Diet of the Eurasian otter (*Lutra lutra*) within the Pembrokeshire Marine SAC region

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Contents

Introduction

1.1 History and current status of the Eurasian otter

The Eurasian otter (*Lutra lutra*) is a semi-aquatic carnivore belonging to the Mustelid family. The sub-family Lutrinae is generally considered to contain 13 species (Carss, 1995) and the Eurasian otter (hereafter referred to as the otter) is the most widely distributed of all (Figure 1.1) extending from the Iberian Peninsula to South Korea and from northern Sweden to Indonesia (Foster-Turley *et al*. 1990; Kruuk, 2006). Otters are charismatic animals and a symbol for wetland conservation (Reuther, 1998) however, across much of their range they are elusive and predominantly nocturnal making direct study problematic. This means that much of our knowledge regarding otters has been obtained indirectly using less invasive but often biased techniques. The otter is one of the few Eurasian predators that have evolved the ability to actively swim and forage in water, rendering it an important element of biodiversity (Oliveira *et al*. 2008). Otters are considered to be a keystone species, defined as having an influence on a community or ecosystem that is disproportionate to their own abundance, and as such should be of special concern to environmental managers and policy makers (Paine, 1969; Power *et al*. 1996). The keystone role of otters is likely to manifest itself in how, as a top level predator, they influence prey populations and promote biodiversity by enabling the co-existence of species that would otherwise competitively exclude each other. It should be noted that relatively little work has been carried out to provide empirical data supporting this, but there is strong evidence that otters play a keystone functional role within their ecosystems (Bifolchi and Lodé, 2005).

Figure 1.1: Worldwide range of the Eurasian otter *Lutra lutra* (map produced by the IOSF)

Otter populations underwent significant declines not only in the UK but across much of their range during the mid to late twentieth century (Chanin and Jefferies, 1978; Mason and MacDonald, 1990). A number of factors have been suggested as having played a role in the declines including; habitat destruction, increased anthropogenic disturbance, persecution and severe winters, but it is now generally agreed that pollution was the key reason for the decline (Chanin and Jefferies, 1978). It should be noted that in a few countries habitat destruction was thought to be the primary reason behind the declines (Erlinge, 1972), and in the case of pollution the source often differed between countries. In the UK the decline has been attributed to the pollution of water courses due to the extensive use of organochlorine pesticides, such as dieldrin and aldrin from 1955 onwards (Chanin and Jefferies, 1978; Jefferies and Hansen, 2001). Where as in Sweden the decline was attributed to industrial waste water produced by paper mills that deoxygenated rivers and lakes destroying fish stocks (Erlinge, 1972). There is no doubt that in some areas otters faced considerable persecution and were killed in large numbers for their pelt, as game and to protect fish stocks, however in many cases otter hunts were the first to draw attention to the drop in otter numbers (Chanin, 1985; Erlinge, 1972). Hunting may have contributed to the declines in some countries e.g. Belarus (Conroy and Chanin, 2000), but it is thought that such activities had a relatively small impact compared to other consequences of

human activity such as pollution and habitat destruction (Chanin and Jefferies, 1978; Erlinge, 1972).

National surveys are now regularly carried out in the UK (e.g. Green and Green, 1980; Strachan and Jefferies, 1996; Jones and Jones, 2004). Over the last two decades these have show that otter populations are recovering and returning to many areas of the UK (Strachan and Jefferies, 1996), a similar trend has been recorded across much of Western Europe (Conroy and Chanin, 2000). This has resulted in the International Union for the Conservation of Nature (IUCN) downgrading the status of the otter being from vulnerable to near threatened (Reuther and Hilton-Taylor, 2004). Although, there seems to be little doubt that otter populations are recovering in many areas some caution must be taken with how the findings of the national surveys are interpreted. The surveys identify sites as positive or negative for otters based on presence of field signs such as spraints, footprints and couches. A key issue is that the absence of signs does not necessarily imply the absence of otters, false negatives can occur as a consequence of the ability of surveyors and otter behaviour (Ruiz-Olmo *et al*. 2001). Additionally the number of signs in one area does not necessarily correlate to the intensity of use or enable reliable estimations of otter numbers (Kruuk *et al*. 1986), although some studies found a general trend that more spraints meant more otters (Strachan and Jefferies, 1996). The use of dieldrin and aldrin is now prohibited in the UK and the biggest cause of unnatural mortality in otters is currently thought to be road death (Philcox *et al*. 1999). Drowning in fyke nets and crustacean traps are considered to be significant risks in some areas (Reuther and Hilton-Taylor, 2004), and other non-violent causes of mortality should also be considered as the precise cause of death is not always apparent (Kruuk and Conroy, 1991). Otter carcasses with signs of disease (Simpson, 2000) and endoparasitic infection (Madsen *et al*. 1999) are frequently found. Additionally gastrointestinal haemorrhaging, possibly as the result of starvation was found in 37% of carcases examined by Kruuk and Conroy (1991), so the possibility that otter populations are trophically stressed in some localities can not be discounted. Habitat destruction and degradation also remains a threat to otter populations. The aquatic habitats of otters are extremely vulnerable to anthropogenic effects and activities such as removal of bank side vegetation, dam construction and draining of wetlands are unfavourable to otter populations (Reuther and Hilton-Taylor, 2004).

