

Research Article

Otter Surveys of the North West Scottish Islands

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Between 1995 and 2003, otter surveys were conducted on 11 islands off the north west coast of Scotland. These located holts in a 100-metre-wide strip along the coasts of these islands. The information was then used to calculate the total number of holts for each island, and from that the adult otter population for each island was calculated using the models based on studies in Skye and Shetland. The diet of marine-foraging otters was assessed from five of these islands using spraint analysis, and was compared with the diet of otters from other coastal areas in Scotland. With the exception of the free-swimming saithe, the diet was dominated by small benthic fish, with the five key prey species being viviparous blenny, five-bearded rockling, butterfish, sea scorpion, and saithe.

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1. Introduction

Since 1995 the International Otter Survival Fund has undertaken surveys of Eurasian otters (*Lutra lutra*) on a number of islands off the north west coast of Scotland. Many, namely, Eigg, Muck, Canna, Pabay, Coll and Tiree, had not been surveyed in the National Otter Surveys of Scotland undertaken in 1977–1979, 1984–1985, and 1991–1994 [1–3]. This paper looks at the otter populations on Skye, Raasay, Pabay, Canna, Eigg, Castle, Muck, Coll, Tiree, South Uist, and Barra (Figure 1) and examines the diet of the species on these islands.

2. Methodology

In Shetland, Moorhouse [4] established a significant correlation between holt (den) and otter numbers, enabling the number of holts to be used as an index for the number of otters [5].

Similar significant correlations were found in extensive and intensive studies carried out on Skye over a two-year period [6]. The extensive study was undertaken on 60% of the Skye coastline, while the intensive study covered four smaller areas covering a total of 30 kilometres. It may, therefore, be possible to use occupied holts to estimate otter populations along the coastlines of Skye and the other islands off the west coast of Scotland.

For the surveys, each island was divided into 500-metre lengths measured at the high watermark. Such distances are easily manageable for fieldwork, while being generally long enough to observe otter activity from a vantage point. The following factors were examined:

- (1) otter observations,
- (2) number of holts and lie-ups,
- (3) number of freshwater pools.

2.1. Otter Observations. Observations, using 10 × 40 binoculars and a ×30 telescope, were made from a vantage point in each 500-metre section before a survey of the coastline for sprainting sites and freshwater pools. 30 minutes were spent in each section.

2.2. Holts and Lie-Ups

Holts. Sites used by otters as holts are very variable and for the purpose of this study are defined as tunnel systems with signs of regular use by otters [5]. The evidence of use consisted in tracks, flattened grass, fresh spraints, and the characteristic odour in the holt. On Skye, holts were found predominately in rock piles within 50 metres of the shore. If two holts were more than ten metres apart, they were considered separate. Holts are often very conspicuous, with well-marked sprainting points and prominent green grassy areas as a result of the nutrients in the spraint.

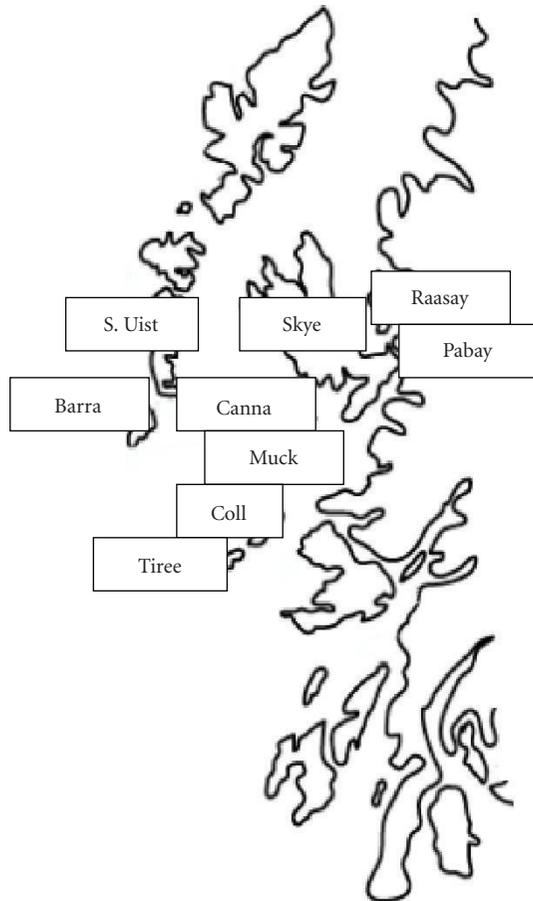


FIGURE 1: Islands surveyed from 1995 to 2003.

