estimated mean percentage occurrence of otters after sequential statistical adjustment accounting for variance in survey team (i.e. surveyor detectability), rainfall $_{7days}$ and the number of bridges at flowing freshwater sites. Species incidence was higher in Northern Ireland than in the Republic of Ireland due to the consistency and reliability of reporting from just one survey team which covered the entire region including a highly experienced individual (see Preston *et al.* 2006). This compared to 17 teams consisting of 75 individuals working throughout the Republic of Ireland. Thus, the estimated mean after adjustment for mean surveyor detectability (**c**) was higher than the observed value in the Republic of Ireland but substantially less than the observed value in Northern Ireland.

Table 16 Statistical adjustment of estimated otter incidence (% occurrence) including flowing freshwater assuming maximum survey team detectability, no $rainfall_{7days}$ (0mm) and multiple bridges (≥2) while adjustments at static freshwater and coastal sites assumed maximum surveyor detectability only.

			Estimated otter incidence % occurrence [95%CI]		
Country	**River Basin District**	***n***	**Observed**	**Corrected**	**Δ occurrence**
Republic Ireland	Eastern	65	52.3 [40.2 - 64.1]	94.1 [83.8 - 97.2]	41.8 [19.7 - 57.0]
	Neagh Bann	26	46.2 [28.1 - 65.3]	94.2 [80.7 - 97.4]	48.0 [15.4 - 69.3]
	North Western	101	62.4 [52.5 - 71.3]	92.9 [76.2 - 96.8]	30.5 [4.9 - 44.3]
	Shannon	216	59.3 [52.6 - 65.6]	93.9 [80.7 - 97.2]	34.6 [15.1 - 44.6]
	South Eastern	130	70.8 [62.4 - 77.9]	94.0 [85.2 - 97.1]	23.2 [7.3 - 34.7]
	South Western	161	68.3 [60.7 - 75.1]	93.8 [76.9 - 97.3]	25.5 [1.8 - 36.6]
	Western	153	65.4 [57.5 - 72.5]	92.6 [73.0 - 96.8]	27.2 [0.5 - 39.3]
	Sub-total	**852**	**63.3 [60.0 - 66.4]**	**93.6 [79.0 - 97.1]**	**30.3 [12.6 - 37.1]**
Northern Ireland	Neagh Bann	162	93.2 [88.2 - 96.2]	93.7 [79.7 - 97.2]	0.5 [-16.3 - 9.0]
	North Eastern	80	87.5 [78.4 - 93.1]	93.9 [68.1 - 98.0]	6.4 [-25.0 - 19.6]
	North Western	135	83.7 [76.5 - 89.0]	93.2 [77.9 - 97.0]	9.5 [-11.1 - 20.5]
	Sub-total	**377**	**88.6 [85.0 - 91.4]**	**93.6 [76.6 - 97.3]**	**5.0 [-14.8 - 12.3]**
All-	**TOTAL**	**1,229**	**71.7 [68.5 - 74.9]**	**93.6 [78.2 - 97.1]**	**21.9 [3.3 - 28.6]**

3.4 EC Habitats Directive Conservation Assessment

Otters were widespread throughout Ireland during 1993-2006 (Fig. 13a). The range in the Republic of Ireland was 665 x 10km cells and in Northern Ireland was 170 cells. Otters remained widespread during 2007-2011 (Fig. 13b) with the number of records (i.e. occupied 10km cells) increasing significantly by 52% in the Republic of Ireland ($\chi^2_{df=1}$ = 11.3, p<0.001) and 6% in Northern Ireland ($\chi^2_{df=1}$ = 2.8, p=0.09; Fig. 13c). As their current distribution was larger than that recorded at baseline, the range was revised and when reassessed on an All-Ireland scale all 1,015 cells available for occupation were deemed suitable for the species. Power analysis suggested that the target for future surveys should be to record the otter as present in 504-581 cells in the Republic of Ireland, 160-182 cells in Northern Ireland or 666-746 cells throughout Ireland (if a trans-boundary assessment is used) in order to demonstrate no significant change (p<0.05) in its range.



c)

		Northern Ireland	Republic of Ireland	All-Ireland
Favourable reference range	Baseline	170	665	826
(bold blue line)	Updated	189 (*+11%*)	870 (*+31%*)	**1,015** (*+23%*)
Distribution	Past	163	358	515
(hatched orange cells)	Current	173 (*+6%*)	543 (*+52%*)	**707** (*+37%*)

Fig. 13 a) Map of the recorded '*distribution*' (orange hatching) i.e. occupied 10km cells; '*range*' (green) i.e. cells enclosed by the observed distribution; and '*favourable reference range*' (bold blue line) i.e. maximum likely extent of the range for the otter in **i)** Republic of Ireland (ROI) and **ii)** Northern Ireland (NI) from 1993-2006 as reported previously under Article 17 of the EU Habitats Directive. Despite sharing 44 x 10km cells along their common border both jurisdictions report to the European Commission separately meaning that the same cell can be otter positive in one country but otter negative in the other (hence the two maps). **b)** The same representation for All-Ireland from 2007-11 treated as a single biogeographical ecoregion. **c)** A descriptive breakdown and analysis of temporal change allowing each jurisdiction to report separately. Note that the All-Ireland figures are not a summation of both countries due to shared cells along their border.

Landscape productivity throughout Ireland changed between 1993-2006 and 2007-2011 with areas of low orthophosphate concentration expanding west-to-east replacing some areas of intermediate productivity, although eastern and southern areas of high productivity remained largely stable due to association with intensive agriculture (Fig. 14a-b). The density of suitable habitat for otters (streams, rivers and lake edge) was highest in the Western River Basin District whilst coastal complexity was high in both the Western and North Eastern River Basin Districts (Fig. 14c). The total estimate of adult otter abundance in the Republic of Ireland was 7,800 (95%CI 7,200 - 10,200) breeding females and did not differ significantly from that reported for 1981/82 which was 7,100 (95%CI 6,600 - 8,500) i.e. the 95% confidence intervals substantially overlapped (Table 17). A total of 1,109 [1,038 - 1,453] breeding female otters were estimated to be within otter designated SACs representing 14.2% of the total population in the Republic of Ireland during 2010/11 (Table 17)

Whilst estimates of otter incidence corrected for survey bias were largely uniform between River Basin Districts (Table 16), variance in the occurrence and density of suitable habitat resulted in regional variation in estimated otter density which was highest in the Western and North Eastern River Basin Districts (Fig. 14d).

Accounting for survey bias (i.e. surveyor, rainfall and bridges), field signs of otters were positively associated with river size (Fig. 15a & 16), banks >1m high sloping at >30^{o}, substrates composed of cobbles, gravel, boulders and exposed bedrock, channel and side bars and salmonid biomass (Fig. 15a). There were no significant variables retained in the top model of otter occurrence at lakes (Fig. 15b). Otter occurrence on the coast was positively associated with the biomass of salmonids in adjacent rivers running out to sea (Fig. 15c).

Some level of perceived disturbance (on an ordinal scale from 1-5) was recorded at 578 sites (59%) but 53% of these had a score of less than 3 (intermediate levels). Sources of disturbance included canal resectioning with bank maintenance at 216 sites (22%) and canalisation with mechanical weed control at 110 sites (11%). Boating activity and harbours occurred at 94 sites (10%) whilst angling, shooting and game keepering were present at 212 sites (22%). Mink were recorded at 117 sites out of 841 (14% occurrence) at which surveyors completed the field survey (see Appendix III). None of these perceived pressures or water quality was determined as actual threats as none was retained in the top models of otter occurrence, and thus had no discernible negative effect on otter occurrence in either rivers, lakes or the coast (Fig. 15).

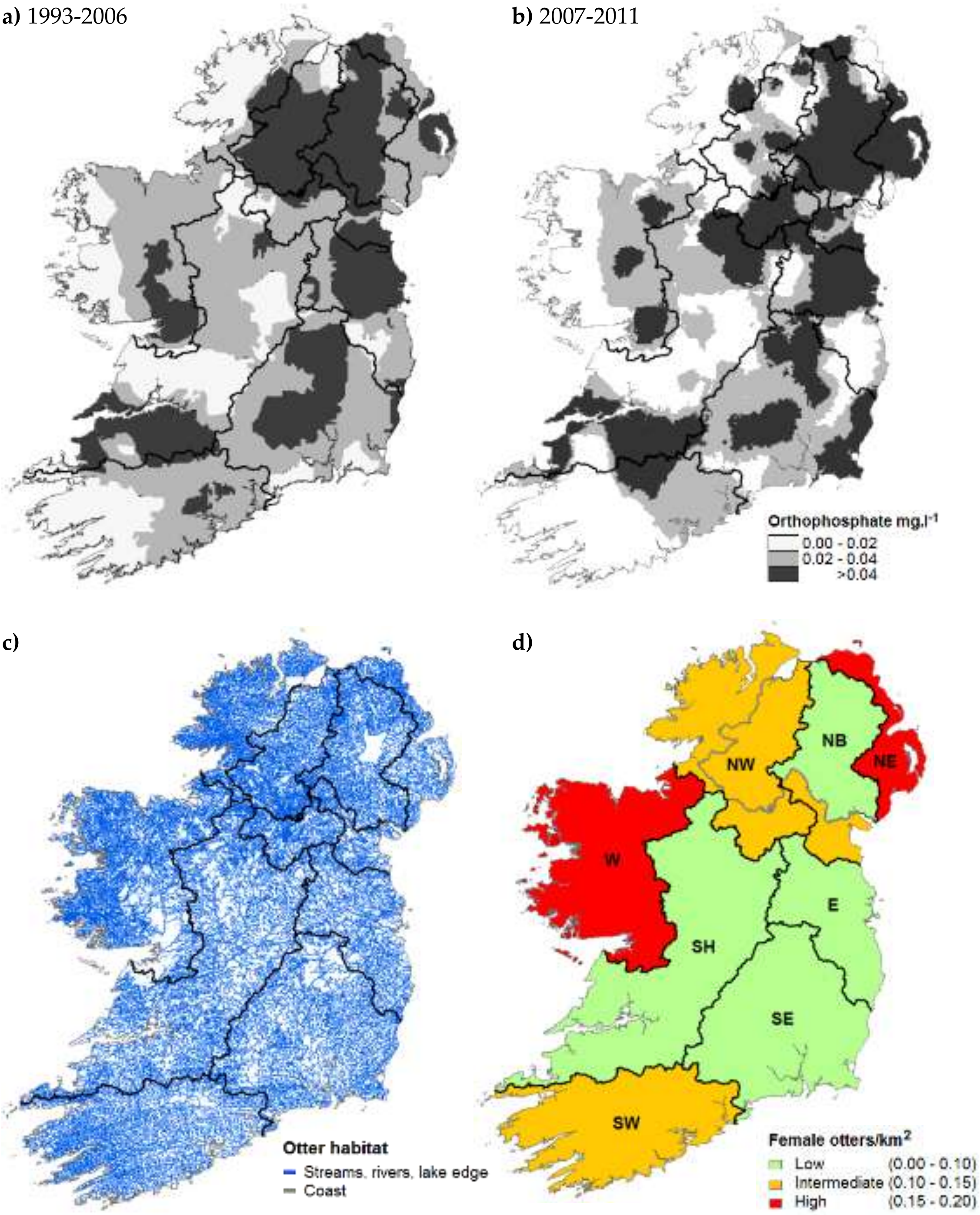


Fig. 14 Isoclines of orthophosphate levels (productivity) in Irish freshwaters during **a)** 1993-2006 [extracted from Ó Néill 2008] and **b)** 2007-2011. Regional variation in **c)** the density of suitable otter habitat represented by streams, rivers, lake edge and the coast and **d)** estimated otter density. Bold black lines represent the boundaries of EU River Basin Districts including North Eastern (NE), Eastern (E), South Eastern (SE), Neagh-Bann (NB), Shannon (SH), North Western (NW), Western (W) and South Western (SW). The Northern Ireland border is presented by a dark grey bold line.

Table 17 Estimates of otter incidence during 1981-82 (extracted from Ó Néill, 2008 based on species incidence from Chapman & Chapman, 1982) compared to current estimates based on incidence from Reid *et al.* (2013b) given as adult females (individuals) ± 95% confidence intervals in parentheses.