1.2 Otter foraging and diet

Otters are highly adaptable semi-aquatic carnivores capable of forging in both freshwater (Carss *et al*. 1990; Copp and Roche, 2003) and marine (Watson, 1978; Heggberget, 1993) environments. Otters are strongly associated with aquatic environments so naturally fish usually constitute a large proportion of their diet (Kruuk, 2006). However, otters are by no means obligate piscivores and wide range of prey groups have been recorded including; amphibians (Weber, 1990), crustaceans (Watson, 1978), Aves (Lanszki and Molnar, 2003), mammalians (Jurajda *et al*. 1996), reptilians (Adrian and Delibes, 1987) and insects (Harris *et al*. 2007). In particular prey that are strongly associated with aquatic habitats, such as amphibians, are frequently recorded often forming an important seasonal component of diet (Weber, 1990; Clavero *et al*. 2005). Otters are thought to be opportunistic foragers taking prey groups roughly according their availability (Watt, 1995; Kruuk, 2006). It is important to remember that the availability of a particular prey species is not merely a factor of its population size but also its behaviour and the environmental conditions. Fast swimming fish, such as whiting and mackerel are rarely recorded in otter diet, although they are often very abundant within the coastal foraging areas (Kingston *et al*. 1999). Other species, such as salmonids, may be easier to catch in the winter when lower water temperatures reduce their swimming speed (Beamish, 1978). Conversely eels may become less available during the winter as they bury into the mud and enter a state of torpidity (Jenkins and Harper, 1980). Peaks in amphibian occurrence in otter diet often coincide with seasonal spawning aggregations (Clavero *et al*. 2005) when the high density of individuals represent easy pickings for an otter.

1.3 Status of Otters on Pembrokeshire

Some of the earliest records of otters on Pembrokeshire were made at Orielton lakes close to Bosherton in 1927 (Henshilwood, 1981). Further observations of otters in Pembrokeshire were made up to the 1960s, but as with other areas in the UK sightings became less frequent following the population decline that began in the 1950s (Henshilwood, 1981). The national otter surveys of Wales classify Pembrokeshire as falling within the Cleddau hydrometric area (Crawford *et al*. 1979; Jones and Jones, 2004). Historically the Cleddau area has always returned one of the highest proportions of positive sites in Wales (Jones and Jones, 2004). The first otter survey

of Wales, carried out between 1978 and 1979, found 41% of sites in the Cleddau area were positive, which rose to 54% and 71% in the subsequent surveys of 1984 and 1991(Crawford *et al,* 1979; Jones and Jones, 2004). The fourth otter survey of Wales (Jones and Jones, 2004) recorded positive signs of otters at 97% of sites within the Cleddau hydrometric area. No other area in Wales returned a greater proportion of positive sites, although 97 % of sites were also recorded as positive in the Teifi area. It is clear that otters are widely distributed on Pembrokeshire and it is probable that it represents one of the most important areas for otters in Wales if not the UK. However, very little is known about the size or biology of the otter population on Pembrokeshire. A small amount of work has been carried out but this has predominantly been restricted to surveys (e.g. Liles, 2003) and the small amount of dietary analysis which has been carried out is limited by both sample size and the area covered.

Otters appear to be widely distributed in freshwater habitats throughout Pembrokeshire, but several sightings of otters in the sea off the Pembrokeshire coast were made in the late 1990s (Liles, 2003). The use of the marine environment by otters in Wales is likely to be underestimated by the national survey as only two coastal sites are visited (Jones and Jones, 2004). The only two coastal sites represented in the entire national survey are located on Pembrokeshire, one close to St. David's and one at Freshwater West, and both were positive for otter presence in 2002 (Jones and Jones, 2004). A more comprehensive survey of the Pembrokeshire coast was carried out by Liles (2003), and found otter signs at 44.82% (13/29) of sites. This survey identified that caves and clefts in cliffs were providing secluded feeding and sprainting platforms for otters and evidence of breeding was found at four of the coastal sites.

1.4 Otter diet on Pembrokeshire

Analysis of spraints collected by Liles (2003) showed that otter diet on Pembrokeshire predominantly consisted of Eel (*Anguilla anguilla*), Salmonidae sp, minnow (*Phoxinus phoxinus*) and three spined stickleback (*Gasterosteus aculeatus*) (Liles, 2003). Although the survey found otters to be extensively utilizing sea and littoral zones marine prey only accounted for a relatively small proportion of the diet. At Bosherton lakes no marine prey were found in the diet despite the site being connected to the sea via a small sandy beach (Henshilwood, 1981). Coastal habitats

are often very productive and it has been suggested that they may represent the optimal foraging habitat for otters (Watson, 1978; Heggberget and Moseid, 1994), so it seems surprising that marine prey did not occur more frequently in the studies of Liles, (2003) or Henshilwood, (1981). The lack of marine prey in these studies may be a result of the integral importance of freshwater to otters both for drinking and maintaining the waterproof properties of their fur (Chanin, 1985; Beja, 1992). There are several streams that discharge into the sea around the Pembrokeshire coast and Liles (2003) found these to be well marked by otters suggesting that frequent forays are made into them. It is also likely that the occurrence of marine prey was underestimated by the study of Liles (2003) as assessment of diet was not its primary objective meaning the sample was limited to 54 spraints collected during the survey period of August-November 2002. The limited collection period meant that if marine prey was of seasonal importance its contribution to diet would be underestimated. Additionally it was noted that marked differences existed in the occurrence of marine prey in spraints from open coastal sites compared to those from within the Milford Haven waterway. Marine prey may constitute a more significant proportion of the diet at coastal sites outside of Milford Haven. At Bosherton the availability of coarse fish and eels throughout the year would probably have negated the need for otters to forage in the sea.

1.5 Study aims

Continued reports of otters swimming in the sea off Pembrokeshire suggest that the marine habitat is of importance and marine prey may become an increasingly frequent component of otter diet on Pembrokeshire. Following the recommendations of Liles (2003) a more extensive study was carried out to determine diet and the extent to which otters were foraging in marine habitats in Pembrokeshire. If otters on Pembrokeshire are increasingly using the coastal environment, and taking marine prey, the potential impact of industrial and leisure activities needs to be assessed and incorporated into management planning.

This study aimed to investigate the diet of otters inhabiting coastal areas of Pembrokeshire over a 12 month period. The aims of the study were:

1. Describe the diet of otters inhabiting coastal areas of Pembrokeshire.
2. Determine the proportion of the diet formed by marine prey.
3. Investigate seasonal variation in otter diet and the use of coastal foraging areas on Pembrokeshire.
4. Investigate spatial variation in marine prey between study sites on the Pembrokeshire coast.