Lie-ups. Otters use resting places throughout their range. These are mostly hollows under rocks or within reed/rush beds and usually have a path leading to them and a sprainting point nearby.

2.3. Number of Freshwater Pools. A freshwater pool was defined as an area of standing water with a minimum width or length of 0.5 metres and minimum depth of 0.1 metres. Personal observations indicated that otters do not use smaller pools. All such freshwater pools were counted and measured and it became evident that most, but not all, had sprainting points adjacent to them.

3. Results

Table 1 details the survey information from the various islands visited. The total time spent on the surveys was 532 hours.

3.1. Relationship between Numbers of Otters and Holts. In his study, Moorhouse [4] used two methods to identify otters. Firstly, individuals could be recognised by characteristic patterns of white and yellow markings on the throat or lips; secondly, 13 individuals were tagged with coloured ear-

tags. In each month, the number of ear-tagged and non-ear-tagged otters was recorded, and the number of otters present was calculated from the ratio of the number of tagged animals and non-tagged animals (Lincoln index), [7]. The number of occupied holts was then related to the number of resident females, and the number of resident females to the numbers of males and transient otters.

On Skye, in four study areas it was possible over a 24-month period to identify individuals, and relate this to the number of holts in use at a particular time. These could be recognised by characteristics such as pink patterns on the nose, “battle scars” (nicks out of ears, scars in fur, etc.) and females with cubs could be identified.

Counts were made of otter holts in use in a number of coastal areas on Skye (Figure 2). It was assumed that a holt was in current use if recent spraints were found within 10 metres of the entrance. In addition to otter observations and other factors mentioned above, the geological nature of the area was identified.

Four areas were intensively studied (Figure 2):

- (1) Bogha an t-Sasunnaich to Ard Dorch: 18 kilometres of Torridonian and Mesozoic coastlines;
- (2) Camas Malag to Boreraig: 8.5 kilometres of mostly Mesozoic coastline;
- (3) Drumfearn: 4 kilometres of Torridonian coastline;
- (4) Loch na Dal: 3.5 kilometres of Torridonian coastline.

Each coastal section was visited for a minimum of one hour every month throughout the 24-month period. From April to October, the four areas were visited on a weekly basis for a minimum of two hours. In view of the length of time spent in each section, we can be confident that all the resident otters were counted correctly.

Certain assumptions are made in this estimate.

- (a) All holts were counted.
- (b) All otters in each area were identified correctly.
- (c) The sections sampled were representative of the Skye coastline.
- (d) The ratio for the number of otters and number of holts was constant for all geological coastal zones.
- (e) The ratio of numbers of females, males, non-residents, and cubs was constant.

These assumptions and their implications will be discussed in Acknowledgments.

3.2. Numbers of Otters and Holts. Figure 3 shows the relationship between occupied holts per resident female in the 100-metre coastal strip in the four study areas of Torridonian and Mesozoic coastlines compared with the number of resident adult females there.

A total of 21 holts were found, with, on average, 45% in use at any one time. There is a strong positive correlation between the two parameters over the four study areas over the two-year period ($r = .93$, $df = 47$, $P < .01$). These study areas were also used by adult resident males, as well

TABLE 1: Islands surveyed for otters (1995–2003).

Island	Year surveyed	Number of 500 m sections surveyed	Percentage of total coastline
Skye	1995	622	55%
Raasay and other islands off Skye	1995	75	19%
Canna	1996	55	79%
South Uist	1999	152	45%
Pabay	2000	11	100%
Barra	2000	72	51%
Eigg	2001	39	78%
Castle, off Eigg	2001	6	100%
Muck	2001	22	100%
Coll	2002	73	44%
Tiree	2003	138	100%

