REVIEW OF WHITE-TAILED EAGLE *HALIAEETUS ALBICILLA* DIET IN EUROPE AND PREY AVAILABILITY IN CUMBRIA

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1. EXECUTIVE SUMMARY

- We reviewed the available published literature from across Europe on white-tailed eagle (WTE) diet and used this to assess the potential food availability for the species within Cumbria.
- Across their European range WTE consume fish, birds, and mammals in varying proportions.
- Fish was identified as the primary food source in nine studies and birds were identified as the primary food source in eight studies.
- The relative proportion of the diet that each prey type contributed (in number of prey items) ranged from 6% to 74.2% for fish, 21.5% to 69.6% for birds, 2% to 33.6% for mammals.
- Important fish species include pike and Cyprinids, key bird species are waders and waterfowl, and key mammals include smaller species such as muskrat and hare that could be taken as live prey as well as larger species consumed as carrion.
- Habitat, season, and age all have an impact on diet composition.
- Across studies, at least 114 bird species, 52 fish species, and 30 mammal species have been recorded in food remains or pellets.
- In mainland Europe sheep is only reported as a small component of WTE diet (<2% of prey items) in three studies and is thought to be consumed as carrion. In Scotland higher dietary percentages and lamb predation have been reported, however a recent study suggests that lamb is not as important for Scottish WTE as previously perceived.
- Species records for Cumbria indicate high prey availability for WTE, with many of the key prey species present in the county.

2. INTRODUCTION

White-tailed eagles *Haliaeetus albicilla* (WTE), are widely distributed across Europe and Asia, with over half of European WTE inhabiting Norway and Russia, large populations in Germany, Poland and Sweden, and many smaller populations breeding across much of Eastern and Northern Europe (BirdLife International, 2023). WTE are usually found near water in a range of inland and coastal habitats providing they have suitable cliffs or large trees for nesting (BirdLife International, 2023).

Previous research has shown that WTE are generalists with a diet consisting mostly of birds, fish, and mammals with prey species varying locally and seasonally. When considering prey availability in Cumbria, it was suggested that geese, black-headed gulls, coots, and crows would be key bird species; mullet and bass important fish species; and rabbits and hare important mammal species (R. Dennis 2022, pers. comm.).

This literature review seeks to investigate WTE diet across Europe in order to check our current assumptions regarding their dietary needs. The findings are then compared to available data on prey species occurrence in Cumbria to help understand prey availability for a potential reintroduced WTE population in the county. The findings will also be helpful to later investigate the potential risk to sensitive species and consider potential risk to WTE associated with consuming certain food sources.

3. METHOD

3.1. Literature review

WTE diet studies were identified in Google Scholar and Web of Knowledge using the key words 'white AND tailed AND eagle AND diet'. Nineteen scientific papers were identified as relevant and selected for review as they focused on European populations. One further paper and a book summarising results from earlier studies were identified in the references. One further paper published after this review was carried out was later integrated as it investigated diet of WTE in Scotland which is the nearest population to Cumbria. One report was accessed using the key words 'white AND tailed AND eagle AND Scotland AND sheep' to inform discussion on this specific topic. Details regarding diet of reintroduced WTE in Ireland and on the Isle of Wight were accessed via in-person communications with the projects and are referred to in the discussion.

Most studies investigated diet by analysing prey remains and pellets collected in and around nests during or shortly after the breeding season. Collections were often undertaken during ringing of chicks, and sometimes also after fledging. One study was able to collect prey items throughout the year using GPS locations and knowledge of roosting sites (Nadjafzadeh *et al.* 2015). In addition to collecting prey items, one study used camera traps to monitor prey items being

brought back to nests (Mirski and Komar, 2023) and one study used direct observations (van Rijn *et al*., 2010). Prey items were identified to the lowest possible taxonomic level using a range of identification keys and expert advice. For each species the minimum number of individuals (MNI) was determined (i.e. remains from one species were considered to be from the same individual unless parts could not be from a single individual). One study investigated WTE diet using a stable isotope analysis (Nadjafzadeh *et al.*, 2016). They examined liver and muscle tissue from 30 WTE recovered after being found dead and used dietary mixing models to determine contribution to the diet of different common food items identified in a previous study.

To investigate prey species preference, all species recorded across the studies were collated in a spreadsheet. Fifteen studies included species-level detail, and Nadjafzadeh *et al.* (2016) was not included in the spreadsheet due to the limited number of species included in their stable isotope analysis.