Materials and Methods

2.1 Study area

Pembrokeshire is located in south west Wales, has a large number of riparian systems and a heterogeneous coastline. The Pembrokeshire coast is popular with walkers, surfers and the relatively new sport of coasteering. Milford Haven is a busy port and the presence of oil refineries means there is a risk of crude oil spillage or contaminations, as was the case when the *Sea Empress* ran aground in 1996. There are a large number of sea caves around the Pembrokeshire coast, which provide potential resting and breeding sites for otters (Liles, 2003). The presence of cold water reefs off the Pembrokeshire coast may provide a profitable and reliable source of prey, but it is not clear whether the otters are foraging on them or not.

Figure 1.2: Pembrokeshire coast with sampling sites marked with red circles (generated from an OS map using Carto by EDINA©)

2.2 Spraint collection

Spraint collections were undertaken on Pembrokeshire by a team of volunteers co-ordinated by the Pembrokeshire Marine SAC officer. The aim was to visit a total of 22 sites every month from July 2007 to June 2008 (Figure 1.2). During each monthly visit volunteers were instructed to search each site for otter spraints and collect up to three spraints for analyses. In some cases this meant that only a sub-set of the spraints from each monthly site visit were analysed, but in many cases less than three spraints were present. Spraints were placed into individual sealed bags, labelled and sent to Swansea University for analysis. Volunteers were given training by the SAC group to help them identify and collect spraints, however all spraint bags returned were checked by the author to confirm that they contained otter spraint. The other criterion required for samples to be included in the dietary analysis was that each bag must contain only one otter spraint.

2.3 Dietary analysis

All spraints were subjected to dietary analysis through the identification of hard prey remains. Prior to analysis spraints were soaked individually in 250ml beakers, containing a saturated solution of biological detergent, for a period of at least 24 hours. The spraints were then gently rinsed through a 420µm sieve to remove excess mucus and grit and turned out onto a sheet of heavy duty paper towel, with care taken to ensure all remains were removed from the sieve. The spraint remains were then wrapped up in the paper towel and left to dry for a period of at least 24 hours before analysis. All spraints were analysed using an Olympus SZ40© dissection microscope. Prey remains were indentified using published keys (Day, 1966; Watson, 1978; Teerink, 1991; Miranda and Escala, 2002; Conroy *et al*. 2005) and a reference collection containing vertebrae and mouth parts of 39 fish species, three amphibian species and two reptile species. Where possible remains were identified to family or species level, but this wasn't possible with some of the remains, particularly for non-fish prey.

There are at least 13 different methods of expressing the results of spraint analysis ranging from a simple percentage occurrence to more complex calculations of biomass intake. All of the methods have biases associated with them, which means none give a completely accurate interpretation of otter diet. One major bias that applies to all spraint analysis techniques is that they underestimate the occurrence of soft bodied prey and overestimate the occurrence of prey with a large number of hard parts. The most frequently used method determines the relative frequency at which prey remains occur in respect to other prey (e.g. Watson, 1978, Lŏpez-Nieves and Hernando, 1984; Watt, 1995). This method defines the presence of a prey category in a spraint as one occurrence regardless of the number of remains. Relative frequency of occurrence (RFO) is subject to the same major biases as frequency of occurrence (Erlinge, 1968; Carss and Parkinson, 1996) and other studies have suggested that there is a lack of independence with relative frequencies that affects the interpretation of dietary variation (Clavero *et al*. 2004) However, feeding studies on captive otters have found that this method gives a reasonably accurate interpretation of diet (Erlinge, 1968; Jacobsen and Hansen 1996).

$$RFO = \frac{\text{Number of occurrences of a prey group}}{\text{Sum occurrences of all prey groups}} \times 100$$

The proportions of marine fish, freshwater fish and non-fish prey in otter diet were assessed in order to determine the extent of marine foraging. Fish groups were classified using the description of Wheeler (1969) (Table 2.1).

Table 2.1: Classification of marine and freshwater fish groups for the purpose of investigating the marine component of otter diet on the Pembrokeshire coast.

Common name	Taxonomic name
Marine Fish	
Blenny	Blennidae
Brill	*Scophthalmus rhombus*
Dab	*Limanda limanda*
Eelpout	*Zoarces viviparus*
Fifteen-spined stickleback	*Spinachia spinachia*
Five-bearded rockling	*Ciliata mustela*
Flounder	*Platichthys flesus*
Four-bearded rockling	*Enchelyopus cimbrius*
Goby	Gobiidae
Great Pipefish	*Syngnathus acus*
Plaice	*Pleuronectes platessa*
Unidentified Flatfish	Heterosomata
Unidentified Sculpins	Cottidae
Wrasse	Labridae
Freshwater fish	
Salmonids	Salmonidae
Bullhead	*Cottis gobio*
Chub	*Leuciscus cephalus*
Unidentified Cyprinids	Cyprinidae
European eel	*Anguilla anguilla*
Three-spined stickleback	*Gasterosteus aculeatus*
Minnow	*Phoxinus phoxinus*

2.4 Statistical analysis

All analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 13.0 (SPSS Inc, Chicago, USA). All data was assessed for normality before analysis and P was set at 0.05.

Niche breadth is a quantitative measure of how specialized the diet of an organism is (Krebs, 1989). There are several different ways of measuring niche breadth such as Levins, which gives more weight to common prey, and Shannon-Wieners, which gives more weight to rare prey. In this study Shannon-Wieners method was used as rarely occurring prey in otter diet may still be of seasonal importance. The equation used to calculate Shannon-Wiener niche breadth is below and produces a value between 0 and 1, with 0 being the most specialised and 1 the least specialised.

$$\text{Shannon-Wiener niche breadth} = -\Sigma P_j \log_e P_j$$

Pj = Proportion of individuals found in or using a resource states
B = Levin's measure of niche breadth
n = Number of possible resource states

Variation in the mean occurrence of marine fish, freshwater fish, non-fish and individual prey categories was investigated using one-way Analysis Of Variance (ANOVA). Where significant results were detected a least significant difference (LSD) *post hoc* test was applied to investigate which pairings differed significantly. A Spearman's rank correlation was used to see if there were any significant correlations between the occurrence of the top six fish prey and the top three non-fish prey.