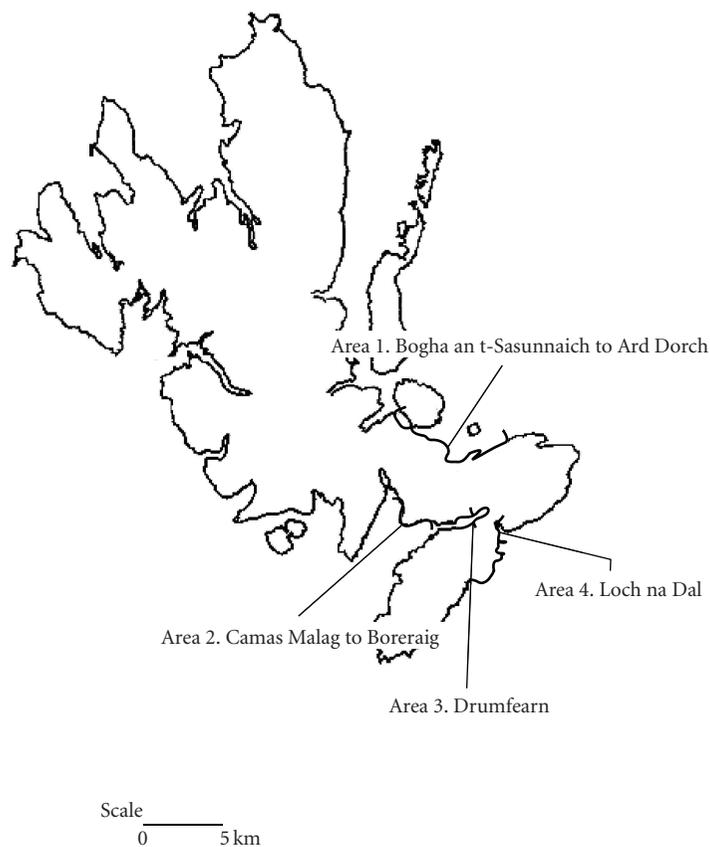


FIGURE 2: Map showing the four areas used in the intensive study.

as other adult/juvenile otters. Male ranges were larger than the resident females, and an estimate was made of how many would be present in the study areas. The mean numbers of otters and holts being used in each of the four study areas are shown in Table 2.

The mean estimate for the total number of adult otters in all four areas is 14.5 ± 1.99 (one otter per 2.1 kilometres

of coastline), where 8.9 (61%) were resident females (0.52 female per holt), 3.5 (24%) resident males, and 2.1 transients.

3.3. Estimating Otter Numbers. Where possible, areas of a particular geological composition were compared with similar areas on Skye.

TABLE 2: Mean numbers of otters and holt in the study areas.

Area	Coastal length	Resident females	Cubs	Males	Other unknown*	Holts in use
1	18 km	4.8 ± 0.13	2.3 ± 0.43	1.8 ± 0.12	0.5 ± 0.15	8.5 ± 0.31
2	4.3 km	2	1	0.7 ± 0.21	0.5 ± 0.22	4.5 ± 0.22
3	4 km	1.1 ± 0.14	1.6 ± 0.30	0.7 ± 0.18	0.57 ± 0.20	2.4 ± 0.20
4	3.5 km	1	0.75 ± 0.13	0.25 ± 0.12	0.5 ± 0.19	1.7 ± 0.25
Total	29.8 km	8.9 ± 0.27	5.7 ± 0.86	3.5 ± 0.63	2.1 ± 0.76	17.1 ± 0.98

*Other unknown = mix of males and females whose sex could not be identified.

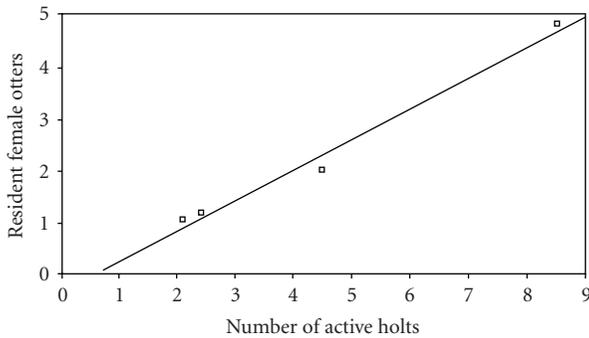


FIGURE 3: The relationship between holt per resident female otter range in the 100-metre coastal strip in the four study areas of Torridonian and Mesozoic coastlines compared with the number of resident adult females there.

The relationship on Shetland was found to be 0.33 female per holt and

$$\text{Total number of otters} = 1.83 \times \text{number of resident females.} \quad (1)$$

The relationship on Skye on four study areas over two years was found to be 0.52 female per holt and

$$\text{Total number of otters} = 1.64 \times \text{resident females.} \quad (2)$$

Using these relationships, an estimate can therefore be made for the otter populations on the islands surveyed (Table 3).