Country	River Basin District	Population estimates 1981-82 TOTAL		Population estimates 2010-11 Otter SACs†		Population estimates 2010-11 TOTAL	
Republic of Ireland	Eastern	552	[497 - 684]	30	[29 - 40]	585	[556 - 742]
	Neagh Bann	121	[107 - 153]			223	[206 - 274]
	North Western	927	[850 - 1,106]	153	[146 - 189]	1,069	[1,015 - 1,316]
	Shannon	1,515	[1,401 - 1,779]	199	[186 - 267]	1,644	[1,531 - 2,200]
	South Eastern	1,024	[918 - 1,295]	106	[99 - 146]	1,153	[1,081 - 1,593]
	South Western	1,204	[1,121 - 1,384]	210	[199 - 266]	1,311	[1,158 - 1,660]
	Western	1,784	[1,664 - 2,073]	411	[379 - 545]	1,809	[1,671 - 2,401]
	Sub-total	**7,127**	**[6,558 - 8,474]**	**1,109**	**[1,038 - 1,453]**	**7,794**	**[7,218 - 10,186]**
Northern Ireland	Neagh Bann	434	[407 - 514]	3	[3 - 4]	555	[507 - 691]
	North Eastern	231	[207 - 285]			572	[518 - 679]
	North Western	469	[435 - 554]	21	[20 - 28]	510	[472 - 663]
	Sub-total	**1,134**	**[1,049 - 1,353]**	**24**	**[23 - 32]**	**1,637**	**[1,497 - 2,033]**
All-Ireland	**TOTAL**	**8,261**	**[7,607 - 9,827]***	**1,133**	**[1,061 - 1,485]**	**9,431**	**[8,715 - 12,219]**

* Note that these figures differ from those reported by Ó Néill (2008) due to the correction of a minor totalling error in the original calculations.

† Population estimates were the cumulative population within 44 SACs where otters were a designated feature and not from all SACs.

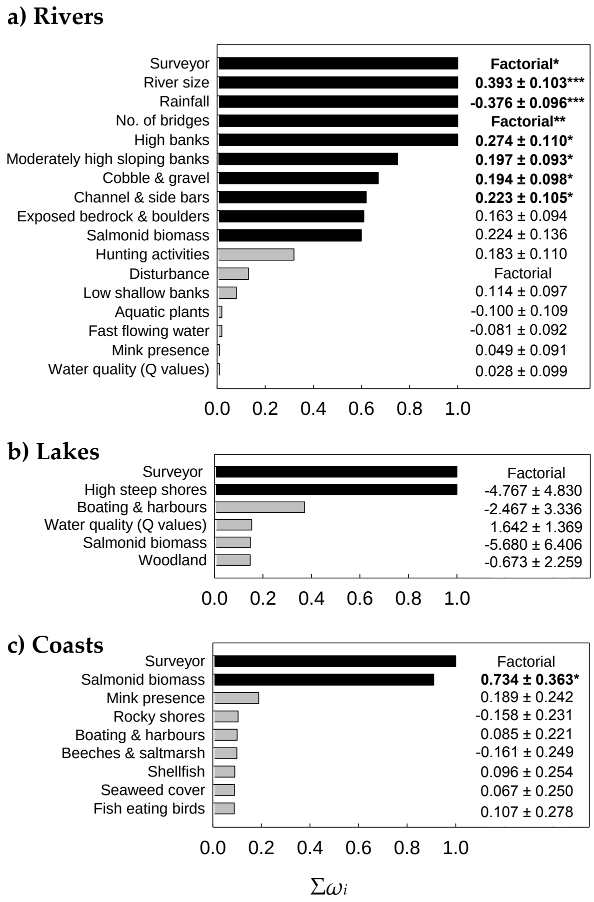


Fig. 15 Relative importance of explanatory variables in explaining variation in otter occurrence at **a)** rivers, **b)** lakes and **c)** the coast. Variables are ranked in order of the sum of their Akaike weights ($\Sigma\omega_i$) within the top set of models i.e. models with $\Delta AIC \leq 2$. Black bars indicate those variables that were retained in the best single approximating model (i.e. that with the lowest AIC value) and grey bars indicate variables included in all other models within the top set. Variables listed in Table 2 that are missing indicate that they were not included in the top set. Model averaged β coefficients ± 95% confidence intervals for each covariate are shown to the right of each bar. Statistical significance is indicated in bold where *** p<0.001, ** p<0.01, * p<0.05.

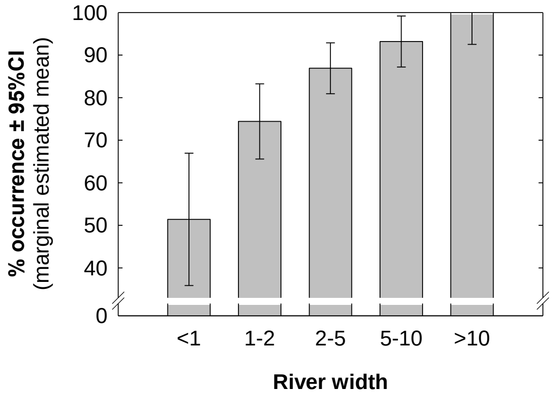


Fig. 16 Otter incidence (corrected for bias in surveyor, rainfall and the number of bridges) at rivers of varying size. Note that river width and depth were positively correlated (r_p =0.484, p<0.001).

3.5 Review and meta-analysis of otter diet

3.5.1 Riverine diet

Eleven studies (52.4%) out of the 21 reviewed provided percentage *frequency* data which summarised the analysis of 4,854 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 & 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 18). 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.,* 2006). 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 (Ó Néill, 1995).

There were no significant differences in the percentage frequency of fragments of each fish species present in spraints reported by previous studies and the current study (Table 18). However, the overall percentage frequency of fish was significantly lower during the current study than previous studies representing 45.8% of items identified during 2010. The difference was made up by a significantly higher percentage frequency of invertebrate prey in the current study, the majority of which (21.1%) consisted of white-clawed crayfish exoskeleton. This was notably higher than previous studies which had a mean percentage frequency of 3.8% crayfish. The remaining difference was made up by a significantly higher frequency of mammal remains representing 8.4% of items in the current study compared to 1.2% in previous studies. Otherwise, the diet of riverine otters described during 2010 was largely similar to that described in the literature.

Table 18 A review of the percentage *frequency* of items in the diet of otters in predominantly riverine habitats throughout Ireland as derived from spraint analysis comparing the mean values (95% confidence intervals) from previous studies with the current study by means of a G-test.

	Republic of Ireland						Northern Ireland							
Prey items	Chapman & Chapman (1980)*	Braethnach & Fairely (1993) †	Tangney & Fairley (1994) †	O'Sullivan (1994)	Ottino & Giller (2004)	Bailey & Rochford (2006)	Vincent Wildlife Trust (1980)‡	Aughey (2004)	Preston et al. (2006)	Preston et al. (2007)	**Previous studies** (mean value)	**Current study** (2011)	**$G_{df=1}$**	***p***
Fish														
Salmonid spp.	20.6	4.9	24.7	25.0	37.9	21.1	37.7	16.9	17.5	39.1	**24.5** (17.7 - 31.3)	**21.7** (17.6 - 25.9)	0.070	0.791
Eel	15.6	2.0	28.7	26.9	14.6	18.4	16.5	7.3	8.9	9.3	**14.8** (9.6 - 20.0)	**7.3** (5.0 - 9.5)	1.940	0.164
Stickleback	23.0	9.3	0.0	1.6	2.8	12.6	9.1	17.5	21.2	8.0	**10.5** (5.5 - 15.5)	**5.9** (3.5 - 8.3)	0.797	0.372
Perch	3.8	9.3	0.0	0.0	0.0	5.5	1.4	2.1	2.4	0.7	**2.5** (0.7 - 4.4)	**4.3** (2.3 - 6.4)	0.094	0.759
Cyprinid spp.	7.3	17.1	0.0	7.5	0.6	4.2	8.2	7.1	12.3	7.4	**7.2** (4.0 - 10.3)	**1.5** (0.6 - 2.5)	2.680	0.102
Stoneloach	0.0	6.0	0.0	7.7	0.0	1.0	5.1	3.7	6.8	1.5	**3.2** (1.3 - 5.1)	**0.7** (0.0 - 1.4)	0.592	0.442
Pike	2.0	6.9	0.0	0.0	0.0	1.2	2.9	1.8	2.8	0.0	**1.8** (0.4 - 3.1)	**4.2** (2.7 - 5.8)	0.330	0.566
Other fish spp.	0.0	2.3	0.0	0.0	0.0	8.5	0.0	4.7	7.1	0.0	**4.6** (1.0 - 8.2)	**<0.1** (0.0 - 0.1)	2.926	0.087
Sub-total	**72.3**	**57.8**	**72.0**	**68.7**	**55.9**	**72.5**	**80.9**	**61.0**	**79.0**	**66.0**	**69.1 (63.6 - 74.6)**	**45.8 (40.4 - 51.2)**	**4.356**	**0.037***
Invertebrates														
Crayfish	1.4	23.6	0.0	0.0	0.3	5.1	0.0	3.2	4.2	0.0	**3.8** (0.0 - 8.3)	**21.1** (16.0 - 26.3)	11.604	<0.001*
Other invertebrates	0.0	4.2	12.0	16.6	18.2	0.0	0.0	12.8	0.0	0.0	**6.4** (1.6 - 11.1)	**5.8** (4.1 - 7.4)	0.013	0.909
Sub-total	**1.4**	**27.8**	**12.0**	**16.6**	**18.5**	**5.1**	**0.0**	**16.0**	**4.2**	**0.0**	**10.2 (4.3 - 16.0)**	**26.9 (21.7 - 32.1)**	**6.858**	**0.009***
Other														
Frog	19.2	9.3	12.3	0.3	17.1	12.8	6.0	16.4	10.9	10.2	**11.5** (8.0 - 14.9)	**6.2** (3.8 - 8.6)	1.055	0.304
Birds	2.2	1.4	1.3	9.8	1.2	3.6	0.0	3.2	0.0	0.0	**2.3** (0.0 - 4.1)	**5.8** (3.2 - 8.4)	0.784	0.376
Mammals	0.2	0.2	0.0	2.0	0.8	5.9	0.0	3.2	0.0	0.0	**1.2** (0.0 - 2.4)	**8.4** (5.3 - 11.6)	4.343	0.037*
Misc & unidentified	4.8	3.5	0.7	2.6	6.2	0	13.1	1.2	5.9	23.1	**5.6** (1.1 - 10.2)	**6.2** (4.2 - 8.1)	0.014	0.907
Sub-total	**26.4**	**14.4**	**14.3**	**14.7**	**25.4**	**22.3**	**19.1**	**24.0**	**16.8**	**33.3**	**20.2 (16.8 - 24.3)**	**26.6 (21.8 - 31.4)**	**0.624**	**0.429**
Total	**100.1**	**100.0**	**98.3**	**100.0**	**99.8**	**99.9**	**100.0**	**101.0**	**100.0**	**99.3**	**99.7**	**99.3**	-	-

* Sprains collected during 1979-81 by Chapman & Chapman (1980) were analyzed during 2004-05 by Bailey & Rochford (2006), † Study included lacustrine and riverine results but only riverine results are presented here, ‡ Spraints collected during 1980 by the Vincent Wildlife Trust were analyzed during 2006 by Preston *et al.* (2007), *NB:* Values that do not sum to 100.0% are due to rounding error.

The percentage frequency of salmonids, crayfish, birds and miscellaneous and unidentified prey items varied regionally (Table 19) being significantly different between River Basin Districts (Wilk's Λ = 0.427, p=0.002). Most notably, salmonid bones dominated spraints collected in the South Western River Basin District whilst crayfish exoskeleton fragments dominated spraints collected in central regions (Fig. 17). For individual records of crayfish occurrence see Appendix IV. Other studies in catchments with relatively high salmonid abundance, for example the Agivey River, indicate that percentage occurrence of salmonids can be as high as 81% (Fairley & Wilson, 1972). Generally, spraint composition did not vary with levels of productivity (Wilk's Λ = 0.909, p=0.339); however, the percentage frequency of salmonids was negatively related to levels of orthophosphate (standardised $\beta \pm$ s.e. = -0.052 ± 0.022) whilst crayfish remains were positively related to productivity (standardised $\beta \pm$ s.e. = +0.064 ± 0.027). Spraint composition did not vary with salmonid biomass (Wilk's Λ = 0.924, p=0.549). This was supported by Compositional Analysis which suggested that otters did not actively select salmonids over non-salmonids during 2010 (Wilk's Λ = 0.982, p=0.266).

Table 19 MANOVA results showing variation in the percentage *frequency* of items in the diet of otters in predominately riverine habitats throughout Ireland during 2010 with respect to regionality or River Basin District (RBD), Productivity (as described by levels of orthophosphate) and Salmonid biomass (from electrofishing surveys).

		RBD		Productivity		Salmonid	
Dependent variables	**r²**	$F_{df=7}$	p	$F_{df=1}$	p	$F_{df=1}$	p
Fish							
Salmonid spp.	0.126	3.29	**0.003****	4.81	**0.031***	0.08	0.780
Eel	0.075	1.92	0.069	0.05	0.832	0.30	0.588
Stickleback	0.042	1.09	0.375	0.31	0.576	0.04	0.847
Perch	0.053	1.08	0.380	0.27	0.603	0.24	0.624
Cyprinid spp.	0.024	0.54	0.802	0.25	0.621	0.61	0.435
Stoneloach	0.057	1.35	0.227	<0.01	0.998	1.06	0.305
Pike	0.036	0.93	0.483	0.02	0.881	0.01	0.920
Other fish spp.	0.014	0.32	0.945	0.06	0.807	0.01	0.927
Invertebrates							
Crayfish	0.179	3.37	**0.002****	6.67	**0.011***	0.70	0.403
Other invertebrates	0.031	0.80	0.593	<0.01	0.998	0.19	0.667
Other							
Frog	0.059	0.62	0.743	0.06	0.814	7.07	**0.009****
Birds	0.119	3.39	**0.002****	1.57	0.211	0.51	0.478
Mammal	0.057	0.94	0.480	0.21	0.644	2.81	0.095
Misc. & unidentified	0.103	2.49	**0.018***	1.20	0.275	0.61	0.435

In the sub-sample of 77 sites for which electrofishing data were available, salmonid bones comprised 25.3% of items in spraints but 45.0% of the total fish biomass available (at riffles). The most notable relationship between the percentage frequencies of various prey items within spraints (Table 20) was a negative correlation between the frequency of salmonids and crayfish reflecting regional variation in prey availability. Crayfish occur predominately in the central lakelands whilst salmonids inhabit rivers close to the coast particularly in North-Western, Western and South-Western River Basin Districts (Fig. 17). Aughey (2004) demonstrated that total weight (bulk) of salmonids in otter diet was positively correlated with altitude and the abundance and diversity of river invertebrates.