Results

3.1: Otter diet on Pembrokeshire 2007-2008

A total of 232 spraints were collected of which 180 passed the criteria to be included in the dietary analysis (Figure 3.1). A total 578 prey occurrences were recorded in the spraints and 30 prey groups were identified, with fish prey making up 85.3% the RFO % (Table 3.1). Gobies, blennies and eels were the most frequent prey items overall, but there was a considerable seasonal variation in the occurrence of many prey groups. Of the non-fish prey avian and crustacean groups were the most frequent

dietary items with amphibians, insects and mammals occurring at relatively low frequencies. The majority of the avian remains were from the Rallidae family with a small number of Charadiformes. Crustacean remains were predominantly *Carcinus sp* and the mammalian remains were predominantly rabbit. The mean Shannon-Wiener niche breadth value calculated for overall otter diet at Pembrokeshire coastal sites was 0.92 (± 0.03 SD). Comparing the niche breadth value obtained in this study to those from other locations across the otter's range it can be seen that otter diet on Pembrokeshire is particularly diverse (Table 3.2).

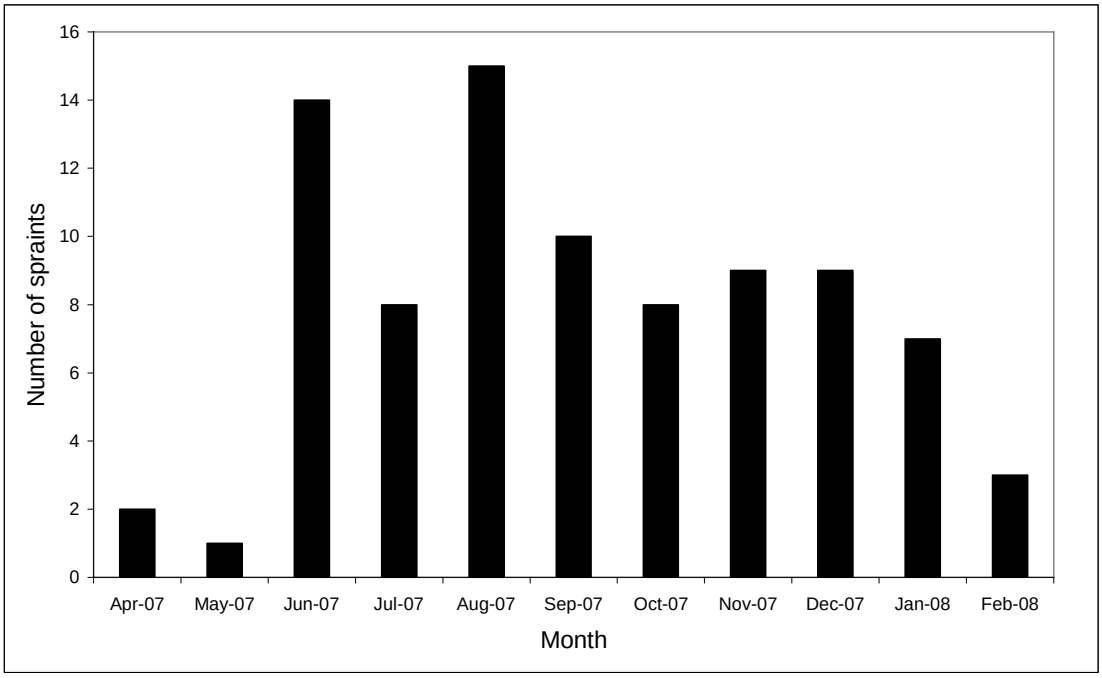

Figure 3.1: Seasonal variation in the number of spraints collected from coastal sites on Pembrokeshire.

Table 3.1: Diet of the Eurasian otter on Pembrokeshire July 2007- June 2008 expressed as relative frequency of occurrence (Watson, 1978).

Prey categories	Taxonomic name	RFO %
Fish		85.3
Common Eel	*Anguilla anguilla*	10.9
Blennies	*Blennidae sp*	10.4
Brill	*Scophthalmus rhombus*	0.3
Brown Trout	*Salmo trutta*	2.8
Bullhead	*Cottis gobio*	2.4
Chub	*Leuciscus cephalus*	0.5
Dab	*Limanda limanda*	1
Eelpout	*Zoarcidae*	0.9
Fifteen spined stickleback	*Spinachia spinachia*	6.2
Five-bearded rockling	*Gaidropsarus vulgaris*	1.9
Flounder	*Platichthys flesus*	1.4
Four-bearded rockling	*Enchelyopus cimbrius*	6.6
Gobies	*Gobiidae sp*	12.5
Minnow	*Phoxinus phoxinus*	0.2
Pike	*Esox lucius*	0.2
Pipefish	*Sygnathidae*	1.9
Plaice	*Pleuronectes platessa*	0.5
Three-spined stickleback	*Gasterosteus aculeatus*	6.6
Wrasse	*Labridae sp*	4.3
Unidentified Cottidae	Cottidae sp	2.8
Unidentified Cyprinidae sp	Cyprinidae sp	5.7
Unidentified Flatish	Hetrosomata sp	5
Unidentified Fish		0.3
Insects		**0.9**
Coleoptera	*Dysticus sp*	0.7
Odonata	*Ashena sp*	0.2
Crustacean	*Crustacean*	6.4
Amphibian		**3.5**
Anuran sp	*Rana temporaria, Bufo Bufo*	1.9
Newts	*Triturus sp*	1.6
Mammlian		**0.7**
Avian		**3.3**

Table 3.2: Shannon-Wiener niche breadth values for Eurasian otter diet from selected coastal and inland studies across their range.