Notes on islands

- (1) Skye: a relationship existed between the geology of the coastline and the number of otter holt [6] ($\chi^2 = 32.4$, $df = 6$, $P < .001$). The Torridonian coastline had the greater number of holt: 1.25 per 500-metre section with the Tertiary intrusives and basalt having $< .001$ per 500-metre section. These were taken into account when estimating total holt numbers.
- (2) Raasay and other islands off Skye: as 1.
- (3) Canna: composed of Tertiary basalt lavas.
- (4) South Uist: composed of Lewisian gneiss.
- (5) Pabay: the whole island was surveyed and no estimate was made.
- (6) Barra: composed of Lewisian gneiss.

- (7) Eigg: again it varies in geology with Jurassic sediments and Tertiary lavas.
- (8) Castle Island: all holt counted.
- (9) Muck: all holt counted.
- (10) Coll: composed of Lewisian gneiss.
- (11) Tiree: composed of Lewisian gneiss.

3.4. *Otters and Geology.* The Isle of Skye was studied for many years and a strong relationship was found between the geology of the coastal zone and otter activity [6].

The island can be divided into seven geological zones as follows.

- (1) Lewisian/Moine: old pre-Cambrian rocks to the south of the island.
- (2) Torridonian: pre-Cambrian sediments (mainly sandstones) in south Skye.
- (3) Cambrian: limestones and sandstones.
- (4) Mesozoics: sediments mainly like limestones, sandstones, and siltstones.
- (5) Tertiary lavas: lava flows to the north west of the island.
- (6) Tertiary intrusives: granites and gabbros in the centre of the island.
- (7) Landslips: to the north and west of Skye.

By comparing the variables in the seven geological coastal zones, certain predictable patterns emerged with more activity, holt numbers, sprainting points, spraint numbers, and freshwater pools being found on the Torridonian coastal zone compared with all others. Both the Tertiary lavas and Tertiary intrusives showed low numbers of each (Table 4).

Visual observations of otter activity were recorded as otters seen per hour in each 500-metre coastal section. Table 5 shows the significant differences between the otter variables and the geological coastal zones.

The greatest number of otters seen was in the Torridonian coastal zone (2.2 otters per hour observation) compared with none in the Tertiary lava and intrusive coastal zones. Holt numbers were also greater in the Torridonian zone, amounting to 1.3 holt per 500-metre section compared with no holt in the sections surveyed in the Tertiary intrusive and lava coastal zones.

Sprainting points were present in all zones from one per 500-metre section in the Tertiary intrusive zone to six in the

TABLE 3: Estimates of numbers of holts and adult otter numbers on the north west Scottish islands.

No.	Island	Number of holts counted	Estimate of total holts for each island	Estimated otter population based on Yoxon [6]	Estimated otter population based on Kruuk [8]
1	Skye	117	192.2	164	116
2	Raasay and other islands off Skye	11	102.9	88	62
3	Canna	3	3.8	3	2
4	South Uist	34	122	104	74
5	Pabay	5	5*	4	3
6	Barra	10	27.2	23	16
7	Eigg	17	22	19	13
8	Castle	2	2*	2	1
9	Muck	5	5*	4	3
10	Coll	30	62.4	53	38
11	Tiree	9	9*	8	6

*These are actual holt numbers.

TABLE 4: Number of 500-metre sections surveyed in each geological coastal zone and the percentage of the total coastal area covered by that particular geological type (total geology). (Activity is the number of times otters were observed in 30 minutes of observation in each 500-metre coastal zone. Sprainting points, spraint numbers, holts, and pools were found in a 100-metre-wide strip along each section.) Results show the mean numbers per 500-metre coastal section with the standard error.

Geology	Sections surveyed	% Total geology	Otters	Holts	Spraint points	Spraints	Pools
Lewisian	71	74	0.03 ± 0.02	0.13 ± 0.05	0.98 ± 0.20	2.30 ± 0.71	0.42 ± 0.14
Torridonian	84	62	0.23 ± 0.07	0.45 ± 0.08	2.5 ± 0.28	6.3 ± 0.56	1.36 ± 0.16
Cambrian	17	100	0	0.2 ± 0.16	1.78 ± 0.68	4.6 ± 0.68	0.5 ± 0.22
Mesozoic	99	100	0.12 ± 0.05	0.29 ± 0.06	1.83 ± 0.20	4.5 ± 0.54	0.69 ± 0.10
Tert lava	206	37	0	0.05 ± 0.02	1.51 ± 0.15	2.95 ± 0.31	0.61 ± 0.07
Intrusive	104	98	0.02 ± 0.01	0.07 ± 0.03	1.11 ± 0.2	2.72 ± 0.39	0.47 ± 0.10
Landslip	41	21	0.05 ± 0.03	0.34 ± 0.01	2.39 ± 0.45	4.49 ± 0.72	0.73 ± 0.21

TABLE 5: Chi-squared tests for the otter variables in relation to geology (*** = $P < .001$, ** = $P < .05$, ns = $P > .05$). The null hypothesis is that no difference in the otter variables between the geological coastal zones can be ascribed to chance.