Crayfish can occur in up to 80% of spraints forming around 76% of their bulk (McFadden and Fairley, 1984). Berried females are also taken (Kyne *et al*., 1989), particularly in winter, suggesting that otters may have an impact on crayfish populations by predating reproductive individuals at a critical time of year. Other invertebrates eaten include large and small insects, such as *Dytiscus* beetles (Breathnach & Fairley, 1993; Kyne *et al*., 1989), and amphipods (Breathnach & Fairley, 1993; Preston *et al.*, 2007) which are typically taken in slow-moving or stagnant water (Tangney & Fairley, 1994). Freshwater mussels (including the critically endangered pearl mussel *Margaritifera margaritifera*) are also taken along rivers in which they occur, for example the River Blackwater, Co. Cork, where indirect evidence has been found including broken shells with serrated tooth marks (Norris, 1974; O'Sullivan, 1994).

Birds appearing in the diet of otters include Anseriformes, Columbiformes, Passeriformes and Rallidae (e.g. O'Sullivan, 1994). Otters are known to feed opportunistically on carrion (O'Sullivan, 1994) which may account for records of large non-waterbird species, for example, members of the Columbiformes including the wood pigeon (*Columba palumbus*).

In the current study, mammalian remains were not identified to species. However, previous studies reported woodmice (*Apodemus sylvaticus*), bank vole (*Myodes glareolus*), brown rat (*Rattus norvegicus*) and rabbit (*Oryctolagus cuniculus*) in the diet (Breathnach & Fairley, 1993; O'Sullivan, 1994; Preston *et al.*, 2006). Otter diet has been observed to change after biological invasions of freshwater systems by invasive species. For example, the invasion of roach into the limestone river systems of the west of Ireland during the 1980s resulted in a major shift in the diet whereby roach became increasingly important (Breathnach & Fairley, 1993; McFadden & Fairley, 1984). Similarly, the bank vole is an invasive species that was introduced to the south-west of Ireland during the late 1920s (Stuart *et al.*, 2007) and has subsequently spread to occupy the south-western third of the island (White *et al.*, 2012). Moreover, it has been shown to have a major impact on native systems changing the structure of mammalian communities (Montgomery *et al.*, 2012).

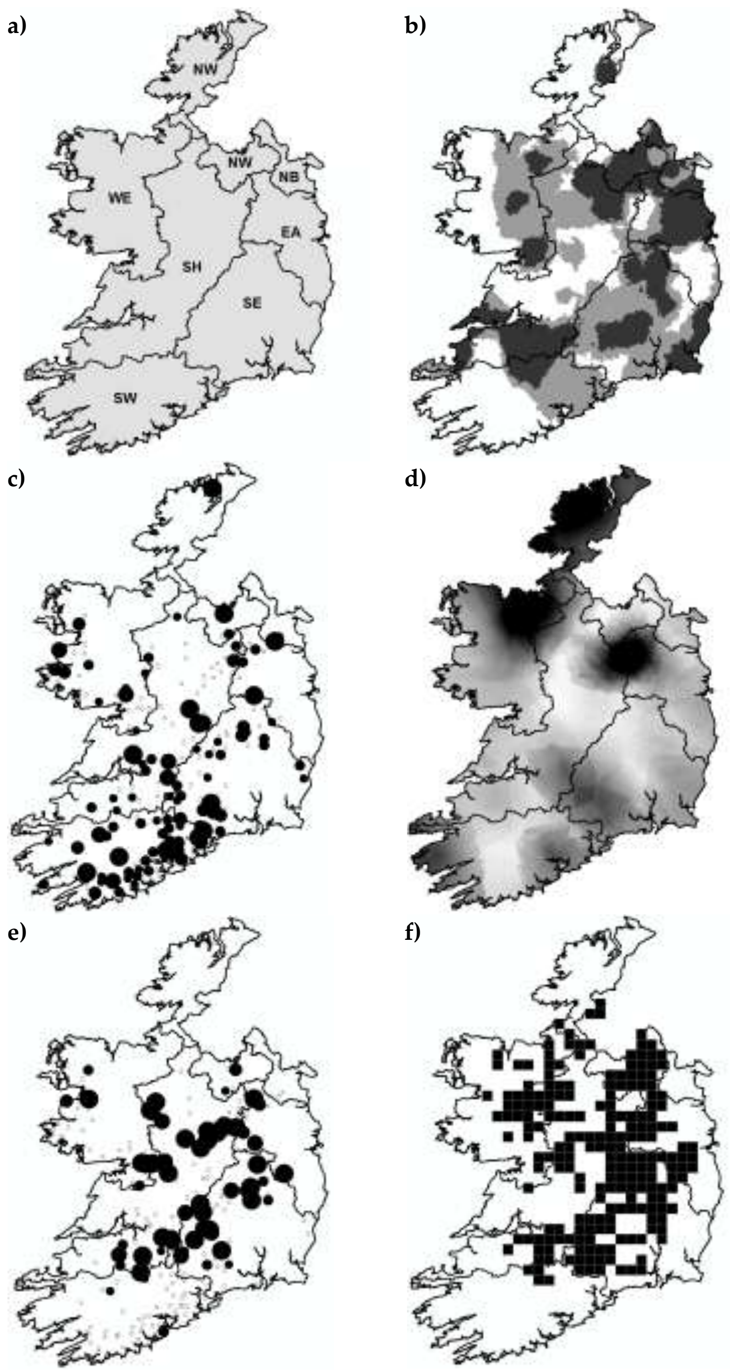


Fig. 17 a) River Basin Districts in the Republic of Ireland, namely the North-Western (NW), Neagh-Bann (NB), Eastern (EA), South-Eastern (SE), South-Western (SW), Shannon (SH) and Western (WE), **b)** isocline of river productivity measured as levels of orthophosphate (high, intermediate and low), **c)** the percentage frequency of Salmonid remains in otter spraints collected along rivers during 2011 (dots are scaled proportionally), **d)** the availability of Salmonids described by biomass (kg/m2) derived from electrofishing data from 2008-10 (dark shading indicate high biomass), **e)** the percentage frequency of white-clawed crayfish in otter spraints (dots are scaled proportionally) and **f)** the distribution of crayfish throughout Ireland during 1993-2006 [extracted from NPWS, 2008].

Table 20 Spearman's rho correlation matrix between the percentage frequency of items in the diet of otters in rivers throughout Ireland during 2010. Values are r_s and significance is denoted as * p<0.05, **p<0.01 and ***p<0.001.

	Salmonid	Eel	Stickleback	Perch	Cyprinid spp.	Stone loach	Pike	Other fish spp.	Crayfish	Other inverts	Frog	Birds	Mammal	Misc
Salmonid spp.	-	0.035	-0.138	-0.018	-0.010	0.104	**0.201****	0.026	**-0.396****	-0.014	**0.240****	-0.032	-0.070	-0.119
Eel		-	**0.179***	0.053	0.054	0.117	0.002	-0.039	**-0.252****	0.083	-0.033	0.004	-0.90	-0.054
Stickleback			-	0.072	-0.075	-0.006	-0.041	-0.033	**-0.148***	-0.108	-0.056	0.072	-0.068	-0.026
Perch				-	0.033	-0.066	0.110	-0.027	**-0.189***	0.032	0.068	-0.015	-0.046	-0.037
Cyprinid spp.					-	0.060	0.099	**0.250****	-0.107	0.020	0.054	-0.051	-0.092	-0.002
Stone loach						-	0.084	**0.392****	-0.116	-0.116	-0.017	0.003	-0.091	-0.127
Pike							-	-0.032	**-0.146***	0.048	**0.143***	**-0.142***	-0.041	-0.058
Other fish spp.								-	-0.047	-0.047	**0.162***	-0.030	-0.037	-0.051
Crayfish									-	-0.028	**-0.189****	-0.163*	**-0.170***	0.017
Other inverts										-	-0.025	0.055	0.105	0.140
Frog											-	-0.007	-0.075	-0.048
Birds												-	-0.045	0.065
Mammal													-	0.055
Misc														-

Miscellaneous and unidentified items typically included groomed hair (Breathnach & Fairley, 1993; Kyne *et al.*, 1989) & vegetation (O'Sullivan, 1994). The latter is sometimes reported in the diet as ingested incidentally; for example, grasses on a river bank consumed whilst eating prey items such as larger fish. However, some studies have recorded blackberries *Rubus* spp. and have suggested that these may have been actively foraged (O'Sullivan, 1994). Certainly, North America otters (*Lutra canadensis*) are known to take blueberries (*Vaccinium* spp.) and rose hips (*Rosa* spp; Whitaker & Hamilton, 1998).

The occurrence and frequency of fish components tends to peak during winter whilst other prey, such as crayfish appear less important at this time of year (Breathnach & Fairley, 1993) probably reflecting their lower levels of activity in colder water (Erlinge, 1968). The common frog *Rana temporaria* is taken most often during late winter and early spring (Fairley, 1984; Ottino & Giller, 2004) reflecting seasonal aggregations and high local abundance during the spawning period from January to April (Reid *et al.,* 2013a). It is notable that otters do not prey on breeding Natterjack toads *Bufo calamita* presumably due to the distasteful exudates from their dermal glands (Fairley and McCarthy, 1985). Some authors have shown remarkably little spatio-temporal variation in the size of prey items taken, such as fish or crayfish (Breathnach & Fairley, 1993) whilst others suggest that any observed variation may reflect the size frequency of prey available rather than active selection (McFadden and Fairley, 1984).

There is significant separation of otter and mink *Mustela vison* diets throughout Ireland with mink taking greater proportions of birds, mammals and substantially fewer fish (Aughey, 2004; Kyne *et al.*, 1989). However, seasonal variation in the diet of mink has been shown to be similar to seasonal variation in the diet of otters with less crayfish and eel during winter and a corresponding increase in fish with more frogs in late winter and early spring (Kyne *et al.,* 1989). Otters and mink typically have greatest niche breath during summer with greatest niche overlap during winter when food resources are more limiting (Aughey, 2004). Elsewhere, it is generally accepted that overlap between otter and mink is not great enough and resources not sufficiently limiting to generate significant competition between the species (Akande, 1972; Day & Linn, 1972; Wise *et al.*, 1981).

Preston *et al.* (2007) described long-term temporal shifts in diet. Sampling identical locations during the 1980s and 2003 in all river catchments throughout Northern Ireland they demonstrated a substantial increase in the percentage occurrence of non-fish remains in spraints, specifically amphipods, birds and mammals. This shift was largely attributed to a perceived change in the availability or profitability of non-fish prey and/or a decline in fish stocks but no evidence was provided to support this claim.

3.5.2 Habtiat niche separation

Otters have larger home ranges in riverine habitat than lacustrine or coastal habitats resulting in varying densities (Ó Néill, 2008) suggesting that the species' ecology differs between environments. Samples from all three habitats were included in sixteen studies (76.2%) out of the 21 reviewed that provided comparable percentage occurrence data summarised from an analysis of 11,572 spraints at 74 sites throughout Ireland when combined with the results from the current study during 2010. Discriminant Function Analysis demonstrated clear separation of the diet between the habitats with Axis 1 differentiating coastal and freshwater environments (eigenvalue = 25.274) accounting for 92.1% of the variation in otter diet (Fig. 18a). It is notable that niche width of coastal otters (indicated by the span of scores on Axis 1) is greater than that at freshwater sites. Axis 2 indicates further separation between riverine and lacustrine habitats (eigenvalue = 2.163) accounting for the remaining 7.9% of the variation in diet. Freshwater sites were characterised by their similarity in terms of the occurrence of salmonid remains. A single study reported results from a brackish water site at Lough Furnace, Co. Mayo (Gormally & Fairley, 1982) which lay in between the coastal and freshwater sites (Fig. 18a).