Study Location	Coastal or inland	Shannon-Wiener niche breadth
Pembrokeshire	Coastal	0.86
Norway (Heggberget, and Moseid, 1994)	Coastal	0.79
Isle of Skye (Yoxon, 1999)	Coastal	0.76
West Irish Coast (Kingston *et al*. 1999)	Coastal	0.73
Portugal (Beja, 1997)	Coastal	0.69
Gower Peninsula (Parry *unpub*)	Coastal	0.61
England (Copp and Roche, 2003)	Inland	0.66
Scotland Carss, *et al*. (1990)	Inland	0.32

3.2 Relative proportions of marine and freshwater fish in otter diet on Pembrokeshire

Marine fish were the largest dietary component accounting for 56% of all prey occurrences (Figure 3.2). Freshwater fish made up 29% of diet and non-fish prey 15%. A very small number of fish remains were not identifiable through either the reference collection or the published keys, which suggests they are novel items in otter diet.

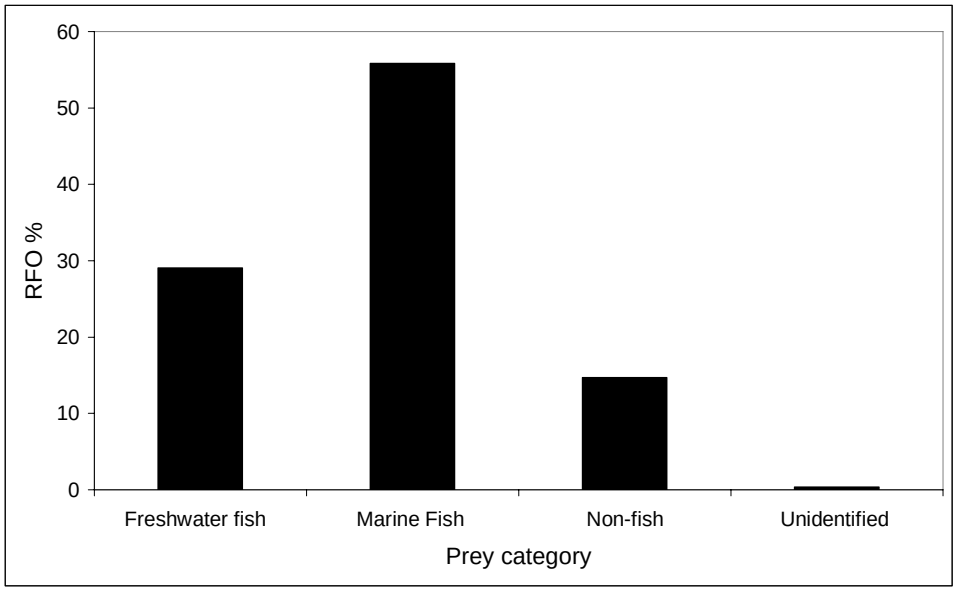

Fig 3.2: Relative frequency of occurrence (RFO %) of freshwater, marine, non-fish and unidentified prey in otter spraints (*n* =180) analysed from Pembrokeshire July 2007- June 2008

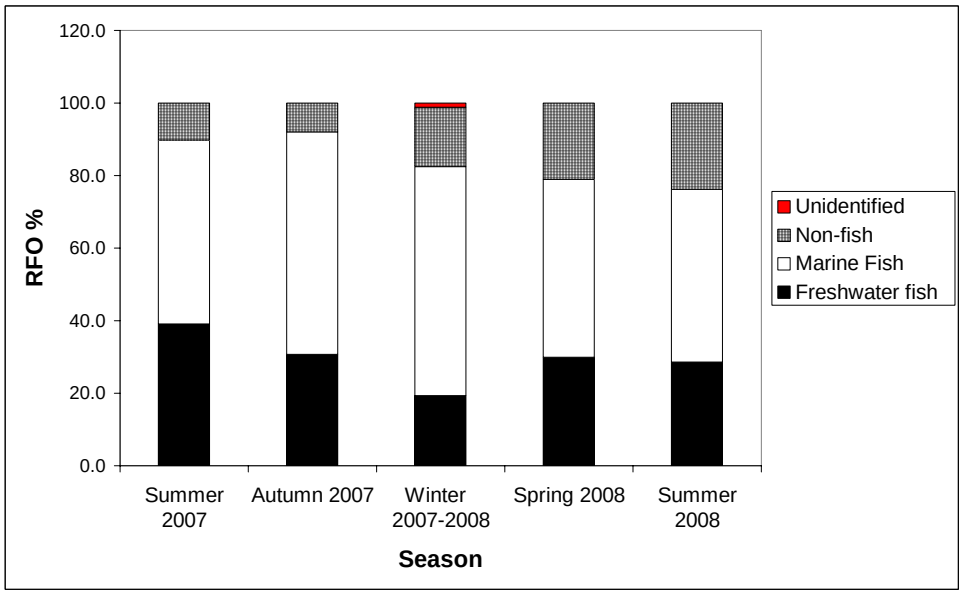

Figure 3.3: Seasonal variation in the relative frequency of occurrence (RFO %) of freshwater, marine, non-fish and unidentified prey in otter spraints analysed from Pembrokeshire July 2007- June 2008 (summer 2007 *n* = 23, autumn 2007 *n* = 35, winter 2007-2008 *n* = 53, spring 2008 *n* = 40, summer 2008 *n* = 7)

3.3 Temporal variation otter diet on Pembrokeshire

There was a large degree of seasonal variation both in the occurrence of individual prey groups (Table 3.3) and in the proportion of marine, freshwater and non-fish prey consumed over the study period (Figure 3.3). Marine fish constituted the largest component of otter diet throughout the year (Figure 3.3), whereas the proportion of freshwater fish peaked in summer and decreased during winter. The proportion of non-fish prey steadily increased over the study period from 10% in summer 2007 to 23.8% in summer 2008. A one-way ANOVA was carried out, which showed that there were no significant seasonal variations in the proportions of marine fish, freshwater fish, non-fish and unidentified prey.