Variable	X	Df	P
Otter activity	29.1	6	***
Holts	32.4	6	***
Sprainting points	65.0	6	***
Spraint numbers	83.4	6	***
Freshwater pools	59.7	6	***

Torridonian zone. Total spraint numbers were greatest in the Landslip and Torridonian zones and lowest in the Tertiary intrusive.

The final variable was the number of freshwater pools available to the otters; the greatest number available was again found in the Torridonian zone (4.4 per 500-metre coastal section) compared with none found in the Tertiary intrusive zone.

Overall, therefore, the Torridonian coastal zone had the greatest number of all otter variables and is the most favoured habitat for otters in this study area.

4. Diet Analysis Using Spraints

In the coastal environment, spraints are found most frequently on rocky shorelines, on well-marked sites at the mouths of rivers, on otter runs, or, at certain times of the year, at the entrance to holts [9, 10]. The droppings add nitrogen to the surrounding area making sprainting points very obvious; grassy areas tend to be very green with a prominent growth of nitrophylous grasses. Rocks may be covered by green algae, and some sprainting areas on the coast are without vegetation exposing soil as a result of the continuous addition of urine [11].

4.1. Analysis of Spraints. Spraints were collected for analysis and stored in labelled plastic bags. In the laboratory, mucus was removed by soaking for 48 hours in Co-op false teeth cleansing solution, and the sample was then washed and

passed through a 0.5 millimetre sieve. This method has been used by many workers, including Erlinge [12, 13], Watson [14], and Beja [15].

The bulk of the prey remains consisted of fish bones, with occasional bird feathers, rabbit hair, and small mammal bones. The prey was identified by comparing the fish vertebrae with a reference collection and/or published keys [11, 14].

No method of expressing the results of spraint analysis describes the diet of otters accurately [16–21]. However, the two most commonly used methods are described by Conroy et al. [11].

(a) *Percentage frequency of occurrence*, where all the remains of each species in a spraint are taken to represent only one specimen and its frequency is calculated as the number of times it appears in all spraints in the sample. It is calculated as:

$$\frac{\text{Number of spraints containing a particular prey item}}{\text{Total number of spraints in sample}} \times 100. \quad (3)$$

(b) *Relative frequency of occurrence*, where all the bones are identified in every spraint, and the frequency of each species in that spraint is determined. It is calculated as:

$$\frac{\text{Number of occurrences of a prey in each spraint}}{\text{Total number of all prey items identified in the spraint}} \times 100. \quad (4)$$

These methods, however, have important limitations, which will be considered in the discussion.

In this paper, the results of spraint analysis are presented by percentage frequency of occurrence and are shown in Table 6. To avoid any problems with seasonality, all spraint and survey work was undertaken in July and August.

4.2. Comparisons with Other Studies. Studies of the diet of coastal otters have been undertaken in Shetland [22, 23], in Norway [24], on Loch Broom [25], on the Isle of Mull [26], and on the Isle of Eigg [27]. The results are shown in Tables 7 and 8.

Spearman rank correlations were undertaken between these different areas and the results are shown in Table 8.

Significant correlations exist between most areas. Small differences did occur with more rabbits (*Oryctolagus cuniculus*) being eaten on Pabay and Eigg. From personal observations, Pabay and Eigg have a lot of rabbits, which are easily available to the otter. Eigg also had a high proportion of gull remains in the spraint, accounting for 18% of the analysis. Gulls are common on Eigg (60 pairs of common gulls (*Larus canus*), 40 pairs of lesser black backed gulls (*Larus fuscus*), on Castle Island (just off Eigg), and 100 pairs of herring gulls (*Larus argentatus*) on Eigg itself [28]. In late summer, young gulls would be especially easy preies for an otter.

The study identified the importance of five key prey species (viviparous blenny (*Zoarces viviparus*), five-bearded rocklings (*Ciliata mustela*), butterflyfish (*Pholis gunnellus*), sea scorpion (*Taurulus bubalis*), and saithe (*Pollachius virens*)), which dominate the otter's diet on all the islands. Flatfish was

also an important component of the diet on the islands of Barra, Eigg, and Coll.