The contribution of each prey species to WTE diet was also collated and variously presented as either percentage contribution to overall diet, percentage contribution to a food group (fish, bird, and mammal), proportion of species consumed within food group, or number of samples collected. Given this variation among studies in how prey species contribution to WTE diet was reported, it was not possible in our review to summarise this in one single metric, thus we report and analyse all four statistics separately.

For each main food group within each dataset, the three species making the most important contribution to diet were identified and ranked. These species were then compared across datasets to identify the overall 5 most important species for each food group.

As noted above, most studies investigate diet by identifying pellets and prey remains in nests. Eagles can digest fish bones (Love, 1983) and most studies recognise this as a limitation of the data collection method likely to lead to fish being underrepresented in the results (e.g. Sulkava *et al*., 1997; Whitfield *et al*., 2013; Ekblad *et al*., 2020). This was confirmed by Whitfield *et al*. (2013) in their study of the Scottish population when they collected in a single nest 49 bottle corks used to keep mackerel (*Scomber scombrus*) afloat when thrown to WTE from tourist boats but found no sign of mackerel in food remains or pellets.

Although diet analysis by identifying pellets and prey remains in nests provides information on what WTE eat, it does not tell us what they kill. WTE are scavengers and it can therefore be assumed that some of the prey items identified, especially larger species, were not killed by the WTE that consumed them. Studying diet by direct observations of predation or scavenging events is onerous and most studies therefore rely on collecting prey remains in and around nests. Most publications therefore investigate diet composition rather than actual predation rates of different prey.

3.2. Cumbria data sources

Fish survey data was accessed on the Environmental Agency's (EA) online open data portal. Transitional and coastal waters (TraC) and freshwater (NFPD)

surveys were accessed to investigate marine and freshwater fish species presence in Cumbria. Additional information was accessed through personal communications with the EA, the Freshwater Biological Association (FBA), and the Centre for Ecology and Hydrology (CEH).

Wetland Bird Survey Data (WeBS) was accessed on the British Trust for Ornithology's (BTO) online platform. The current 5-year averages of annual peak counts (2017/18 to 2021/22) for 120 non-breeding bird species were accessed for 6 coastal sites, and 81 inland sites including the major lakes (no recent data available for Windermere and Millom to Eskmeals Point). A Cumbria Biodiversity Data Centre (CBDC) and Cumbria Bird Club (CBC) report as well as the CBC's British Birds List were accessed to investigate local abundance of resident species (Cumbria Biodiversity Data Centre and Cumbria Bird Club, 2015; Cumbria Bird Club, 2023).

National Biodiversity Network (NBN) Atlas data was accessed via their online portal and a CBDC report was accessed to investigate mammal species distribution in Cumbria (Cumbria Biodiversity Data Centre and Cumbria Mammal Group, 2017).

4. RESULTS AND DISCUSSION

4.1. Literature overview

A total of 22 published papers were reviewed, which were published over a broad time period from 1996 to 2023 and analysed prey item data collected between 1978 and 2021. These papers studied WTE populations over a broad geographic region comprising Belarus, Croatia, Estonia, Finland, Germany, Greece, Lithuania, Netherlands, Poland, Romania, and Scotland. A summary of the relative share of each food group in WTE diet as reported in these papers is presented in Table 1.

4.2. Contribution of the main food groups to WTE diet

Early studies of WTE diet established that these raptors prey on fish, birds, and mammals (Table 2 in Love, 1983) with local and seasonal variations in the relative proportion of each food group and range of prey species, as well as occasional records of reptiles, amphibians, and molluscs (Love, 1983).

In the 17 studies detailing diet composition, percentage of fish in WTE diet ranged from 6% in Scotland to 74.2% in Poland (mean = 44%; table 1). In 9 of the 17 studies, fish was identified as the primary food source. Birds were identified as the primary food source in the 8 other studies, with percentages ranging from 21.5% in Poland to 69.6% in the Åland Islands of Finland (mean = 44.2%; table 1). When considering all age classes, birds have also been reported as the main food group for the WTE reintroduced on the Isle of Wight (S. Egerton-Read 2023, *pers. comm*.). Mammals make a smaller contribution to WTE diet with percentages ranging from 2% in Estonia to 33.6% in Scotland (mean = 11.1%; table 1). Although mammals account for a smaller percentage of WTE

diet in most studies, they could make a higher contribution when considering biomass (Sándor *et al*., 2015). Reptiles and amphibians were only recorded in 3 studies (Table 1), however they accounted for 10.6% of overall WTE diet in Greece making turtles and tortoises the third most important food type for the 2 pairs studied (Bounas *et al*., 2023). There are also several mentions of WTE feeding on molluscs (Love, 1986; Reid *et al*., 2023), with common cuttlefish (*Sepia officinalis*) identified as a seasonally important prey species on the Isle of Wight (S. Egerton-Read 2023, *pers. comm.*).