There was seasonal variation in the occurrence of several individual prey categories most notably for eel, which peaked in summer and decreased during autumn before falling to very low levels during winter and spring (Table 3.3). The occurrence of cyprinids had an almost reciprocal pattern to that of eel peaking in winter and decreasing in summer. However, a Spearman's rank correlation showed that the occurrence of eel was not significantly correlated with the occurrence of cyprinids. Only two significant correlations existed between the occurrences of individual prey groups. The occurrence of stickleback was negatively correlated with the occurrence of goby ($r_s = -0.623$, $p = 0.03$). The occurrence of crustacean had a significant negative correlation with that of avian groups ($r_s = -0.578$, $p = 0.049$), but this should be treated with caution as the significance was very close to the critical level of 0.05. The occurrence of Blenny had two clear peaks in summer 2007 and spring 2008, whilst the occurrence of crustacean almost doubled in frequency from 8.8% in summer 2007 to 14.29% in summer 2008. Most of the non-fish prey featured at low levels throughout the year, but the occurrence of amphibians peaked winter and spring making them one of the most important prey groups during these periods. A one-way ANOVA was used to see if any of the seasonal variations in individual prey groups were significant. The results showed that the occurrence of eel varied significantly between seasons ($F_{3/8} = 9.076$, $p = 0.006$). A least significance test (LSD) was then applied to the eel data, which showed that the RFO values for winter ($MD = -13.4$, $p = 0.001$) and spring ($MD = -8.4$, $p = 0.015$) were significantly lower than those recorded in summer. The RFO of eel in winter was also significantly different from that recorded in autumn ($MD = -8.0$, $p = 0.019$). The occurrence of salmonids also significantly varied during the year ($F_{3/8} = 5.582$, $p = 0.023$). A least

significant difference (LSD) test showed that the occurrence of salmonids during the summer months was significantly higher than in autumn ($MD = 4.4$, $p = 0.037$), winter ($MD = 5.0$, $p = 0.021$) and spring ($MD = 6.9$, $p = 0.004$). No other prey groups displayed discernable seasonal variations in their occurrence.

Table 3.3: Seasonal variation in the relative frequency of occurrence (RFO %) of the top ten prey groups in otter spraints analysed from Pembrokeshire July 2007- June 2008

Prey Category	Summer 2007	Autumn 2007	Winter 2007-2008	Spring 2008	Summer 2008
Blenny	14.04	9.49	7.69	13.21	4.76
Salmonidae	8.77	2.92	2.31	1.89	9.52
Crustacean	8.77	2.92	6.15	11.32	14.29
Cyprinidae	7.07	7.3	8.46	5.66	0.00
European Eel	22.81	11.68	3.08	5.66	14.29
Flatfish	5.25	10.95	9.23	15.66	9.52
Goby	14.04	12.41	13.08	18.87	9.52
Rockling	5.26	13.14	6.92	7.55	9.52
Stickleback	7.07	12.41	14.61	5.66	14.28
Wrasse	3.51	1.46	4.62	5.66	4.76

The diversity of otter diet remained relatively constant throughout the year (Table 3.4). There was a low level of similarity in diet between seasons over the study period with the exception of spring, which was relatively similar to all other seasons (Table 3.5) with a mean similarity of 72.2% ($\pm$ 14.7 SD). The diet of summer 2008 had a low level of similarity with all other seasons and in particular with that of summer 2007. The highest similarity in diet was between winter 2007-2008 and spring 2008, when diet was dominated by marine fish and amphibians (winter RFO % = 6.93%, spring RFO % = 9.43%) although there was also a relatively high degree of similarity between autumn 2007 and summer 2007.

Table 3.4: Variation in the number of prey groups and breadth of otter diet on Pembrokeshire 2007-2008

Season	Number of spraints	Number of prey groups	Niche breath Shannon-Wiener (*H'*)
Summer 2007	23	22	0.94
Autumn 2007	35	26	0.89
Winter 2007-2008	54	23	0.92
Spring 2008	40	19	0.90
Summer 2008	7	13	0.96

Table 3.5: Percentage similarity between seasons in otter diet on Pembrokeshire 2007-2008

Renkonen's Similarity %	Summer 2007	Autumn 2007	Winter 2007-2008	Spring 2008
Summer 2007	-	-	-	-
Autumn 2007	72.0	-	-	-
Winter 2007-2008	54.6	73.0	-	-
Spring 2008	81.8	82.4	100	-
Summer 2008	50.9	64.7	62.3	80.3

3.4 Spatial variation otter diet on Pembrokeshire and within Milford Haven

A full year of spraints was only provided by one site, which meant that statistical analysis of spatial trends between sites was not possible due to the effect that unequal sampling periods and sample size would have on the data.

Discussion

4.1 Otter diet on Pembrokeshire

Otter diet on the Pembrokeshire coast between July 2007 and June 2008 was highly diverse, including a large range of freshwater, marine and non-fish prey. Small, demersal, slow swimming fish, associated with rocky shores were the most frequent prey items indicating that the marine habitat is an important foraging area for otters on Pembrokeshire. Marine fish formed the largest proportion of diet throughout the year, as may be expected considering the coastal location of the study sites. The

Pembrokeshire coast is very long and heterogeneous providing a complex and diverse habitat for otters. Otters inhabiting Pembrokeshire coastal regions rely heavily on marine food resources, but are by no means obligate marine foragers with around one third of diet composed of freshwater fish and 10-25% of non-fish groups. Access to freshwater is also imperative to otters for washing and drinking so coastal freshwater streams are likely to be of considerable importance. Gobies appear to be an important staple prey occurring at high frequencies throughout the year. Other frequently consumed prey were blennies, rockling, eels and sticklebacks but, as has been found in several other studies (e.g. Kruuk and Moorhouse, 1990; Beja, 1991; Kingston *et al.* 1999; Roche, 2001), otter diet on Pembrokeshire was subject to temporal variation.