Significant correlations can be seen between the data from Skye, Shetland and Norway and from Shetland and Norway. There was also a significant correlation between Mull and Loch Broom.

Several differences have emerged in the composition of spraints between Skye and Mull, with viviparous blenny dominating the diet on Skye, but being absent from the diet on Mull [29] even though it is relatively common near the Marine Biological Station, Oban [30]. In fact, five-bearded rocklings were taken in very much lower numbers on Mull than on Skye, where they were one of the dominant prey species. On Mull, butterflyfish dominated the diet but was taken in much lower numbers in all the other study areas. Despite these differences, all these studies have in common that otters were feeding mostly on small benthic prey. This suggests that even within the food category "fish," otters are highly selective foragers specialising in easily caught prey species.

5. Discussion

5.1. Otter Population Estimates. Based on the data, the estimated otter population for these islands has been achieved by working out a relationship between resident females and active holts and a relationship between resident females and other otters. The estimate is however likely to be an underestimate because of otters living in inland freshwater systems. From personal observations, I have seen otters in Loch Suardal, Loch Coruisk, and other inland freshwater lochs on Skye. However, work undertaken on freshwater systems on Skye showed that all spraints from freshwater lochs had evidence of marine fish, indicating that otters using the freshwater systems are also utilising the coast [31].

The results can be compared with those of Kruuk et al. [5] who found 0.33 resident female per holt, and the total number of adult otters was $1.83 \times$ the number of resident females. They estimated the total number of adult otters on Shetland as 718, one otter per 1.2 kilometres of coastline, which is a similar figure to that found in an earlier study on the islands [14].

Despite the difficulties of estimating otter numbers and the errors due to the above assumptions, I am confident that these results give a reasonable estimate of otter numbers on these islands. The figure is lower than that reported by Harris et al. [32], who estimated otter numbers of 1000 for the west coast of Scotland and 1200 for the Western Isles and Orkney. The data presented here estimate otter numbers to be much lower, with 370–522 for the Western Isles and 268–380 for the Inner Hebrides.

5.2. Otters and Geology. Until now, little was known about the relationship between otter utilisation of the coast and geology.

On Shetland, Milner [33] categorised major coastal types and identified eight major coastal types using 81 physical and 18 geological attributes. Conroy AND French [9] classified the Shetland coast using over 200 attributes that were

TABLE 6: Occurrence of prey items in otter spraints collected, expressed as percentage frequency of occurrence.

Prey items	Skye	Pabay	Barra	Eigg	Tiree	Coll
N	1,480	15	20	139	12	20
Blenny-Viviparous (<i>Zoarces viviparus</i>)	29.2	22.6	20.0	5.0	32.0	23.0
Rockling (<i>Ciliata mustela</i>)	18.1	19.2	23.2	12.0	15.3	23.0
Butterfish (<i>Pholis gunnellus</i>)	10.0	9.1	8.5	12.0	14.5	10.2
Saithe (<i>Pollachius virens</i>)	10.8	10.9	12.3	2.0	5.0	10.0
Sea Scorpion (<i>Myoxocephalus sp.</i>)	5.5	3.6	2.4	11.0	0.0	5.2
Flatfish (<i>Pleuronectes sp.</i>)	5.0	6.4	12.0	15.0	8.2	10.4
Common Eel (<i>Anguilla anguilla</i>)	3.6	4.3	7.5	5.0	13.1	3.2
Shore Crab (<i>Carcinius maenas</i>)	3.6	2.7	1.0	9.0	0.0	2.0
Conger Eel (<i>Conger conger</i>)	3.3	0.0	0.0	0.0	0.0	0.0
Sand Eel (<i>Ammodytes sp.</i>)	2.2	0.0	0.0	0.0	0.0	1.0
Sea Snail (<i>Liparis sp.</i>)	1.3	0.0	0.0	0.0	0.0	0.0
Frog (<i>Rana temporaria</i>)	1.3	0.0	0.0	0.0	0.0	0.0
Birds	1.1	3.5	1.6	18.0	0.0	3.4
Sea Stickleback (<i>Gasterosteus aculeatus</i>)	1.1	0.0	0.0	1.0	0.0	0.0
Angler (<i>Lophius piscatorius</i>)	0.8	0.0	5.0	0.0	4.2	0.0
Gobies (<i>Gobius sp.</i>)	0.5	0.0	0.0	1.0	0.0	0.0
Small mammals (<i>Sorex sp.</i> , <i>Microtus sp.</i> , <i>Apodemus</i>)	0.9	2.4	6.4	0.0	0.0	0.0
Sea Trout (<i>Salmo trutta</i>)	0.7	0.0	0.1	1.0	0.0	0.0
Lumpsucker (<i>Cyclopterus lumpus</i>)	0.5	0.0	0.0	0.0	0.0	0.0
Rabbit (<i>Oryctolagus cuniculus</i>)	0.0	6.5	0.0	8.0	7.7	9.5
Unknown	0.5	8.8	0.0	0.0	0.0	0.0