Table 1: Contribution of each of the three food groups (bird, fish, mammal), to WTE diet in Europe, with the mean relative share across all studies listed indicated in the final row in bold.

Country	Foraging habitat	Season	Proportion in diet of the number of prey items identified in %				Sampling method	Territory / pairs sampled	Visits / samples	Identified prey items	Reference
			Bird	Fish	Mammal	Other					
Greece, Koroneia and Volvi National Park	Two inland lakes, wetlands, forests, semi-natural area, agricultural areas	April-October	70.9	15.1	3.5	10.6 % reptile	Prey remains + pellets	2	25	199	Bounas *et al*. (2023)
Lithuania	Coastal and inland areas, diverse habitat	May-June	34	62	4		Prey remains +pellets	60		2272	Dementavičius *et al*. (2020)
Finland, Åland Islands	Archipelago	May-June	69.6	27.3	3.1	2 reptiles, 1 frog	Prey remains +pellets	117	664	7734	Ekblad *et al*. (2016)
Finland, Lapland reindeer herding area.	Lakes, low forests, peat bogs, open areas, marshlands	June-August	28.5	64.3	7.2		Prey remains +pellets	45	83	763	Ekblad *et al.* (2020)
Poland, Podlasie region	Mosaic farmland, forest complexes, marshy river valleys, fishponds	May-October	21.5	74.2	4.3		Camera monitoring of nests + prey remains	12		749	Mirski and Komar (2023)
Germany, nature park Nossentiner Heide	60 freshwater lakes, large forests, extensive pastures	Year round	21.9*	65.1*	13*		Prey remains +pellets	7		705	Nadjafzadeh et al. (2013)
Germany, nature park Nossentiner Heide	60 freshwater lakes, large forests, extensive pastures	Year round	29	58	13		Prey remains + pellets	7			Nadjafzadeh et al. (2015)
Germany, Federal state of Mecklenburg-Western Pomerania	Numerous lakes, rivers, pine and mixed forest	March-August	27.2	59.8	13		Stable isotope analysis (using 16 potential prey species)	75 individuals			Nadjafzadeh et al. (2016)

Germany, Federal state of Mecklenburg-Western Pomerania	Numerous lakes, rivers, pine and mixed forest	September-February	22.7	47.8	29.5		Stable isotope analysis (using 16 potential prey species)	75 individuals			Nadjafzadeh *et al.* (2016)
Estonia	Islands, coastal areas, inland lakes, and rivers		54	44	2						Randla and Tammur (1996)
Scotland	Islands, coastal, inland	April-August	67	6	27	Occasional amphibians crustaceans, molluscs	Prey remains	92	293	11375	Reid *et al*. (2023)
Romania, Danube Delta Biosphere reserve	River delta wetland complex	April-May	50	44.6	5.4		Prey remains +pellets	17	21	260	Sándor *et al*. (2015)
Finland, Åland Islands and the SW archipelago off Turku	Archipelago, islands dominated by pine forests, steep shores, deep waters	End of nestling season (~July)	65.3	27.4	7.4		Prey remains +pellets			1331	Sulkava *et al.* (1997)
Finland, Quark archipelago	Archipelago, mixed forest, unstable shoreline, shallow waters	End of nestling season (~July)	58.9	31.6	9.6		Prey remains +pellets			1071	Sulkava *et al*. (1997)
Finland, Lapland	Inland reservoirs, natural lakes, bogs, forests	End of nestling season (~July)	29.2	67.2	3.6		Prey remains +pellets			750	Sulkava *et al*. (1997)
Scotland, Skye, Mull, Lewis, Harris	Islands	May-August	59.7	6.1	33.6		Prey remains +pellets	9		1937	Whitfield *et al.* (2013)
Belarus, Polesski State Radiation Ecological Reserve	Inland habitats: woodland, bogs, rivers, other waterbodies	April-may	41.7	48.1	10.2		Prey remains +pellets	5		127	Yurko (2016)
Overall mean			44.2	44	11.1	0.6					