4.2 Temporal variation in the occurrence of fish prey in otter diet

Although it was not significant there was a general decrease in the proportion of freshwater fish in diet during winter, which suggests that freshwater environments on Pembrokeshire may be less profitable for otters during this period. The low occurrence of freshwater prey during winter could be due to a decrease in the availability of freshwater prey populations during this period. In this study eels were the most important freshwater prey, but there was significant seasonal variation in the occurrence of eel. A winter drop in eel predation has been recorded by several other studies (e.g. Jenkins and Harper, 1980; Davies, 1994). During winter eels bury into the sediment at the bottom of rivers and lakes entering a state of torpor (Jenkins *et al*. 1979; Murphy and Fairley, 1985), this period of inactivity and inaccessibility significantly reduces their availability to otters. The activity of Cyprinids decreases during winter, but unlike eels they do not burrow into the substrate, instead becoming inactive at the bottom of water bodies (Cunjak, 1996). This behaviour makes them a relatively easy prey for otters (Lŏpez-Nieves and Hernando, 1984). In contrast during summer cyprinid activity increases and they form shoals in vegetation or open water (Cunjak, 1996), which makes them less vulnerable to predation (Bekker and Nolet, 1990).

The occurrence of salmonids and eel was remarkably lower than that recorded by Liles (2003) which could be linked to a decrease in their populations or an increase in marine foraging. Eel populations across the UK and Europe have declined rapidly over the last two decades (Feunteun, 2002). This may pose a major challenge to otters as Eels are frequently reported as the most important and frequently taken prey item

of otters (Jenkins *et al*. 1979; Jenkins and Harper, 1980; Erlinge and Jensen, 1981; Murphy and Fairley, 1985; Weber, 1990; Kingston *et al*. 1999; Britton *et al*. 2006). Although eels are an important prey group in some regions they are only a minor component of otter diet in others (e.g. Erlinge, 1969; Arca and Prigioni, 1987; Kemenes and Nechay, 1990; Clavero *et al*. 2004). The overriding importance of eels in otter diet is appears to be restricted to a relatively narrow band of high latitudes and low longitudes (Parry and Forman *unpub*). The significant seasonal variation in the occurrence of salmonids is in contrast to the temporal patterns of salmonid consumption recorded in other studies. Typically salmonid consumption peaks during the cold months (Jenkins and Harper, 1980; Baltrūnaitė, 2006), which has lead to suggestions that due to the effect temperature has on swimming speed (Lee *et al*. 2003) salmonids are easier to catch during winter. In contrast the results of this study indicate that a summer increase in the swimming speed of salmonids does not prevent otters from catching them. The summer peak in salmonid occurrence could be explained by seasonal differences in the activity patterns of salmonids. During summer salmonid species are active during the day and at night, but during the winter the water temperature decreases and they shelter in the substrate during the day (Gardiner, 1984; Carss, 1995). The increased level of salmonid activity during summer may increase their availability to otters. Alternately there may be seasonal variation in the availability of different salmonid species or size classes resulting in a summer peak in categories that are easier for the otters to catch. It is also possible that during winter easy to catch prey, such as amphibians, is plentiful so it is less profitable for otters to try and catch larger, faster fish such as salmonids (Sulkava, 1996).

The occurrence of four and five bearded rockling peaked in autumn. This pattern has similarly been observed by other studies (e.g. Watt, 1995; Kingston *et al*. 1999) Rockling are thought to be an important prey group for coastal foraging otters as they are relatively large and slow swimming compared to other rocky shore species (Kingston *et al*. 1999). Summer peaks in the occurrence of blennies may be due to increased densities as a result of inshore spawning migrations that take place between late spring and early summer (Fives, 1986). It appears that an increase in the density of a fish prey, which is already utilised, results in an increase in consumption. However, just because a potential prey item is present in high densities does not necessarily mean it is consumed. Mullet (*Chelon labrosus*) did not appear in the

spraints despite being abundant at several of the study sites (Rosemary Royle and Geoff Liles *pers com*). It is possible that, due to their size, mullet bones are not consumed or recovered in spraints, but this is unlikely to be the case as mullet predation has been recorded previously through spraint analysis (Beja, 1991). The most likely explanation is that the otters disregard mullet due to the abundance of smaller easier to handle prey, but further work is required to confirm this.

4.3 Temporal variation in the occurrence of non-fish in otter diet

Non-fish prey occurred at relatively low levels at the start of the study (Summer 2007 RFO = 10.1%) but showed a gradual increase in occurrence towards the end of the study (Summer 2008 RFO = 23.8%). The variation in the proportion of non-fish prey taken over the study period was not significant. Amphibians were particularly frequent items in spraints during winter and spring, a period when trophic stress in otters is believed to be highest, due to lower prey availability and increased foraging costs (Kruuk *et al*. 1987; Kruuk and Conroy, 1991). The positive occurrence of newt is of note as it represents only the fourth record of predation on newts by otters. In times of low temperatures and low prey availability certain foraging areas may become untenable leading to otters increasing their range, foraging in different habitats or taking alternative prey (Roche, 2001). The role of alternative or seasonally important prey such as amphibians can not be underestimated, as they are potentially instrumental in maintaining the otter populations during the most trophically challenging periods. The steady increase in the occurrence of non-fish prey through the study period is an interesting trend, reflected in the diversity of otter diet on the Pembrokeshire coast, and is potentially due to changes in prey communities. There is emerging evidence that otters can respond to climatic changes which affect the profitability of a habitat (Remonti *et al*. 2008). Periods of high rainfall leads to increases in the flow rate of rivers and streams, which may result in an increase in the amount of time spent foraging in terrestrial or marine habitats. Similarly unfavourable sea conditions may reduce the success of marine foraging whilst increasing the associated risk. It is not clear whether otters living on the Pembrokeshire coast are adapting their foraging behaviour in reaction to changing conditions in riparian and coastal habitats. To investigate this further research is required with replication of seasonal dietary data and the collection of concurrent information regarding sea state and riparian discharge.