The niche width of otters in freshwater systems was greater at lacustrine sites (indicated by the span of scores on Axis 2) where the diet was characterised by a predominance of Atlantic eel and other freshwater fish spp. (Fig. 18b). The percentage occurrence of salmonids was largely similar between rivers and lakes but Atlantic eel occurred in 73.4% of spraints from the latter (Table 20). Fairley & Murdoch (1989), working during 1987, reported that eel occurred in 83.6% of spraints at Lough Leane and Muckross Lake in Killarney National Park though twaite shad *Alosa fallax* was also notably common occurring in 29.3% of spraints. The latter species is an endemic of the Killarney lake system and is considered Vulnerable in the most recent Irish Red Data List (King *et al.*, 2011). For the purposes of this analysis it was listed with 'Other freshwater fish spp.' Similar results highlight the importance of eel in lacustrine habitats in Connemara National Park, Co. Galway (Tangney & Fairley, 1994).

Analysis of otter alimentary canals, rather than fragment analysis of spraints, suggests differences in detection of fragments between the stomach and intestines (Fairley, 1972) but the results are largely similar to spraint analysis. Fairley (1972) collected otter carcasses from throughout the Corrib lake system, Co. Galway where eel, perch *Perca fluviatilis*, frog and pike were most common items in the guts relative to much a lower incidence of salmonid remains.

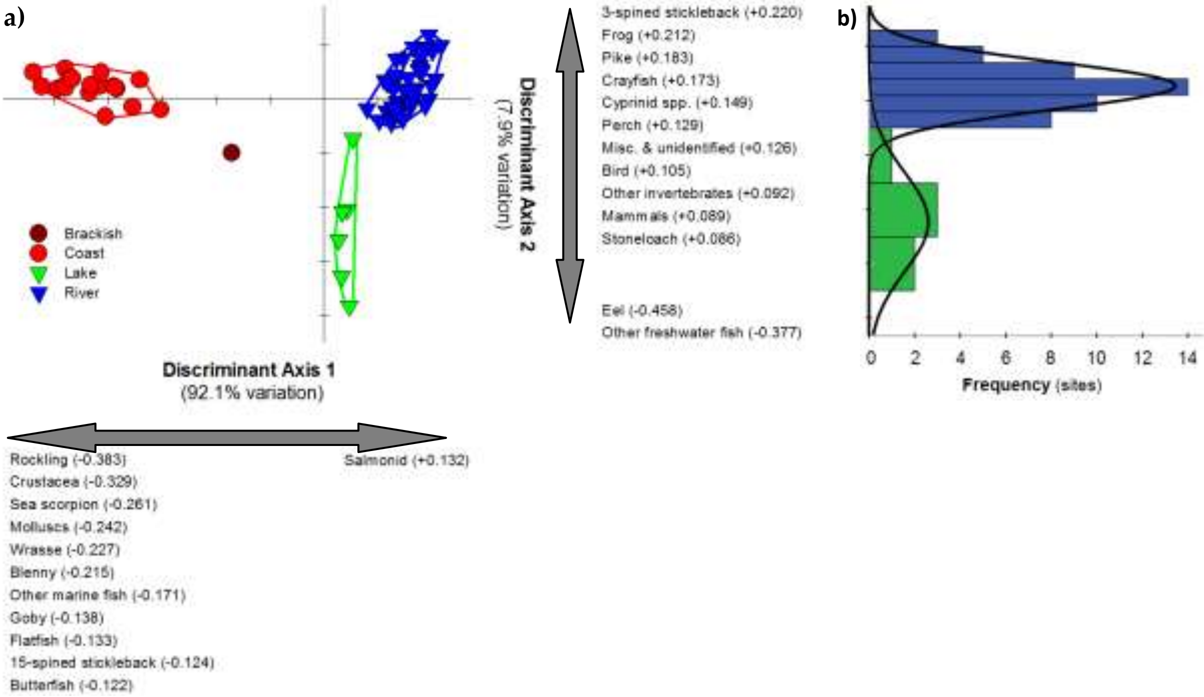


Fig. 18 a) Discriminant Function Analysis of otter diet described by percentage *occurrence* of prey items at 74 sites (individual datum points) within 16 studies (involving the analysis of 11,572 spraints). Axes 1 described differences between coastal and freshwater habitats and Axes 2 described differences between riverine and lacustrine habitats. Correlation coefficients between prey species and their parent axes are shown in parentheses. **b)** The frequency distribution of scores on Axes 2 demonstrate niche separation at freshwater sites.

Table 20 Summary of percentage *occurrence* (%) of prey items in a meta-analysis of otter diet throughout Ireland split between the riverine, lacustrine, brackish and coastal habitats. Sample sizes (*n*) are given as sites. 95% confidence intervals are shown in parentheses.

Prey species	Riverine *n* = 49	Lacustrine* *n* = 6	Brackish *n* = 1	Coastal *n* = 18
Freshwater fish				
Salmonids	35.7 [28.4 - 64.1]	33.2 [14.1 - 47.3]	28.4	
Atlantic eel	22.7 [17.5 - 40.2]	73.4 [57.3 - 100.0]	90.7	23.4 [13.5 - 36.9]
3-spined stickleback	23.2 [18.0 - 41.2]	0.9 [0.0 - 0.9]	27.0	3.6 [0.6 - 4.2]
Perch	13.3 [9.5 - 22.8]	3.0 [0.5 - 3.5]		
Cyprinid spp.	8.9 [5.8 - 14.7]			
Pike	7.4 [5.3 - 12.7]			
Stoneloach	3.6 [1.4 - 5.0]			
Other freshwater fish	5.3 [3.2 - 8.6]	20.2 [5.7 - 25.9]		0.4 [0.0 - 0.4]
Freshwater invertebrates				
Crayfish	30.6 [21.5 - 52.1]			
Other inverts	8.6 [4.4 - 13.0]	1.1 [0.0 - 1.1]	12.1	1.5 [0.0 - 1.5]
Other				
Frog	21.1 [16.5 - 37.6]	1.7 [0.0 - 1.2]	1.8	3.9 [0.2 - 4.1]
Bird	10.3 [5.9 - 16.2]	1.2 [0.8 - 0.4]	2.0	0.9 [0.0 - 0.9]
Mammals	5.4 [2.3 - 7.7]			
Misc. & unidentified	13.3 [7.8 - 21.1]			0.4 [0.0 - 0.4]
Marine fish				
Rockling				53.8 [44.4 - 98.1]
Wrasse				37.8 [25.3 - 63.1]
Goby		0.1 [0.0 - 0.1]	8.2	18.5 [7.7 - 26.2]
Blenny				10.1 [6.6 - 16.7]
15-spined stickleback				9.1 [3.4 - 12.4]
Flatfish		0.1 [0.0 - 0.1]	11.1	8.2 [3.0 - 11.1]
Butterfish			3.0	6.2 [2.1 - 8.3]
Other marine fish		0.8 [0.0 - 0.8]	7.5	15.1 [8.1 - 23.2]
Marine invertebrates				
Crustacea		0.3 [0.0 - 0.3]	4.8	36.4 [28.3 - 64.7]
Mollusca		0.5 [0.0 - 0.5]	9.8	23.9 [16.1 - 40.0]
Sea scorpion			0.7	16.5 [11.8 - 28.4]

* Some freshwater lakes and/or loughs had narrow river channels connecting them to the coast resulting in some saltwater species being included in the diet.

3.5.3 Marine diet

Coastal otters feed predominately on marine species but may also travel inland via estuaries to feed on brackish or freshwater food resources as well (Weir & Bannister, 1973; 1977). Coastal diets (Table 20) were dominated by rockling (Gadidae), wrasse (Labridae), Crustacea, Mollusca, Atlantic eel, goby (Gobiidae), sea scorpions (Cottidae) and blenny (Blenniidae; Murphy and Fairley, 1985a,b; Kingston *et al.*, 1999). However, others have found that the diet of coastal otters feeding in brackish sea loughs is similar to those feeding entirely within freshwaters being dominated by Atlantic eel and salmonids (Gormally & Fairley, 1982). It seems likely that this disparity is due to spatial variation in sampling locations with the former diet being associated with rocky shores and the later with shorelines close to estuaries.

Marine diets appear to exhibit stronger seasonal variation than freshwater diets. For example, the frequency of wrasse has been shown to increase during winter, presumably due to their semi-torpid behaviour during colder conditions whilst the frequency of blennies, butterfish *Pholis gunnellus,* Atlantic and conger eels *Conger conger* have all been shown to decrease during winter (Kingston *et al.* 1999). It is notable that eels tend to bury themselves in soft sediments during winter reducing their accessibility compared to summer (Chanin, 1991). Shifts in marine diet during winter also show an increased dependence on sea urchins (Kingston *et al.,* 1999). Species such as the purple sea urchin *Paracentrotus lividus* come into breeding condition during cold weather when their gonads enlarge making this otherwise indigestible prey item more palatable and nutritious (Kingston *et al.,* 1999; P. Leighton *pers. comm. op. cit.*).

Pelagic fish such as pollack *Pollachius pollachius*, saithe *P. virens*, whiting *Merlangius merlangius*, sprat *Sprattus sprattus* or mackerel *Scomber scombrus* are rarely taken due to their offshore distribution. They are also generally too agile and fast swimming to be caught by otters (Kingston *et al.,* 1999). However, elsewhere, saithe and pollack have been reported in the diet during winter as these species may move inshore to invade dense seaweed (Kruuk, 1995).

It is also evident that individual otters are opportunistic in specialising on food items at certain times. For example, during spring 2011, an otter on Mew Island, Copeland, Co. Down began taking breeding seabirds including an estimated 325 Manx shearwaters *Puffinus puffinus* returning to their nests on the ground at night. The same individual also raided the nests of black guillemots *Cepphus grille* in rock crevices reducing reproductive success from 70-80% the previous year to 21.4% during 2011 whilst predating at least 11 other birds (Leonard, 2011). This provided a conservation dilemma as the birds were the designated feature of a Special Protection Area (SPA) whilst the otter was protected under law (D. Looney, *pers. comms.*). Nevertheless, the animal was successfully discouraged using a combination of ultrasonic and light deterrents (Leonard, 2011).

4. Discussion

4.1 National Otter Survey 2010/11

This was the fourth National survey in Ireland of the European otter (*Lutra lutra*). It provided the *preliminary* assessment of the species' conservation status in preparation for Article 17 reporting under the EU Habitats Directive (due 2013). The first survey in 1980/81 reported otter tracks and signs at 92.5% of sites (Chapman & Chapman, 1981). The second survey in 1990/91 reported otters at 89.5% (Lunnon & Reynolds, 1991) whilst the third in 2004/05 reported 70.5% site occupancy (Bailey & Rochford, 2006). The current survey recorded otters at 63.3% of sites. Taken at face value these results suggest a consistent and significant decline in the occurrence of otters throughout the Republic of Ireland. However, this is at odds with distributional data from the last Article 17 report which suggested that otter records occurred in 358 x 10km squares throughout the Republic of Ireland compared to 543 x 10km squares during the current assessment indicating a 51.7% increase in the *known* distribution of the species which remains widespread. Moreover, temporal trends in otter incidence varied markedly between the Republic of Ireland and Northern Ireland. The first survey of Northern Ireland in 1980/81 reported that otter tracks and signs occurred at 84.9% of sites (Chapman & Chapman, 1981). The second survey in 2001/02 reported that otters occurred 67.5% of sites (Preston *et al.* 2004) and the third survey in 2010 recorded otters at 88.6% of sites (Preston & Reid, 2010). Taken at face value these results suggest that otter incidence throughout Northern Ireland underwent a decline between the 1980s and early 2000s comparable to that observed in the Republic of Ireland but increased dramatically by 2010 returning to levels similar with those recorded at baseline.

4.1.1 Surveyor effects

However, naive species incidence (i.e. that recorded in the field) was significantly and substantially contributed to by sources of bias and error in the sampling methods. For example, detection of otter tracks and signs varied markedly between DCO survey teams. It was important to disentangle the effects of true regionality in otter incidence, described at a large-scale (River Basin District) and small-scale (hydrometric area) from the variation described by DCO survey teams working in discrete areas. Otter incidence was better described by DCO survey team than either River Basin District or hydrometric area. Some survey teams working within the same River

Basin District or spanning the boundaries of multiple hydrometric areas reported significantly different levels of otter incidence. Whilst survey teams worked regionally their effect seem likely to be due to varying levels of survey effort, search time or differing levels of ability in detecting spraint. The Republic of Ireland, which was surveyed by 75 individuals, reported significantly lower otter incidence with a notably wider confidence interval compared to Northern Ireland which was surveyed by a single survey team which included a highly experienced individual. This was further exemplified by comparing results from a River Basin District which spanned the border between both jurisdictions. In Northern Ireland, the observed incidence of otters in the Neagh Bann River Basin District was 93% compared to 46% in the same district in the Republic of Ireland. Yet after accounting for sources of bias and error the marginal mean occurrence was just short of 94% in both jurisdictions. Nevertheless, where surveyors are of comparable ability no significant impact was descerned (for example, see Case Study of Quality Assurance of the Upper Shannon Catchment Rapid Assessment Survey in Appendix V). The Habitats Directive, requires the surveillence of otter populations throughout Europe and whilst different regions are likely to experience differing sources of survey bias, the substantial effect of multiple surveyors is likely to be an endemic failure in most surveys. In addition to spatial effects, changes in the identity of surveyors over time makes temporal comparisons difficult.