*** Mean for 6 of the 7 pairs studied**

4.2.1. Effect of season on typical diet

Most studies collect data when visiting nests to tag chicks therefore results are focused on summer diet. With their year-round studies in Germany, Nadjafzadeh *et al*. (2013, 2016) bring some insight on seasonal variations in WTE diet. In their study of 2013, fish was identified as the primary prey in spring and summer (up to 92.1% of diet), birds were found to make the biggest contribution to diet in summer (up to 35.7% of diet), and mammals were identified as the main prey in autumn and winter (up to 44.1% of diet). However, in their study of 2016 fish was found to remain the primary food source throughout the year, but the decline in availability in winter meant that its contribution to diet declined sharply and again led to an increase in mammalian prey being consumed.

4.2.2. Effect of age on typical diet

Sampling of pellets and food remains in active nests focuses on breeding pairs and nestlings' diet therefore does not provide much insight into diet variations with age. Using stable isotope analysis Nadjafzadeh *et al*. (2016) were able to confirm the importance of carrion for juvenile WTE suggested by earlier studies. This was also confirmed by observations of the UK reintroduced populations: young birds in Ireland were reported to spend a lot of time inland feeding on carrion before gaining enough experience to fish successfully (A. Mee 2023, *pers. comm*.); and results from the Isle of Wight diet studies show that carrion makes up most of the young birds' diet in their first year, with birds spending time foraging inland especially near gamebird shoots, and decreases as fish becomes a more important part of their diet (S. Egerton-Read 2023, *pers. comm*.). In their study of early-life WTE diet, Nebel *et al.* (2023) found that nestlings being fed a diet consisting mostly of fish was linked to higher breeding success, however these birds had a lower adult survival rate whereas chicks being fed a varied diet had a higher adult survival rate. They suggest the benefits of a varied diet being fed to chicks when considering fitness could be linked to a reduced risk from environmental toxins, higher nutrient intake, or increased diet plasticity as adult birds.

4.2.3. Effect of habitat on typical diet

Variations in diet linked to habitat is reported by several studies. In the Åland Islands archipelago (Finland), Ekblad *et al*. (2016) found that inland landscapes were associated with a decrease of birds in the diet and an increase of fish and mammals. High percentage of birds in diet are generally reported by studies of coastal populations (Randla and Tammur, 1996; Sulkava *et al*.,1997; Whitfield *et al*., 2013; Sándor *et al*., 2015; Reid *et al*., 2023), and high percentage of fish in diet reported by studies of inland populations (Sulkava *et al*., 1997; Nadjafzadeh *et al*., 2013**,** 2015, 2016; Yurko, 2016; Ekblad *et al*., 2020; Mirski and Komar, 2023). However, in the Lithuanian population studied by Dementavičius *et al*. (2020), an increase in terrestrial habitat led to a higher percentage of avian prey and lower percentage of fish prey in the diet, with the exception of WTE pairs nesting close to inland reservoirs. Ekblad *et al*. (2020) also report a positive

correlation between the increase of freshwater features in a territory and fish in diet. They concluded that WTE favour nest sites close to suitable fishing areas. Bounas *et al.* (2023) found birds to be the primary food source for the two WTE pairs studied despite their territories being inland and close to two lakes. They suggest this could be due to the depth of the largest lake limiting their fishing opportunities.

4.2.4. Effect of behaviour specialisms on typical diet

Although WTE within a population tend to utilise the same food sources and have similar diets, some pairs sometimes adapt to local availability and can specialise on a specific prey. This was the case in Belarus (Yurko, 2016) where WTE were found to feed primarily on fish, except for one pair that increasingly targeted storks (*Ciconia nigra* and *Ciconia ciconia*) after changes in their habitat meant that fish was less accessible. Similarly, in their study of seven WTE pairs in Germany, Nadjafzadeh *et al*. (2013) found that six pairs had very similar diets and were mostly eating fish (65.1% of diet) then birds (21.9% of diet), but one pair specialised in mammals (48.6% of diet) with fish being the least important part of their diet (27.1% of diet). In Scotland, Reid *et al*. (2023) also report pairs specialising on Northern fulmar (*Fulmarus glacialis*) or rabbit (*Oryctolagus cuniculus*). The importance of mammals for specific pairs is also reported by Sándor *et al*. (2015).