grouped into seven headings. Still on Shetland, Kruuk [5] grouped the coast into six types based on evidence from maps, reports, and prior knowledge of the area. He found a strong relationship between numbers of holts and peaty coasts with little agriculture and no high cliffs, and a negative association between holts and tall cliffs.

On Orkney, in sharp contrast to Shetland, there are relatively few otters (Kruuk, 1995). This difference could possibly be attributed to distribution of prey species but it seems likely that Orkney shores are just as productive as

those of Shetland. J. Green and R. Green [3] stated “that despite the productive nature of Orkney’s fresh and coastal waters, the otter population was less dense than those of other island regions or parts of mainland Scotland.” A more likely reason for the difference is the geology of the Orkney coast, which makes it a less suitable habitat for otters. The Torridonian sandstone on Skye is impervious and has very low porosity (TIM ASTIN, Department of Geology, Reading University, *personal communication*), allowing freshwater pools to build up readily on the coastal fringe. By contrast,

TABLE 7: Comparing principal prey taxa consumed by otters in four areas of Scotland and Norway. Data from Skye and Mull are from spraint analysis using percentage frequency of occurrence. Data from Norway and Loch Broom were analysed using relative frequency of occurrence. Shetland data were from direct observation. n = the number of spraints sampled, or for Shetland the number of preies identified. The number in brackets is the number of individual vertebrae.

Species	Skye	Mull	Loch Broom	Shetland	Pabay	Barra	Eigg	Coll	Norway
N Occurrences	1,480 (4,588)	958	50	2028	15	20	139	20	1074
<i>Zoarces viviparous</i>	30.5	0	8.6	33.8	22.6	20	5	23	7.9
<i>Chirolophis ascan.</i>	0	5.1	10.7	0.1	0	0	0	0	0
Gadidae	28.4	17.1	15.7	25.1	30.1	35.5	14	33	17.5
<i>Pholis gunnellus</i>	10.8	25.8	11.4	9.9	9.1	8.5	12	12	12.4
Cottids	5.9	11.8	2.1	17.5	3.6	2.4	11	5.2	12.8
Flatfish	4.4	3.1	7.9	1.9	6.4	12.0	15	10.4	11.4
<i>Anguilla anguilla</i>	3.5	7.3	8.6	0.2	4.3	7.5	5	3.2	1.6
Crab	3.5	7.3	17.9	0.2	5.8	1	9	2	1.6
<i>Conger conger</i>	3.3	0.2	0	0	2.4	0	0	0	0
<i>Spinachia</i> sp	0.8	0	2.1	0.2	1.7	0	1	0	7.7
<i>Gobius</i> sp	0.7	2.6	2.1	0	0	0	1	0	4.9
Salmonidae	0.5	0.1	2.1	0	0	0	0	0	2.0
Other	7.7	19.6	10.8	11.1	14.0	13.1	27	11.2	20.2

TABLE 8: Spearman rank correlation coefficients (rs) comparing data from Skye, Mull, Loch Broom, Shetland, and Norway.

	Mull	Loch Broom	Shetland	Pabay	Barra	Eigg	Coll	Norway
Skye	Ns	**	***	***	***	**	***	*
Mull		Ns	Ns	Ns	Ns	*	Ns	Ns
L. Broom			*	**	*	*	**	Ns
Shetland				***	***	*	***	**
Pabay					***	**	***	*
Barra						**	***	*
Eigg							**	*
Coll								*

ns = not significant ($P > .05$), * = significant ($P < .05$), ** = highly significant ($P < .01$), *** = very highly significant ($P < .001$).

Devonian sandstone has a high degree of porosity and permeability, and so it would be difficult for freshwater pools to build up on these rock types in the same numbers as on the Torridonian sandstone. The Orkney landscape is composed of Devonian sandstones and is well drained with rich farmland. The low density of otters from Dunnett Head to the Moray Firth could equally be a consequence of the geology of the coastal fringes, which also consist of Devonian sandstones.