4.1.2 Deviation from protocol

Standard survey protocols followed by volunteers are not always adhered to strictly. Departure from protocol can lead to major sources of bias and error of which data analysts may be unaware. This study provides a good example: Lenton *et al.* (1980) dictates that Standard Otter Surveys should not be conducted within 5 days of heavy rain or flooding whilst Chanin (2003) suggests that periods of heavy rain, high water flow and the immediate period following flood events should be avoided. Nevertheless, examination of our results suggested that there was substantial variation in rainfall between individual survey sites. Rather than choosing an arbitrary cut-off for the amount of rain permissible prior to analysis, we included rainfall at various temporal lags in statistical models and found that the cumulative volume of rainfall during the month prior to survey biased results significantly. Thus, even if surveyors had complied fully with the Standard Otter Survey method, results would have still been negatively biased as the volume of rain before the 5 days prior to the survey would have been ignored. The effect of rainfall was evident only at flowing freshwater sites and was absent from lakes, reservoirs and coastal sites. This suggests that it is not rainfall *per se* that influenced otter detection (i.e. people were less likely to conduct thorough surveys during wet weather or rain washed spraints off rocks), rather it was more likely to be a corresponding rise in river level that washed spraint away. Previous studies have reported apparent regional or altitudinal variation in otter incidence in Ireland (e.g. Bailey and Rochford 2005) but we conclude this was likely due to relative variation in rainfall.

4.1.3 Species behaviour and ecology

Otters preferentially spraint at conspicuous features, usually boulders under natural conditions, but will also often utilise hard engineering such as bridge footings (Reuther & Roy 2001; Elmeros & Bussenius 2002; Gallant *et al*. 2008). Thus, in addition to the effects of DCO survey team and spatial variation in rainfall, any apparent regional variation in otter incidence may have been due to variation in the densities of rivers and roads and their intersection (i.e. prevalence of bridges).

At flowing freshwater sites otter incidence was positively associated with human-dominated pastoral landscapes. Here, rivers run through well-drained agricultural land (the predominant land cover in Ireland) which may provide greater accessibility to better maintained banks that are firmer underfoot and, therefore, spraints may be more easily detected. By comparison, otter incidence at coastal sites was positively related to surrounding inland freshwater landscapes with high densities of riparian corridors and lakes fringed with broad-leaved woodland. This supports findings from elsewhere (e.g. Kruuk 1995) that otters living on the coast may require access to freshwater, presumably for bathing and maintaining their fur but perhaps also for occasional foraging.

4.1.4 Interpretation of naïve species incidence

We are highly cautious about the temporal trends observed in naive species incidence from past surveys (Chapman & Chapman, 1981; Lunnon & Reynolds, 1991; Bailey & Rochford, 2006) or differences observed between Northern Ireland (Chapman & Chapman, 1981; Preston *et al.* 2004; Preston & Reid, 2010) and the Republic of Ireland.

4.2 EC Habitats Directive Conservation Assessment

4.2.1 *Range*

The previous European Commission assessment was based on a 13-year period (1993-2006) compared to the current 4-year period (2007-2011). Nevertheless, with increased survey effort, we demonstrated not only that there has been no decline in the distribution of the species, but that its *known* range is more extensive than previously reported. Consequently, the range established during the baseline survey, against which future changes are supposed to be measured, was reassessed to include all possible 10km squares available for occupation. All future surveys should thus be compared to the current study and not the baseline data. As the species remains widespread the conservation assessment parameter of '*range*' was judged favourable.

4.2.2 *Population*

A baseline population estimate was taken from the first national otter survey of Ireland during 1981-82 (Chapman & Chapman, 1982); back calculated by Ó Néill (2008). Baseline total abundance of adult breeding females in the Republic of Ireland was taken as 7,100 [95%CI 6,600-8,500] individuals (Ó Néill, 2008). Current estimates of species incidence for each River Basin District, corrected for negative survey bias, and similar calculations to those adopted by Ó Néill (2008) and further outlined in Marnell *et al.* (2011), were used to estimate the adult breeding female population during 2010-2011 to be 7,800 [95%CI 7,200-10,200] individuals. As the 95% confidence intervals overlap considerably between both estimates we conclude that the current population estimate was not significantly different from that estimated at baseline. Thus, the conservation assessment parameter of '*population*' was judged favourable.

It is noteworthy that despite no variation in otter incidence being observed between regions after correction for survey bias, variation in the availability of suitable habitat led to regional variation in predicted densities. Specifically, otter densities appeared highest in the Western River Basin Districts which had a high density of streams, rivers, lakes, other inland waterways (e.g. Turloughs) and a notably complex, convoluted coastline providing greater habitat availability to otters and thus supporting higher densities per unit area.

4.2.3 Habitat

It was essential to account for known biases in surveyor methodologies when analysing habitat associations otherwise variation attributable to the survey method may have been erroneously attributed to environmental parameters which may have appeared more important than they might otherwise have been in reality. Having accounted for survey biases, otter incidence was positively associated with large (wide and deep) rivers with in-channel features such as bars and side bars, hard substrates including gravel, cobbles, boulders and exposed bedrock with high, moderately sloping banks. These findings are consistent with previous studies which have shown similar results (Bailey & Rochford, 2006).

Whilst these may represent true ecological relationships it may also be the case that surveyors preferentially examine bars and side bars for footprints and boulders and exposed bedrock for spraints. If the bank was tall and sloping it may have provided a better vantage point from which to search for spraint than if the bank was low and flat. Otters are known to be positively associated with river width and depth (Bailey & Rochford, 2006) with larger rivers supporting higher densities of individuals (Ó Néill, 2008) due to reduced competition of territorial space and food resources. However, large rivers tend to have few in-channel features, for example, bars and side bars or exposed boulders, whilst their depth often prohibits the survey of any such features present. Thus, possible sprainting sites on large rivers generally include bridge footings or boulders at the bank whilst these areas were usually the only places where thorough surveys could be completed. Thus, it might be that even the relationships found here may be confounded by survey bias rather than being meaningful ecological associations.

Otter occurrence at rivers was positively influenced by salmonid biomass, derived from electrofishing data in riffle habitat. Salmonids constitute, on average, 18-31% of the diet of otters in Ireland though in some catchments this can be as high as 81% (Fairley & Wilson, 1972). Thus, they are the single most important prey item in the diet of Irish otters. Nevertheless, it was shown that they do not actively select salmonid over non-salmonid prey (see *Section 3.5.1*). This may be because salmonids are present in practically every waterway in Ireland with most rivers containing brown trout (*Salmo trutta*) and many lakes stocked with rainbow trout (*Oncorhynchus mykiss*). Salmonid density varied throughout Ireland being highest in rivers in the north- and south-west that drain into the Atlantic Ocean suggesting that these areas are important in sustaining Atlantic salmon (*S. salar*) and sea trout (*S. trutta* morpha *trutta*) returning to freshwater and augmenting resident salmonid (i.e. *Salmo trutta*) numbers. Thus, otter abundance may reflect variation in salmonid abundance on a very coarse scale whilst at a regional level there is little correspondence between otter and salmonid populations. Otter occurrence on the coast was positively influenced by the coverage of adjacent inland freshwater-dominated landscapes, principally high densities of riparian corridors and standing freshwater (lakes) fringed with broad-leaved woodland. Coastal otters are dependent on freshwater rivers for bathing to maintain their fur or for foraging (Kruuk, 2006; Chanin, 2013). Certainly, coastal radio-tracked otters in Co. Cork have been seen to travel upstream into freshwater systems on occasions (de Jongh *et al.* 2010). All coastal sites surveyed in the current study were adjacent to the mouth of a river or stream. Our results suggest that otters on the coast were positively influenced by salmonid biomass in these adjacent rivers supporting the previous supposition that coastal otters may return to freshwater to feed. Thus, in coastal areas otters may indeed actively select salmonids, principally, sea trout and salmon.

None of the factors that significantly influenced otter occurrence (river size, substrate type, bank elevation and slope or salmonid biomass) are likely to be limiting or impacted detrimentally by human activities. Consequently, the conservation assessment parameter of '*habitat*' was judged favourable.

4.2.4 *Future prospects*

It was notable that otter occurrence was unaffected by water quality (Q-values), perceived levels of disturbance, mink occurrence or water use. Other pressures such as by-catch in fishing gear and road kill may be important locally but were not considered to be significant threats to the long-term persistence of the species regionally or at the national level, especially considering the widespread distribution of the species. Consequently, the conservation assessment parameter of '*future prospects*' was judged favourable.

4.2.5 National Conservation Assessment

The conservation status of the otter in the Republic of Ireland is now judged to be Favourable. The previous Article 17 (NPWS, 2008) assessed the species as Poor suggesting an improving trend. However, this change was considered to be due to improved knowledge and more accurate data rather than a real temporal trend.

4.3 Otter diet and implications for its status as a bioindicator

Otter diet has been well studied throughout Europe (Clavero *et al.*, 2003) but at a time of significant decline in the majority of otter populations (Mason & Macdonald, 1986). Ireland, therefore, offers a unique opportunity to examine the ecological niche of the species where it is widespread and at relatively high densities not provided elsewhere. Early studies suggested the otter was a fish specialist (Mason & Macdonald, 1986) but it is now widely accepted that the species is an opportunist whose diet varies depending on prey availability (e.g. Breathnach & Fairley, 1993; Carss & Nelson, 1998; Carss & Parkinson, 1996; Chanin, 1991; Kruuk, 1995; Kruuk & Moorhouse, 1990; Ottino & Giller, 2004). Throughout Europe, there is a clear latitudinal gradient in otter dietary composition with a narrow fish-based niche breath at higher latitudes (Clavero *et al.*, 2003). Studies of otter diet across a more limited geographical area, as in Ireland, however, reveals a high level of spatio-temporal variation that is unrelated to latitude.

In Ireland, the diet of otters exhibited substantial spatio-temporal variation related mostly to habitat and appeared unrelated to productivity or the availability of salmonid prey. We concluded that the plasticity of the trophic ecology of the otter makes it a poor 'bioindicator' for environmental water quality or the status of aquatic food webs more generally. This is supported by their large home ranges and broad-scale habitat associations (Lundy & Montgomery, 2010). We suggest that the sustained abundance of otters in Ireland reflects its unique combination of geographical factors; low latitude is associated with less reliance on fish (Clavero *et al*., 2003); it has a complex, largely undeveloped coastline (ca. 8,800km) characterized by rocky shelves; high rainfall throughout the year; an abundance of lakes of varying sizes; and numerous rivers and streams (ca. 93,000km). Otter abundance is a product of immediate-habitat and large-scale landscape factors (Lundy & Montgomery, 2010; *this study*). Thus, otters have always been able to find suitable habitat and a diverse food supply in Ireland even at times when environmental degradation led to a reduction in occurrence and abundance elsewhere in Europe.

4.4 Rapid Assessment Surveys

Rapid Assessment Surveys were derived from the 'spot-check' method proposed by Chanin (2003) who suggested that 70-80 sites per river was necessary to establish otter prevalance. In Ireland, this method was deployed at 8 representative catchments to detect local changes in otter populations more quickly than might be discernable during the 6-yearly National Surveys. However, although an average of 70 sites were covered per catchment, analyses resulted in relatively large confidence intervals around estimates of otter incidence. Moreover, the small number of catchments covered synchronously *within* years makes it difficult to decern any appreciable *spatial* variation in otter incidence. Power analyses for assessing *temporal* trends *within* catchments suggested that Rapid Assessment Surveys were not capable of detecting a 10% change in *observed* otter incidence with 80% power and that the sample sizes required to do so would be impractical and statistically non-independent. Rapid Assessment Surveys can, however, detect a 30% change in naive or observed otter incidence with 80% power.

Analyses of the effects of surveyors, rainfall and the number of bridges for the Rapid Assessment Surveys was beyond the remit of the current study but would nevertheless likely negatively bias results. Without a re-analysis of the Rapid Assessment Survey data to include these parameters naive otter incidence is likely to be just as biased as those from the National Survey before statistical correction.

4.5 Recommendations for monitoring protocols

4.5.1 Rapid Assessment Surveys vs. National Surveys

Given the likely sources of bias and error *and* the problems of low statistical power, we advocate discontinuing these Rapid Assessment Surveys surveys and advise that the detection of a 10% change in otter incidence with 80% power can only be reliably achieved at the National Level. Thus, we advocate conducting National Surveys within the existing 6-year cycle of Article 17 reporting with the next survey due during autumn/winter 2017/18 in time for reporting during 2019.