4.4 Temporal variation in the breadth of otter diet

The high diversity of otter diet on Pembrokeshire is highlighted by the particularly wide niche breadth value of 0.92, which is higher than those obtained from studies of coastal foraging otters at other locations (Table 3.2) The diet of otters on the Gower peninsula contains markedly more freshwater prey than on Pembrokeshire, which is to be expected considering the coastal location of the Pembrokeshire collection sites (Parry *PhD thesis*). The factor commonly cited as driving seasonal and spatial variation in diet is prey availability with otters thought to take prey in proportions roughly equivalent to their density in the surrounding environment (Kruuk and Moorhouse, 1990; Heggberget, 1993; Watt, 1995). However, many factors other than population size affect the availability of a particular prey species, meaning it is very difficult to quantify prey availability. The most likely explanation for the low level of similarity between summer 2008 and the other seasons of the study is the low sample size collected during that period. Changes in prey communities and the size or demographics of the otter population could also have contributed to the differences in diet recorded in summer 2008. Little is known about the importance of maternally learnt hunting techniques and foraging patches, which may play a considerable role in the idiosyncratic variation of otter diet (Watt, 1993; Kitchener, 1999), as such behaviour is extremely difficult to measure. The high level of similarity in the prey groups taken between winter 2007-2008 and spring 2008 suggests that certain prey groups are of considerable importance during these periods. Otters are thought to be at the highest risk of starvation during spring and winter (Kruuk *et al*. 1987; Sulkava *et al*. 2007) and it has been suggested that otters take more alternative prey during times of trophic stress (Beja, 1997). So although some prey groups with a seasonal peak in occurrence, such as amphibians, may not necessarily be of importance over the entire year they are still an instrumental component of otter diet.

4.5 Limitations of study

Spraint analysis tends to over overestimate the occurrence of prey with a large number of hard parts and underestimate the occurrence of soft bodied prey (e.g. Erlinge, 1968; Carss and Elston, 1996; Carss and Parkinson, 1996). Spraints from the Pembrokeshire coast were analysed using the relative frequency of occurrence method described by Watson (1978). This method was used as it gives a reasonably accurate picture of diet (Erlinge, 1968) and produced data that is comparable to that produced

by other methods (Parry *PhD thesis*). The spraint collection focussed on coastal sites, so the high proportion of marine species in diet is likely to be higher than would be obtained from inland locations on Pembrokeshire. However, as the objective of this study was to describe otter diet at coastal sites on Pembrokeshire, this does not affect the context of the results. The sample size for each season was not equal which could influence the trends identified, but the overall sample size was over the minimum of 94 required to identified effect sizes over time (Trites and Joy, 2005). Analysis of spatial variation in diet was not undertaken due to the incomplete collections at some sites.

4.6 Conclusions and implications for conservation management

This study builds upon the previous work carried out by Liles (2003), and further confirms that otters are living and foraging on the Pembrokeshire coast throughout the year. Diet of otters inhabiting coastal regions of Pembrokeshire is distinctly marine. The evidence presented here confirms that otters on the Welsh coast are foraging in the marine environment. Marine species are the major dietary component throughout the year on Pembrokeshire although freshwater prey is also taken, being of particular importance during summer. Non-fish prey is taken at a similar level throughout the year, with amphibians of particular importance during winter and spring. It is thought that marine feeding otters have a distinctive preference for rocky substrates (Kingston *et al*. 1999; Kruuk, 2006), but spraints collected from the Pembrokeshire coast contained a large proportion of demersal prey associated with soft substrates. Work carried out by Nolet *et al*. (1993) showed that otters are capable of diving to at least 15m, although most of their dives were less than 2m. The majority of the fish predated by otters on Pembrokeshire were coastal species, which would be present in relatively shallow water, well within the diving abilities of otters. A long heterogeneous coastline, such as that of Pembrokeshire, provides a rich and reliable food source. The occurrence of freshwater fish and non-fish prey, in spraints from Pembrokeshire, demonstrates the flexibility of otter foraging techniques, which are effective at catching a wide diversity of prey in a range of different habitats.

Management planning for otter populations on Pembrokeshire needs to incorporate both marine and freshwater habitats as both are of considerable importance. Otters are obtaining a large proportion of their food from marine habitats, but access to freshwater, for washing and drinking, is essential (Kruuk, 2006). A significant

proportion of otter diet also consists of prey caught in freshwater and terrestrial habitats. Food rich, relatively undisturbed coastal sites are likely to be instrumental to the otters and as such need to be protected in order to ensure the future conservation of otters on Pembrokeshire. Otters are protected under annexes II and IV of the European Habitat Directive and by schedules 5 and 6 of the Wildlife and Countryside Act 1981. This means that disturbance of otters should be avoided, particularly during breeding as cubs may be deliberately abandoned if the mother is disturbed or in poor condition (Kruuk and Conroy, 1991). The disturbance of otters at coastal locations on Pembrokeshire should be avoided, particularly during the breeding. It should be noted here that otters are polyestrous, which means they can potentially breed throughout the year, although reproduction is usually timed to coincide with periods of high food availability Activities, such as coasteering and coastal boat trips need to be aware that they are potentially encroaching on previously undisturbed otter habitat. The importance of coastal streams was identified by Liles, (2003) and the accessibility and habitat quality of these important sources of freshwater needs to be maintained. Organisations involved in such activities should be advised to give otters a wide berth and not to enter coastal caves in case they are being used by resting or breeding otters. Similarly the use of marine habitats by otters should be taken into account when assessing the risk posed by industrial activities and crude oil transportation around the Pembrokeshire coast. Further work is required to look at the spatial variation in otter diet on Pembrokeshire, determine if otters are foraging in the coldwater reefs and to identify coastal streams which are being used to access to sea.

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