4.3. Key prey species

4.3.1. Fish

At least 52 species of fish were identified across the studies reviewed (Appendix 1.1), with up to 30 species identified in a single study (Reid *et al*. 2023). Northern pike (*Esox Lucius*) remains were found in all studies (Table 2). It was the main fish prey species in seven studies, and in the top three fish species in six other studies, as well as accounting for half of overall WTE diet in Lapland (Sulkava *et al*., 1997; Ekblad *et al*., 2020; Table 2). However, Sulkava *et al*. (1997) suggest pike could be overrepresented in pellets and food remains as the hard jaw bones are easy to find.

Cyprinid species make up most of the other prey, with common carp (*Cyprinus carpio*) being the main fish species in four studies, common bream (*Abramis brama*) recorded in eight studies and in the top three fish species in six of those, and ide (*Leuciscus idus*) recorded in six studies and in the top three in five of those (Table 2). European perch (*Perca fluviatilis*) although making a smaller contribution to overall diet, was recorded in nine studies (Table 2).

For the UK reintroduced populations, mullet (Mugilidae spp.), sea bass (*Dicentrarchus labrax*) and Black bream (*Acanthopagrus butcheri*) appear to be the main fish prey for the Isle of Wight birds (S. Egerton-Read 2023, *pers. comm*.), and dog fish (Squalidae spp.) is commonly found in nests in Ireland (A. Mee 2023, *pers. comm*.). In Scotland, the main fish species identified in prey

remains were lesser-spotted dogfish (*Scyliorhinus canicular*), cod species, and European hake (*Merluccius merluccius*; Reid *et al*., 2023).

Table 2: Main fish prey species identified in European studies of WTE diet.

	Number of studies in which it is fish species:			
	Number 1	Number 2	Number 3	Total studies where recorded (n=15)
Northern pike *Esox lucius*	7	4	2	15
Common carp *Cyprinus carpio*	4	0	0	5
Common bream *Abramis brama*	2	2	2	8
Ide *Leuciscus idus*	0	4	1	6
European perch *Perca fluviatilis*	0	2	0	9

4.3.2. Birds

A wide range of bird species have been identified in food remains and pellets with a total of 114 species recorded across the studies reviewed (Appendix 1.2), and one study identifying up to 70 different species (Reid *et al*., 2023). Waterfowl and waders make the biggest contribution to diet with 54 species recorded. Eurasian coot (*Fulica atra*) was recorded in nine studies and was the main bird prey species in five of those (Table 3), accounting for up to 15.6% of overall diet in Greece (Bounas *et al*., 2023). Mallard (*Anas platyrhynchos*) and grebes were found in 12 and 11 studies respectively and were in the top three bird species in five of those (Table 3). Geese (*Anser* and *Branta spp*.) and common eider (*Somateria mollissima*) were also recorded in the top three species in several studies (Table 3). At least 37 bird species were recorded as prey of the Isle of Wight WTE, with geese and gulls making the biggest contributions, and gamebirds being consumed as carrion inland (S. Egerton-Read 2023, *pers. comm*.). In Scotland, Northern fulmar, guillemot (*Uria aalge*), and shag (*Phalacrocorax aristotelis*) were the main three bird species identified in remains, with other sea birds, waterbirds, and red grouse (*Lagopus lagopus scotia*) also found in high numbers (Reid *et al*., 2023). As well as waterfowl and waders, species recorded in diet analyses have included gulls, terns, corvids, raptors, grouse, and small passerines (Appendix 1). Two cases of cannibalism were recorded in Belarus (Yurko, 2016).

Table 3: Main bird prey species identified in European studies of WTE diet.