4.5.2 National Survey methodology

Occupancy modelling by Parry *et al.* (2013) has been used on spraint survey data from small lowland rivers in Wales to spatially and temporally resample species incidence to show that the mean probability of detecting otters using the standard 600m transect method is very low (P = 0.26). Spraint activity was generally clustered such that single site visits consistently failed to achieve the recognised minimum detection probability of 0.80 (Kendall *et al.* 1992) regardless of transect length (even if extended to 4km). Surveying multiple transects per site separated by 500m markedly improved the detection probability but it was only possible to achieve an 80% detection using the Standard Otter Survey method if six fortnightly repeat surveys were conducted at two transects. Occupancy modelling suggested that the optimum survey design achieving a detection probability of 0.80 was to undertake three fortnightly repeat surveys at two transects >800m in length separated by 500m (Parry *et al.* 2013). The difficulty with the recommendations of Parry *et al.* (2013) is that they are drawn from a single region with a markedly lower occurrence of otters (27-85%) than that likely to be present in Ireland (94% after correction for bias and error). Thus, their results may not be readily transferrable. However, their general concern about the reliability of data from national surveys composed of numerous independent 600m transects is reflected by the current survey. More broadly, our results support their concern that single one-off Standard Otter Surveys may be used for the purposes of Environmental Impact Assessments (EIAs) in which the failure to detect otter field signs may be construed as favouring local development.

The unconventional analysis method used here (the use of marginal estimated means to correct sources of bias and error) whilst utilitarian in dealing with a survey that had been completed, does not provide a means by which clear recommendations can be made for future surveys. Occupancy modelling is now common place and frequently taught in many undergraduate courses whilst the provision of specialist freeware, such as the programme PRESENCE2 (Hines, 2006), as well as user support from online mailing lists mean that well designed binary wildlife surveys should not be beyond wildlife conservation practitioners or Government departments. Future otter surveys should be designed to ensure that there is sufficient spatial and temporal resampling and redundancy to accommodate a rigorous occupancy modelling approach similar to that conducted by Parry *et al.* (2013). Wildlife management and conservation personnel may perceive that multiple survey sites of greater length than that used in the Standard Otter Survey method and repeated site visits are unnecessarily time consuming whilst requiring a greater investment of manpower and funding but the dividends should be apparent from the current survey which shows clearly that naïve species occupancy rates are sufficiently biased as to be next to useless for conservation assessments unless survey bias and error can be removed.

Here, we have focused on negative biases but false positives may also be a problem if the scats of other species are misidentified as otter spraints. This is highly unlikely due to their distinctive positioning, texture, scent and contents (McElwee 2008). However, future work could evaluate the role of false positives by incorporating genetic analyses to exclude other species and verify otter spraints specifically.

Given the apparent disparity between naïve otter incidence between the Republic of Ireland and Northern Ireland and the apparently differing temporal trends, we recommend that a formal trans-boundary assessment is submitted for the next Article 17 report and strongly advocate that neighbouring EU member states that share habitats and species across comparable ecoregions should work together to standardise and synchronise monitoring and surveillence regimes to ensure conservation assessment data are biologically meaningful.

4.5.3 Surveyors

Whilst we have shown that the use of NPWS Conservation Rangers yields a high degree of variation in recorded otter occurrence, multiple surveyors are the only practical means by which to survey the number of sites required during National Surveys. It will be necessary to ensure that the identity of each survey team and their managing District Conservation Officer (DCO) are clearly recorded on survey sheets. The options in future will include statistical adjustment for surveyor at the analytical stage to correct levels of incidence. More practical methodological solutions may include surveying each site twice using different survey teams to provide a repeated measure which would facilitate statistical adjustment. However, to remove the problem as far as possible, if the true incidence of otters is required (rather than relative change) consideration may be given to returning to sites on multiple occasions to allow analysis of site occupancy to determine the optimum survey methodology. See *Section 4.5* above.

4.5.4 Health & Safety

Survey teams should consist of a minimum of two persons for Health & Safety reasons. Wading within rivers and streams on uneven substrates may be treacherous. It is important to carry a handheld GPS device (with spare batteries) and a 1:10,000 map to aid navigation and a mobile phone for communication should surveyors get into any difficulties. A Health & Safety risk assessment should be carried out in accordance with NPWS standard guidelines (or those of any contractor undertaking the work). Outdoor clothing is essential including waterproofs and sufficient water must be carried to remain hydrated as some sites are a considerable distance from the road.

4.5.5 Site access

Survey sites may be on rivers within farmland. Therefore, it is important to respect people's rights and employ good practise to raise awareness of future surveys and to make contact with farmers and local landowners prior to accessing each site. Whilst locals may not be the owners of the land to be surveyed it may be important to make contact to allay any fears within Community Watch groups.

4.5.6 Technical support

Field teams should be supported by at least one person with appropriate IT skills including GPS and GIS expertise. Hardware required includes a laptop (preferably a notebook suitable for use in the field), Personal Digital Assistants (PDAs) and a handheld GPS device whilst software required includes Microsoft Excel, Microsoft Access (i.e. Microsoft Office), ArcGIS 10 (ESRI, California, USA). It is essential that data are collected in a fashion compatible with standard methods of data storage (principally, Microsoft Access).

4.5.7 Training

Quantifying the skills of observers working on wildlife surveys to be used as an explanatory variable in data analysis would be helpful. Thus, it is essential to accurately record the identity of surveyors and estimate their reliability during pre-survey training. For otter surveys throughout Europe, it may be beneficial to develop a similar programme to that offered by the CyberTracker Certification in the USA to provide an objective test of an observer's reliability (see http://trackercertification.com).

Fieldworkers should be familiar with the locations that otters are likely to use for sprainting and the associated Health & Safety hazards of the surveys. A clear understanding of the field survey methods is also required to ensure data are collected in a consistent manner. Generally, two training days are required; one located in the south and one in the north to enable access to training by all NPWS Conservation Rangers. An inventory should be kept of attendance as the quality of the data returns may vary and this is likely to be associated with whether a surveyor attended a training session. It is recommended that each training event has an indoor session to cover the theoretical basics including the layout of survey sheets, how they should be completed, relevant equipment, software etc and an outdoor session at a suitable water body (or multiple water bodies of different types) to demonstrate the field methods to ensure consistency between surveyors. The length of the training session should be tailored to the previous experience of the surveyors. Training should include identification of spraint and its differentitation from the scats of other species (mink, fox, pine marten etc), all relevant aquatic and terrestrial variables to be collected and information on the guidelines relating to the presence of perceived impacts and threats as listed by the EU Habitats Directive.

4.5.8 Timing

Otter spraint may be found at any time of year. However, territorial behaviour of otters may vary seasonally and it has been established that the volume of rainfall prior to the survey creates negative bias in the results. We suggest that future surveys focus on the same period of time covered by the current survey (autumn) for comparability. Standard Otter Survey protocol prohibiting surveys within 5 days of heavy rain or flooding *must* be strictly adhered too. Nevertheless, it is essential that future surveys obtain rainfall data from Met Éireann and that this is incorporated into statistical analysis to allow correction of any negative bias (if present).

4.5.9 Survey sheets

The survey sheets used to collect spraint and habitat data in the field during this survey (see Appendix I) were relatively straightforward including 2 pages of tick boxes. Whilst we could recommend that these be refined further with variables restricted to only those found to statistically influence otter occurrence it seems more appropriate, for consistency, to collect the same data during the next round of monitoring. Moreover, all perceived pressures found during the current survey should be assessed during future monitoring to evaluate their frequency and any temporal change. Survey team identity (pair or trio) and their managing District Conservation Officer (DCO) must be clearly recorded on survey sheets in future.

4.5.10 Quality assurance and data manipulation

It is a frequent problem in large, national surveys involving multiple surveyors that data quality may vary. Each surveyor should be individually responsible for ensuring that all their data are clear, complete, correct and in the right format prior to the end of the field season and returning the data for analysis. Any abbreviations used should be fully explained in accompanying notes and should follow accept standards e.g. EU Habitat Directive *impact and threat* codes. Quality control surveys by multiple surveyors or professionally employed surveys could be used to validate the data obtained from Conservation Rangers, however, a case study example of this during 2011 in the Upper Shannon Catchment demonstrated relatively little merit in this approach (see Appendix IV).

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Appendix I – Otter Survey Recording form (e.g. rivers)

10km square reference		**County**	
1km square reference		**River**	
Grid reference of site		**Site Code**	
Date		**Otter Y/N**	

Habitat type		**Adjacent land use**		**Water Use**	
Estuary		Farm – Livestock		Abstraction	
River		-Arable		Boating – powered	
Canal		Woodland – broadleaved		– sailing	
Ditch		– conifer		– man powered	
		Peat bog		Bank angling	
		Arable		Shooting	
		Saltmarsh		Keepered	
		Heath			
		Urban / industrial / road			
		Park / garden			

Width (m)		**Depth (m)**		**Current**		**Substrate (%)**	
< 1		< 0.5		Rapid		Bedrock	
1 - 2		0.5 - 1		Fast		Boulders	
2 - 5		1 – 2		Slow		Cobbles	
5 - 10		> 2		Sluggish		Gravel	
10 - 20		**Exposed Boulder (%)**		Static		Sand	
20 - 40				Tidal		Silt	
> 40						Unknown	

Vegetation (%)		**RB**	**LB**	Bank surveyed		Bank slope (°)		Bank height (m)	
Banks	Trees					0 – 30		< 1	
	Shrubs					30 – 60		1 – 2	
	Tall herbs					60 – 90		2 – 3	
Channel	Emergent							> 3	
	Floating attach			Tree species				Weed control	
	Floating free			Alder		Cherry		Mechanical	
	Submerged			Hawthorn		Holly		Chemical	
Tree extent				Sycamore		Elder		None	
Isolated				Horse chestnut		Conifer		Bank treatment	
Regular				Beech		Blackthorn		Canalised	
Clumps				Oak		Gorse		Resectioned	
Semi-continuous				Willow		Hazel		Maintained	
Continuous				Ash		Giant Hog		Wild	

Associated features		**Other features**		**Pollution**					
Channel shading		Weirs		**Present**		**Absent**			
Overhanging boughs		Waterfalls		Agricultural		Domestic		Industrial	
Roots		Channel bars							
Fallen trees		Side bars							
Debris		Islands							

Survey distance (m)			Other animals				
Survey direction	U/S		Animal	**Obs**	**Tracks**	**Faeces**	**Other**
	D/S		Fox				
	both		Badger				
Disturbance factor **0 = no disturbance**	0 1 2 3 4 5		Mink				
			Heron				
Photographs			Dipper				
Number	**Description**		Moorhen				
	Spraint site		Coot				
	River view - facing		Ducks				
			Kingfisher				
			Fish				
			Other				

Otter signs – spraint sites and tracks										
Location(s)										
No. of sites										
Spraints (number) and condition	Site					Remains in spraint				
	Old					Fish bones		Other Bones		
	Recent					Crustaceans		Scales		
	New					Mollusc		Other		
Tracks	Yes		No							
Runs /glides	Yes		No							
Holt	Yes		No							

Appendix II – Power Analyses (supplementary tables)

Table S1 Statistical power (%) to detect a 10% relative decline in otter occurrence between two Rapid Assessment Surveys assuming a range of sample sizes (30-200 sites) within hydrometric areas (showing the 2.5th and 97.5th percentiles to demonstrate levels of uncertainty in the most recent estimate of occurrence). Values in dark grey italics highlight unusual cases were the predicted power did not increase with sample size.

		Hydrometric area								
Sample size	**Percentile**	**Boyne**	**Corrib**	**Lennan**	**Lough Derg**	**Munster**	**Roaringwater**	**Slaney**	**Upper Shannon**	**Average Power**
30 sites	2.5th	7.0%	5.4%	4.8%	4.8%	8.2%	4.2%	4.0%	5.0%	5.4%
	Median	**10.0%**	**7.6%**	**7.7%**	**7.8%**	**16.8%**	**7.3%**	**7.0%**	**7.4%**	**9.0%**
	97.5th	22.8%	13.6%	32.4%	12.0%	47.0%	11.8%	12.4%	10.6%	20.3%
50 sites	2.5th	8.4%	5.8%	*5.8%*	6.0%	10.0%	5.2%	4.2%	5.8%	6.4%
	Median	**13.1%**	**9.6%**	**8.8%**	**9.9%**	**20.8%**	**8.7%**	**7.4%**	**9.2%**	**10.9%**
	97.5th	26.4%	16.8%	*26.8%*	16.2%	60.2%	18.0%	15.2%	11.8%	23.9%
75 sites	2.5th	9.8%	7.0%	4.4%	7.8%	13.4%	5.4%	4.6%	6.6%	7.4%
	Median	**18.4%**	**12.5%**	**10.8%**	**12.4%**	**29.3%**	**10.7%**	**8.8%**	**11.9%**	**14.4%**
	97.5th	*42.2%*	26.2%	49.8%	21.0%	77.2%	24.0%	22.0%	18.2%	35.1%
100 sites	2.5th	12.4%	7.8%	5.4%	8.4%	15.4%	5.6%	*4.4%*	8.2%	8.5%
	Median	**21.8%**	**13.8%**	**11.6%**	**14.3%**	**36.0%**	**13.0%**	*8.7%*	**13.4%**	**16.6%**
	97.5th	39.2%	28.0%	58.0%	25.2%	77.8%	30.0%	*20.4%*	20.2%	37.4%
200 sites	2.5th	22.4%	11.4%	6.0%	11.4%	28.4%	6.8%	5.6%	12.4%	13.1%
	Median	**37.8%**	**22.2%**	**15.3%**	**21.9%**	**57.4%**	**16.8%**	**14.1%**	**20.6%**	**25.8%**
	97.5th	84.8%	60.6%	85.4%	38.8%	97.6%	49.4%	36.0%	38.0%	61.3%

Table S2. Statistical power (%) to detect a 10% and 30% relative decline in otter occurrence between two 'National Surveys' assuming three indicative samples sizes were the 2.5th and 97.5th percentiles accounted for estimated levels of uncertainty observed during the current survey (i.e. 2010).