5.3. Otter Spraint Analysis

5.3.1. Limitations of Data. The study was carried out over eight years from 1995 to 2003, in 11 Scottish islands. The small size of the mesh of the sieve used for the preparation

of the spraint for analysis ensured that all hard remains from commonly eaten prey were identified.

The problems of interpreting data from spraint analysis have been widely discussed in the literature, and it appears that no single method provides a true picture of the importance of the different constituents of the diet [16, 18, 34].

Percentage frequency of occurrence of prey remains is the most easily applied spraint analysis method, and it has been used in numerous studies Mason and Macdonald [35], Carss [21], Beja [36]. However, there seems to be little agreement among authors on precisely how to interpret the results.

The percentage frequency of occurrence relies on the presence of undigested hard parts; therefore, both soft-bodied prey and large animals, where only the flesh is eaten, will leave no remains in the spraints [37]. Food which has

a relatively large proportion of soft material and hard parts of some preies which are broken up or digested will be underestimated. These methods will therefore only give an indication of what otters have eaten. As different types of fish have different numbers of bones (Wheeler [38]), and some bones are more prone to breakage than others [39], the relationship between the number of bones counted and the number of fish consumed may be tenuous. Overall, minor items will be overestimated, and frequently occurring items will be underestimated. While many authors accept these limitations, most claim that it gives a reasonable picture of the diet quoting the feeding trials undertaken by Erlinge [13]. Erlinge tested the accuracy of percentage frequency of occurrence by giving food of a known composition to captive otters. Spraints from these otters were then collected and analysed, and the relative proportions of the prey categories eaten were in close agreement with the frequency analysis. However, his results were not tested statistically.

Rowe-Rowe [18] suggested that the analysis of otter spraints calculated by frequency gave a reasonably true picture of the relative importance of the food taken, but he also did not test this statistically.

Kruuk et al. [34] showed similar results from four captive otters with a strong correlation between the percentage of fish fed to the otters and the percentage frequency of identifiable remains found in the spraints ($r_s = .9$; $P < .001$). Carss [21] also undertook feeding trials on four captive otters and attempted to put confidence estimates on the analysis of spraints using percentage frequency of occurrence. He found strong positive correlations between the values obtained for each of the ten prey groups and their true proportions in the diet, but found that this gave a poor estimate of the true proportions of prey by number or biomass for the ten prey groups. (The methods overestimated the true proportions by 5% to 2,900% and underestimated them by 12.5% to 50%). He therefore concluded that for prey which does leave remains, percentage frequency of occurrence allowed dietary items to be ranked with a high degree of accuracy, but gave poor estimates of the true percentage proportions of the various prey groups in the diet. Carss [21] also found that prey was over-estimated if sequentially deposited spraints are collected regularly from frequently used sites.

The assumption that each occurrence of a prey item in different spraints represents a single individual animal is not necessarily true; Carss [21] found the remains of seven fish of a similar size recorded in a single spraint and therefore spraints cannot be assumed to represent a single prey item.

In Shetland, Kruuk and Moorhouse [23] used direct observations to assess the diet of otters, and their results showed close agreement with those undertaken by Herfst [40] using spraint analysis by percentage frequency of occurrence. The inaccuracies of this method are therefore assumed to be acceptable within the aims and limitations of this study.

Given these difficulties, percentage frequency analysis has the advantage of being relatively quick compared to more complex and not necessarily more accurate methods of analysis. (Counting all vertebrae and volumetric analysis have not been found to be more accurate [26]). Any bias

which does occur is likely to operate on all the samples equally. Thus, they should not effect conclusions with regard to seasonal and area-related trends within a taxon [16] or comparisons with other studies using similar methods of analysis. A further problem could be pseudoreplication whereby one meal contributes to a number of spraints. It is not inconceivable that some adjacent spraints may have come from the same meal. However, this potential difficulty in statistical analysis has been ignored in this and previous studies.

5.4. Comparisons with Other Studies. Studies of the diet of coastal otters have been undertaken in Shetland [22, 23], in Norway [24], on Loch Broom [25], the Isle of Mull [26], and on the Isle of Eigg [27]. These all show the importance of the same five key prey species (viviparous blenny, five-bearded rockling, butterfish, sea scorpion, and saithe) to the diet of the otter population.

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