	Number of studies in which it is bird species:			
	Number 1	Number 2	Number 3	Total studies where recorded (n=15)
Eurasian coot *Fulica atra*	5	1	1	9
Mallard *Anas platyrhynchos*	1	3	1	12
Grebes	2	0	3	11
***Mergus/Mergellus* spp.**	1	2	1	8
Geese *Anser* and *Branta* spp.	1	1	1	8
Common eider *Somateria mollissima*	2	0	0	4

4.3.3. Mammals

Thirty mammal species were identified across the studies reviewed (Appendix 1.3), with up to 17 identified in one study (Reid *et al*., 2023). Muskrat (*Ondata zibethicus*) was recorded in seven studies, being the main mammal species in five of those (Table 4). Deer and hare species were also in the top three mammals in nine and 10 studies respectively, with roe deer (*Capreolus capreolus*), reindeer (*Rangifer tarandus*), and brown hare (*Lepus europaeus*) being the main mammal species in one study each (Table 4). Wild boar (*Sus scrofa*) was recorded in five studies and the main mammal species in three of them (Table 4). Raccoon dog (*Nyctereutes procyonoides*) was recorded in five studies and beaver (*Castor fiber*) in three studies, both accounting for less than 2% of overall diet (Table 4). Rabbit was also an important species in WTE diet in Scotland (Reid *et al*., 2023). All other mammals were recorded in only one to two studies in very small percentages. Sheep (*Ovis aries*) in the diet is discussed in the next section. Small species such as muskrat and hare can be taken as live prey by WTE (Love, 1983; Sándor *et al*., 2015), however most mammals are thought to be consumed as carrion (Nadjafzadeh *et al*., 2013; Sándor *et al*., 2015; Bounas *et al*., 2023).

Table 4: Main mammal prey species identified in European studies of WTE diet.

	Number of studies in which it is mammal species:			
	Number 1	Number 2	Number 3	Total studies where recorded (n=15)
Muskrat *Ondata zibethicus*	5	2	0	7
Deer species	4	2	3	9
Hare *Lepus* sp.	2	6	2	10
Wild boar *Sus scrofa*	3	0	0	5
Domestic sheep *Ovis aries*	1	2	0	3

4.3.4. Sheep

WTE reintroduction projects have led to some farmers expressing worries about predation of livestock including in Cumbria. In mainland Europe, sheep is only reported as a small component of WTE diet in Romania (1.15% of all prey items; Sándor *et al*., 2015), Greece (two items, corresponding to 1% of all prey items; Bounas *et al*., 2023) and Norway (2% of prey items but also including deer; Halley, 1998) and is thought to be consumed as carrion. Sheep was found in higher percentages in the diet of WTE in Scotland: 26% of prey items (including sheep, goat and deer; Halley, 1998), and 19.2% of prey items (Whitfield *et al*., 2013), however a recent study by Reid *et al*. (2023) which analysed prey data collected over 20 years across Scotland in 92 WTE territories reports a much lower average of 6% of prey items identified as lamb per territory. This corresponds to 1350 items identified as lamb across 76 territories during the study. A study on Mull (Marquiss *et al*., 2003) found that although lamb predation did occur, 75% were scavenged. Reid *et al*. (2023) report variations in the proportion of lamb items between WTE territories, with lamb contributing to 30% or more of prey items in seven territories, and contributing only 0% to 6% in half of the territories sampled. Higher percentages of lamb in diet are associated with territories on Mull and surrounding areas, where WTE settled during early stages of recolonisation following reintroduction. The authors suggest this pattern could be explained by inexperienced birds first settling in areas with higher carrion availability, whereas the expanding population now favours areas with greater wild prey availability. This study therefore suggests that lamb is not as important for Scottish WTE as previously perceived. However, it does suggest that a potential release location in Cumbria should be carefully chosen to limit the risk of young WTE becoming accustomed to consuming sheep carrion and instead attempt to focus their attention on areas rich in wild prey. No predations on sheep or lambs by WTE have been recorded in Southern England since reintroductions began in 2019 on the Isle of Wight (S. Egerton-Read 2023, *pers. comm*.).

4.4. Feeding behaviour

WTEs use a 'sit and wait' hunting strategy (Love, 1983). They are not agile hunters therefore rarely target birds in flight (Love, 1983) and only catch fish within 0.5m of the water surface (Ekblad *et al*., 2016). Ekblad *et al.* (2016) describe WTEs as opportunistic foragers who sometimes target specific species due to hunting efficiency. However, Nadjafzadeh *et al.* (2015) describe WTEs as selective rather than opportunistic predators. Their study showed that WTE in Northeastern Germany do not hunt randomly and favour large fish (30-50cm) when prey is abundant, with Sándor *et al*. (2015) also reporting a preference for medium to large fish in the Danube Delta. However, Mirski and Komar (2023) highlight a preference for medium to large fish only in suboptimal habitats. A wide range of bird species are consumed by WTE and no particular size appears to be targeted, although a preference for less agile waterfowl is suggested by

Nadjafzadeh *et al*. (2016). Observations of kleptoparasitism are also relatively common, with WTEs stealing food items from other predatory birds such as gulls, waders, and other raptors (Love, 1983; S. Egerton-Read 2023, *pers. comm*.), as well as mammals such as otters (Love, 1983). The Isle of Wight reintroduction project have observed a relative increase in piracy events among older WTE (S. Egerton-Read 2023, *pers. comm*.).