Country	Observed occurrence & assumed 10% decline	Power to detect a 10% decline				Observed occurrence & assumed 10% decline	Power to detect a 30% decline			
		Sample size (*n*)	Percentile 2.5th	Median	97.5th		Sample size (*n*)	Percentile 2.5th	Median	97.5th
Republic of Ireland	63.3 - 56.9%	666	57.8%	65.1%	73.0%	63.3 - 44.3%	77	57.2%	64.2%	71.0%
		740*	61.0%	70.2%	75.8%		85*	65.6%	71.8%	77.6%
		814	67.6%	74.6%	78.6%		94	66.8%	73.7%	78.6%
Northern Ireland	88.6 - 79.7%	188	53.4%	65.9%	77.8%	88.6 - 62.0%	29	61.4%	71.5%	77.2%
		209*	62.8%	71.1%	80.2%		32*	66.4%	73.4%	80.0%
		230	64.4%	75.0%	84.8%		35	69.8%	78.3%	85.2%

* the number of samples needed to obtain a 'theoretical' power of 80% (derived from simulations). However, when this sample size was applied to the observed data from the current survey (2010) estimated levels of uncertainty in occurrence resulted in a lower 'actual' power. Thus, analyses were repeated for samples 10% less than and greater than the value obtained from simulations to examine changes in power.

Table S3. Statistical power (%) to detect a 10% and 30% relative decline in otter occurrence within River Basin Districts between two 'National Surveys' assuming three indicative samples sizes were the 2.5th and 97.5th percentiles accounted for estimated levels of uncertainty observed during the current survey (i.e. 2010).

		Observed occurrence & assumed 10% decline	Power to detect a 10% decline				Observed occurrence & assumed 10% decline	Power to detect a 30% decline			
			Sample size (n)	Percentile				Sample size (n)	Percentile		
				2.5th	Median	97.5th			2.5th	Median	97.5th
Republic of Ireland	Eastern	52.3 - 47.1%	1016	44.4%	62.8%	87.2%	52.3 - 36.6%	111	48.2%	64.0%	86.8%
			1129	48.6%	70.2%	88.0%		123	52.4%	68.3%	86.0%
			1242	58.0%	74.6%	90.4%		135	57.2%	73.8%	89.0%
	Neagh Bann	46.2 - 41.5%	1286	35.4%	63.9%	88.8%	46.2 - 32.3%	138	40.4%	65.9%	88.2%
			1429	30.4%	66.3%	95.0%		153	31.0%	67.4%	95.0%
			1572	43.6%	77.9%	95.8%		168	46.0%	78.4%	95.4%
	North-Western	62.4 - 56.1%	690	50.2%	65.8%	80.8%	62.4 - 43.7%	78	49.0%	63.9%	79.4%
			767	55.8%	71.1%	87.4%		87	58.4%	72.6%	84.8%
			844	59.8%	72.9%	87.8%		96	60.4%	73.8%	85.2%
	Shannon	59.3 - 53.3%	779	53.8%	65.4%	78.2%	59.3 - 41.5%	87	57.4%	67.5%	78.6%
			866	59.4%	69.5%	79.6%		97	59.0%	70.3%	78.8%
			953	61.6%	74.4%	84.2%		107	64.0%	74.0%	83.2%
	South-Eastern	70.8 - 63.7%	489	47.0%	66.7%	83.2%	70.8 - 49.5%	59	52.8%	66.2%	81.2%
			543	60.4%	72.0%	83.8%		65	59.2%	71.6%	84.0%
			597	61.2%	73.9%	88.0%		72	63.0%	74.8%	86.8%
	South-Western	68.3 - 61.5%	543	50.4%	64.3%	78.8%	68.3 - 47.8%	64	51.6%	65.0%	78.0%
			603	56.4%	69.2%	84.6%		71	56.2%	71.5%	84.2%
			663	61.6%	72.5%	87.4%		78	61.4%	73.2%	86.6%
	Western	65.4 - 58.8%	613	53.8%	65.3%	79.0%	65.4 - 45.8%	71	56.2%	67.4%	76.2%
			681	56.8%	69.2%	85.8%		79	56.4%	68.9%	83.0%
			749	62.8%	74.0%	87.4%		87	65.6%	75.8%	86.2%
Northern Ireland	Neagh Bann	93.2 - 83.9%	130	52.0%	66.0%	88.6%	93.2 - 65.2%	23	58.0%	71.0%	84.6%
			144	55.2%	69.9%	86.2%		25	62.8%	74.5%	85.6%
			158	58.0%	73.8%	87.2%		28	69.6%	79.3%	88.8%
	North-East	87.5 - 78.8%	203	44.2%	67.3%	88.2%	87.5 - 61.2%	31	50.0%	72.1%	86.8%
			226	49.6%	70.4%	90.8%		34	56.2%	74.2%	89.0%
			249	56.6%	73.5%	90.8%		37	61.6%	76.4%	88.8%
	North-West	83.7 - 75.3%	258	51.0%	65.2%	81.4%	83.7 -58.6%	36	57.2%	69.2%	80.6%
			287	56.8%	68.4%	88.0%		40	61.2%	71.9%	85.8%
			316	57.2%	75.0%	88.0%		44	64.2%	77.0%	86.6%

Table S4. Statistical power (%) to detect a 10% and 30% relative decline in otter occurrence within habitat types between two 'National Surveys' assuming three indicative samples sizes were the 2.5th and 97.5th percentiles accounted for estimated levels of uncertainty observed during the current survey (i.e. 2010).

Country	Habitat type	Observed occurrence & assumed 10% decline	Power to detect a 10%				Observed occurrence & assumed 10% decline	Power to detect a 30%			
			Sample size (n)	Percentile				Sample size (n)	Percentile		
				2.5th	Median	97.5th			2.5th	Median	97.5th
Republic of Ireland	Running freshwater	64.8 - 58.4%	626	57.4%	65.0%	72.2%	64.8 - 45.4%	72	61.4%	67.1%	72.4%
			695	63.0%	70.6%	76.8%		80	63.0%	70.5%	77.0%
			765	68.8%	73.6%	82.2%		88	70.2%	76.2%	81.4%
	Static freshwater	54.2 - 48.8%	947	36.2%	62.8%	90.8%	54.2 - 37.9%	104	37.2%	62.6%	89.2%
			1052	41.4%	69.4%	95.6%		116	45.0%	71.3%	94.4%
			1157	44.6%	73.2%	95.4%		128	48.6%	75.0%	95.4%
	Coastal	56.7 - 51.0%	860	50.0%	64.5%	78.6%	56.7 - 39.7%	95	52.0%	65.1%	77.4%
			955	57.2%	72.2%	84.8%		106	59.0%	70.4%	84.0%
			1051	62.4%	73.9%	87.2%		117	64.2%	75.9%	86.4%
Northern Ireland	Running freshwater	87.5 - 78.8%	203	54.8%	67.0%	78.4%	87.5 - 61.3%	31	59.8%	71.2%	78.2%
			225	59.2%	70.6%	79.8%		34	65.8%	74.3%	81.6%
			248	64.4%	75.5%	86.2%		37	68.6%	78.2%	84.6%
	Static freshwater	91.4 - 82.3%	151	36.8%	66.1%	97.4%	91.4 - 64.0%	25	44.2%	70.1%	91.4%
			168	43.0%	73.3%	96.0%		28	50.8%	78.0%	93.4%
			185	43.8%	75.8%	95.4%		31	53.0%	80.6%	93.8%
	Coastal	94.6 - 85.1%	113	35.2%	64.7%	94.4%	94.6 - 66.2%	22	49.6%	72.6%	91.0%
			125	40.0%	71.0%	93.6%		24	51.2%	75.1%	92.4%
			138	37.4%	71.8%	96.8%		26	51.6%	78.8%	95.2%

Table S5. Statistical power (%) to detect a 10% and 30% relative decline in otter occurrence at sites in the wider countryside (non-SACs) and SAC sites between two 'National Surveys' assuming three indicative samples sizes were the 2.5th and 97.5th percentiles accounted for estimated levels of uncertainty observed during the current survey (i.e. 2010).

Country	Designation	Observed occurrence & assumed 10% decline	Power to detect a 10% decline				Observed occurrence & assumed 10% decline	Power to detect a 30% decline			
			Sample size (n)	Percentile				Sample size (n)	Percentile		
				2.5th	Median	97.5th			2.5th	Median	97.5th
Republic of Ireland	Wider countryside (non-SACs)	61.8 - 55.6%	707	58.0%	65.3%	74.0%	61.8 - 43.3%	80	56.6%	64.8%	70.8%
			785	62.0%	69.1%	76.2%		89	62.6%	69.7%	75.4%
			864	66.6%	73.7%	79.4%		98	68.6%	74.7%	79.6%
	SACs	67.1 - 60.4%	571	53.6%	65.1%	78.2%	67.1 - 47.0%	67	55.0%	64.6%	76.0%
			634	58.6%	70.6%	80.0%		74	64.4%	72.6%	80.2%
			697	62.2%	74.4%	86.8%		81	62.2%	74.3%	84.6%
Northern Ireland	Wider countryside (non-SACs)	88.8 - 79.9%	185	54.2%	65.9%	77.2%	88.8 - 62.2%	29	63.4%	71.5%	79.2%
			206	59.4%	70.0%	80.6%		32	66.4%	73.5%	81.2%
			227	61.8%	75.4%	86.0%		35	69.8%	79.5%	86.4%
	SACs	84.2 - 75.8%	250	26.6%	68.3%	96.6%	84.2 - 58.9%	35	30.6%	71.5%	92.6%
			278	37.2%	74.8%	99.6%		39	44.6%	75.5%	97.4%
			306	27.2%	71.6%	99.4%		43	32.8%	73.0%	96.2%

Appendix III – American mink (*Neovison vison*) distribution

Tracks and signs of American mink *Neovison vison* (predominately scat) were recored at 117 sites out of the 825 sites surveyed (14.2%). This was similar ($\chi^2_{df=1}$ = 0.287, p=0.592) to a previous occurrence during 2004/05 (Bailey & Rochford, 2006) of 80 sites out of 525 sites surveyed (15.2%). Consequently, mink remained widespread at the 10km scale (Fig. S1).

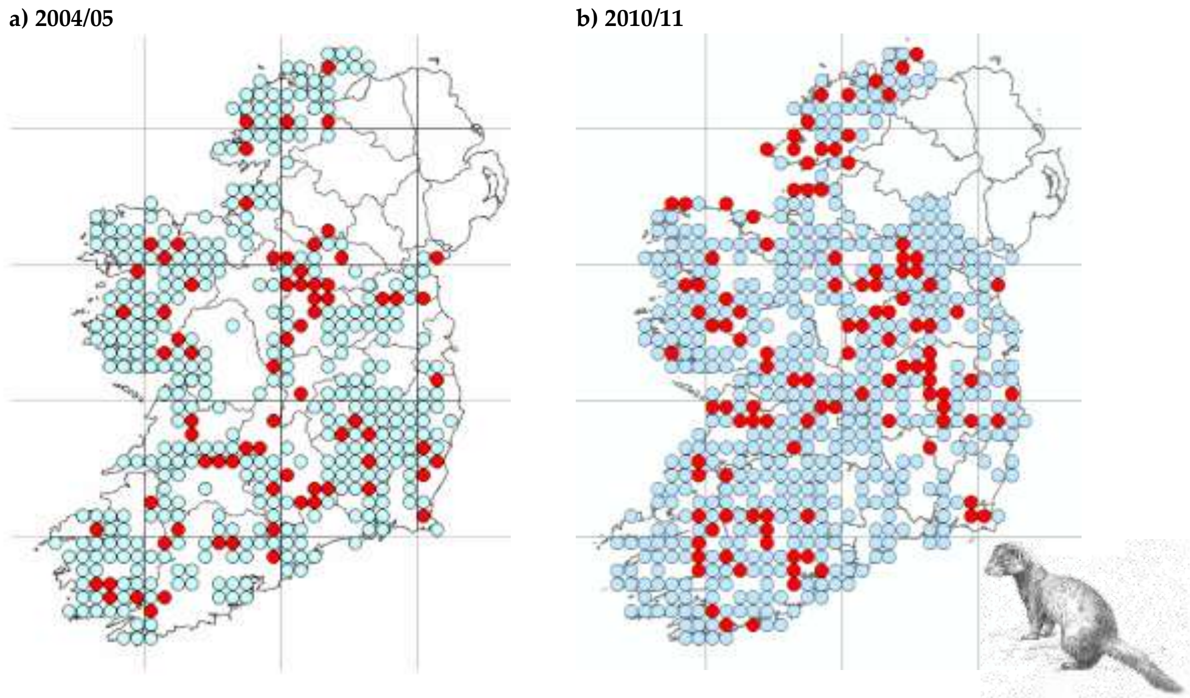

Fig. S1 Distribution of invasive American mink in Ireland during: **a)** 2004/05; and, **b)** 2010/11. Note the larger sample size during the latter period results in a greater number of absolute records.

Appendix IV – Locations of white-clawed crayfish

Locations (XY coordinates) of sites were crayfish remains were found in the otter spraint analysed for diet (listed in ascending order of % frequency).

#	River Basin District	County	River name	X	Y	% frequency of Crayfish
1	South Western	Cork	Owentaragline	123400.00	96000.00	5
2	South Eastern	Tipperary	Fidaghta	195733.17	135009.27	10
3	South Eastern	Tipperary	Suir	238500.00	121900.00	10
4	Shannon	Tipperary	Mahore	172860.61	135203.95	20
5	North Western	Cavan	Erne	235282.56	290631.95	20
6	South Western	Cork	Awbeg R.	156700.00	108200.00	20
7	Shannon	Limerick	Deel (Newcastlewest)	135547.00	141297.00	25
8	South Eastern	Tipperary	Suir	217600.00	121300.00	30
9	Western	Galway	Owendalulleegh (Derrywee)	151800.00	198400.00	30
10	South Eastern	Kildare	Finnery	272200.00	202600.00	30
11	South Eastern	Kildare	Lerr	276800.00	184200.00	30
12	South Western	Cork	Riugobella	174400.00	56800.00	30
13	Western	Mayo	Deel	102200.00	310900.00	30
14	Shannon	Limerick	Broadford St	133234.94	121016.81	35
15	Shannon	Limerick	Deel (Newcastlewest)	129909.88	132703.21	40
16	South Eastern	Laois	Timogue	255200.00	193800.00	45
17	Eastern	Meath	Boyne	268500.00	277900.00	50
18	North Western	Cavan	Annalee	245300.00	311600.00	50
19	Western	Mayo	Bunowen	80700.00	280800.00	50
20	Eastern	Westmeath	Riverstown	252850.00	250500.00	60
21	Shannon	Tipperary	Nenagh	196367.74	172183.00	65
22	South Eastern	Laois	Cappanacloghy	241193.00	193775.16	70
23	Shannon	Galway	-	164346.97	269482.04	70
24	Shannon	Galway	Kilcrow	176312.25	221924.68	75
25	Shannon	Limerick	Deel (Newcastlewest)	131806.30	130995.42	80
26	South Eastern	Tipperary	Black (Twomileborris)	221472.62	152923.52	80
27	Eastern	Kildare	Boyne	263806.86	240222.38	80
28	Shannon	Galway	-	173716.00	260960.00	80
29	South Eastern	Tipperary	Aherlow	191800.00	130300.00	80
30	South Eastern	Tipperary	Suir	213800.00	157100.00	80
31	South Eastern	Tipperary	Nore	210833.81	180506.81	85
32	Western	Mayo	Carrowbeg (Westport)	102282.97	282744.91	85
33	Shannon	Roscommon	Cross R	196200.00	244400.00	85
34	Eastern	Kildare	Liffey	292151.80	210379.50	90
35	Shannon	Westmeath	BOOR	211187.00	235324.00	90
36	Shannon	Westmeath	Rath	227164.20	250536.31	90
37	South Western	Cork	Awbeg (Buttevant)	152700.00	114300.00	90
38	Eastern	Cavan	Blackwater	263100.00	283500.00	90
39	Shannon	Westmeath	Brosna	245600.00	254900.00	90
40	South Eastern	Laois	Stradbally	259700.00	197100.00	90
41	Shannon	Limerick	Dead R	182500.00	146400.00	90
42	Shannon	Limerick	Maigue	154954.38	130436.38	100
43	South Eastern	Tipperary	Black (Twomileborris)	219628.64	155933.09	100
44	South Eastern	Tipperary	Suir	213092.66	172533.99	100
45	South Eastern	Laois	Douglas (Laois)	260882.00	184658.00	100
46	Shannon	Galway	-	179767.61	211016.27	100
47	South Eastern	Kildare	Slate	266577.62	219141.68	100
48	Western	Galway	-	157984.33	219742.96	100
49	Western	Galway	-	164634.00	220261.00	100
50	Western	Galway	-	153850.00	220611.00	100
51	Shannon	Westmeath	Dungolman	217749.80	242919.15	100
52	Shannon	Westmeath	Dungolman	217727.66	251956.41	100
53	Shannon	Galway	-	162379.82	271983.94	100
54	Shannon	Roscommon	Suck	167305.09	280261.43	100
55	Shannon	Westmeath	Royal Canal	234300.00	256500.00	100
56	Shannon	Limerick	Mulkaer R	174100.00	148000.00	100
57	South Eastern	Tipperary	Anner	231400.00	135500.00	100
58	South Eastern	Tipperary	Suir	205100.00	145800.00	100

Appendix V – Case Study – Upper Shannon Catchment 2011

Quality Assurance – Case Study of the Upper Shannon Catchment 2011

Abstract

A Rapid Assessment Survey was conducted by NPWS Conservation Ranger staff from June-September 2011 and Quercus survey staff during May and July 2010 in the Upper Shannon catchment. Rivers had a higher occurrence of otters than lakes and rainfall caused a significant negative bias in results. This was best expressed as a lag of 2 days which may reflect catchment-specific idiosyncrasies in hydromorphology. Surveyor had little effect on the detection of otter tracks and signs suggesting that the NPWS Conservation Rangers and Quercus staff were similar in their ability to detect otter spraints. This suggests the NPWS and Quercus staff conducting the survey were of comparable ability in detecting otter spraint.

Methods

A Rapid Assessment Survey technique was conducted by NPWS Conservation Ranger staff from June-September 2011 to survey the Upper Shannon hydrometric area. The same area was surveyed by Brian Hayden, *Quercus* during May 2011 and again during July 2011 to assess the effect of variability between NPWS staff and professional surveys. It was originally hoped that these surveys would provide variability in rainfall to elucidate the effects of flooding on spraint detection.

A Generalised Linear Mixed Model assuming a binomial error structure and logit link function was used to analysis the Rapid Assessment Survey data. Otter occurrence was fitted as the dependent variable, Site_ID was fitted as a Random factor (to account for repeated observations per site), Surveyor (NPWS or *Quercus*) and Survey period (May, Jun-Sept or July) were fitted as fixed factors. All sites were analysed together fitting Habitat (River or Lake) as a fixed factor. Subsequently, a sub-sample representing the river sites only were analysed fitting Rainfall as a covariate and No. of bridges as a 3-level factor (None, 1 or >2). Just as in the main report, cumulative rainfall in the 1, 2, 3, 4, 5, 7, 14, 21 and 28 days prior to the survey were tested to select the most appropriate temporal scale prior to model building. As the NPWS survey spanned 4 months we also analysed a subsample during July only to provide a directly comparable contemporaneous sample during this month. Finally, lake sites were analysed separately.

Results

A total of 138 sites were surveyed within the Upper Shannon Catchment from May to September 2011. Surveyor (NPWS or *Quercus*) and Survey Period (May, June-Sept and July) had no significant effect on otter detectability (Table Xa-c). Otter occurrence was significantly higher at river sites than lakeland sites (Fig. S2). There were no other significant influences on otter detectability within river or lakes (Table S7c).

However, a sub-sample of 58 sites where sampled during July by NPWS and *Quercus* representing a contemporaneous directly comparable sub-sample. Again, Surveyor had no significant influence on otter occurrence (Table 1d). However, rainfall did negatively bias survey results. Unlike, the results in the main report were the effect of rainfall was expressed most clearly at a lag of 7 days, in the Upper Shannon catchment during July the effect of rainfall was expressed most clearly at a lag of 2 days (Fig. S3).

Table S7 GLMM results for otter occurrence using various sub-samples of data collected from May to September 2011.

Dataset	Random term	Explanatory variable	*Wald*	*F*	df	*p*	Sig.
a) All sites (n=138)	Site_ID	Surveyor	0.18	0.18	1, 83.9	0.672	
		Survey period	0.5	0.5	1, 84.5	0.480	
		Habitat	5.76	5.76	1, 57.3	**0.020**	*
b) All rivers sites (n=109)	Site_ID	Surveyor	0.13	0.13	1, 66.1	0.722	
		Survey period	0.35	0.35	1, 77.8	0.555	
		Bridges	0.88	0.44	1, 36.1	0.649	
		Rainfall $_{2\ days}$	2.31	2.31	1, 99.5	0.132	
c) All lakes sites (n=27)	Site_ID	Surveyor	0.55	0.55	1, 15.3	0.471	
		Survey period	0.00	0.00	1, 16.1	0.955	
		Rainfall $_{14\ days}$	1.47	1.47	1, 16.3	0.242	
d) All rivers sites during July only (n=58)	Site_ID	Surveyor	0.2	0.2	1, 35.7	0.654	
		Bridges	0.3	0.15	1, 26.3	0.863	
		Rainfall $_{2\ days}$	4.92	1.92	1, 52.0	**0.031**	*

As described in the main report, otter occurrence was statistically adjusted to account for the negative bias of rainfall $_{2\ days}$. Adjustment increased occurrence within the NPWS data by +15.8% from 59.0% to 74.8% of sites. This compared to a correction of just +0.4% for sites surveyed by *Quercus* from 66.2% to 66.6% of sites (Fig. S4). This difference was accounted for by differences in the periods of survey. NPWS staff surveyed sites from 25th - 29th July whilst *Quercus* surveyed sites from 11th - 14th July during which it was generally drier than later in the month.

Discussion

The results obtained from Rapid Assessment Surveys of the Upper Shannon catchment during 2011 are consistent with the results of the National Survey during 2010/11. Rivers had a higher occurrence of otters than lakes and rainfall caused a significant negative bias in results. This was best expressed as a lag of 2 days within the Upper Shannon which may reflect catchment-specific idiosyncrasies in hydromorphology. Surveyor had little effect on the detection of otter tracks and signs suggesting that the NPWS Conservation Rangers and *Quercus* staff were similar in their ability to detect spraints.

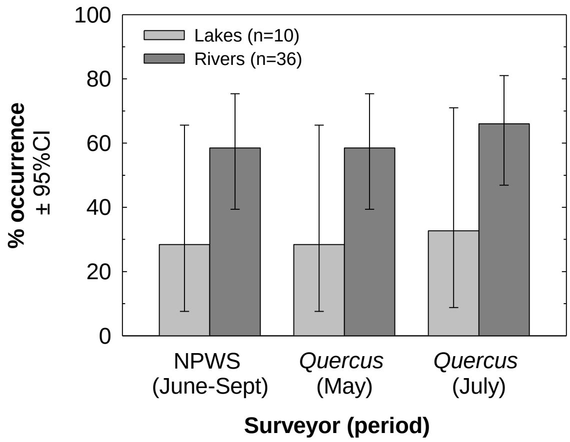

Fig. S2 Otter occurrence during 3 Rapid Assessment Surveys on the Upper Shannon catchment conducting during 2010.

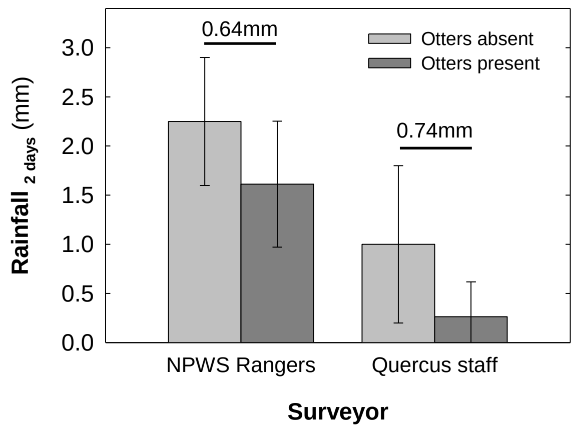

Fig. S3 Variation in rainfall during the 2 days prior to survey at sites were otter tracks and signs were detected compared to sites were they were not detected.

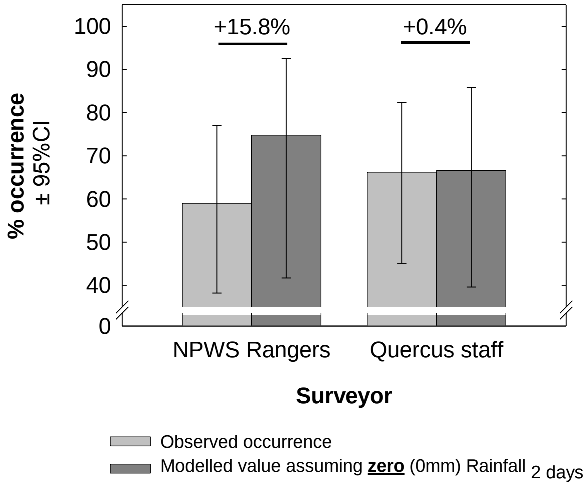

Fig. S4 Otter occurrence as detected in the field (light grey bars) and after statistical correction for rainfall during the 2 days prior to the survey (dark grey bars).