4.5. Risks associated with diet

Several studies investigate heavy metal poisoning associated with diet. Mercury exposure was found to be highest in WTE with a mainly aquatic diet (Komosa *et al.*, 2009; Kitowski *et al*., 2015; Ekblad *et al.,* 2021; Bjedov *et al*., 2023) and associated with feeding on high trophic level prey, especially the predatory fish pike. Although the levels in which it was found were not thought to pose a health risk to the birds, further investigations were recommended (Ekbald *et al*., 2021; Bjedov *et al*., 2023). Lead poisoning was identified as the cause of death for 19 out of 109 WTE studied by Nadjafzadeh *et al*., 2013). By studying their stomach contents, they were able to determine that lead poisoning was associated with consuming mammals, especially ungulates, highlighting the risk of feeding on game carrion and the need to ban lead ammunition to reduce the risk to scavenging raptors. In the UK the use of lead ammunition is restricted and is prohibited: over areas of foreshore, over SSSIs, and for shooting ducks, geese, swans, coots or moorhen in England and Wales; and on or over wetlands in Scotland and Northern Ireland (Game and Wildlife Conservation Trust, 2024). However lead shots are still used to shoot game such as pheasants and deer which could be consumed as carrion by WTE. A voluntary switch to non-lead ammunition was proposed by shooting organisations in 2020 with a target to achieve the transition by 2025, however monitoring of the progress showed that 94% of the pheasants sampled in the 2022/2023 season were still shot with lead (Green *et al*., 2023).

4.6. Food availability in Cumbria

Cumbria has approximately 180km of coastline with several large estuaries, as well as 16 lakes and many tarns. Fish are likely to be taken by WTE in the shallow estuaries and lakes, as well as pirated from other species or consumed as carrion along the coastline. Both resident and wintering birds gather along the coastline and around inland waterbodies where they could be targeted by WTE. A range of mammals are also widespread across the county.

4.6.1. Fish availability in Cumbria

Potentially important coastal and estuary fish prey species were recorded in surveys both in Morecambe Bay and the Solway Estuary, however there are no abundance estimates available. Species include common bream, sea bass, and three species of mullet (Golden grey mullet *Liza aurata*, thick lipped grey mullet *Chelon labrosus*, thin lipped grey mullet *Liza ramada*; Figure 1). Dog fish

Scyliorhinus canicular, an important species for WTE in Ireland and Scotland, is also present along the northern half of coastline down to St Bees head (Figure 1). Atlantic salmon *Salmo salar* and sea trout *Salmo trutta* are present both in the North and South of the county (Figure 1) and could be an important food source as carrion after spawning in the autumn (L. Lavictoire FBA 2023, *pers. comm*.).

EA freshwater surveys focus mainly on rivers and lake inlets therefore data are limited. However, they have recorded important species such as pike, perch, chub (*Leuciscus cephalus*), roach (*Rutilus rutilus*), and tench (*Tinca tinca*; Figure 2), all of which appear in WTE diet in Europe.

An assessment of fish species in 19 Cumbrian waterbodies was undertaken by the CEH as part of the Lakes Tour 2015 (Winfield *et al*., 2015). Pike and perch are widespread and were recorded in 13 and 17 waterbodies respectively (Table 5). Bream and carp are also present in some waterbodies (Table 5), with an increase in the bream biomass reported in Windermere (G. McKee EA 2023, *pers. comm*.). Other important species could be brown trout which is present in all waterbodies, and roach present in over half of them (Table 5). Fish was not included in the most recent Lakes Tour report and there appears to be a general lack of fish data in recent years.

Observations of the ospreys (*Pandion haliaetus*) breeding at Foulshaw Moss suggest that Morecambe Bay is a very productive area. The pair regularly rears three chicks which is a testament to the quality of their feeding grounds. The pair has also been observed only consuming the brains of the fish they caught and discarding the rest, which suggests abundant prey in the area (D. Harpley, 2023, *pers. comm*).

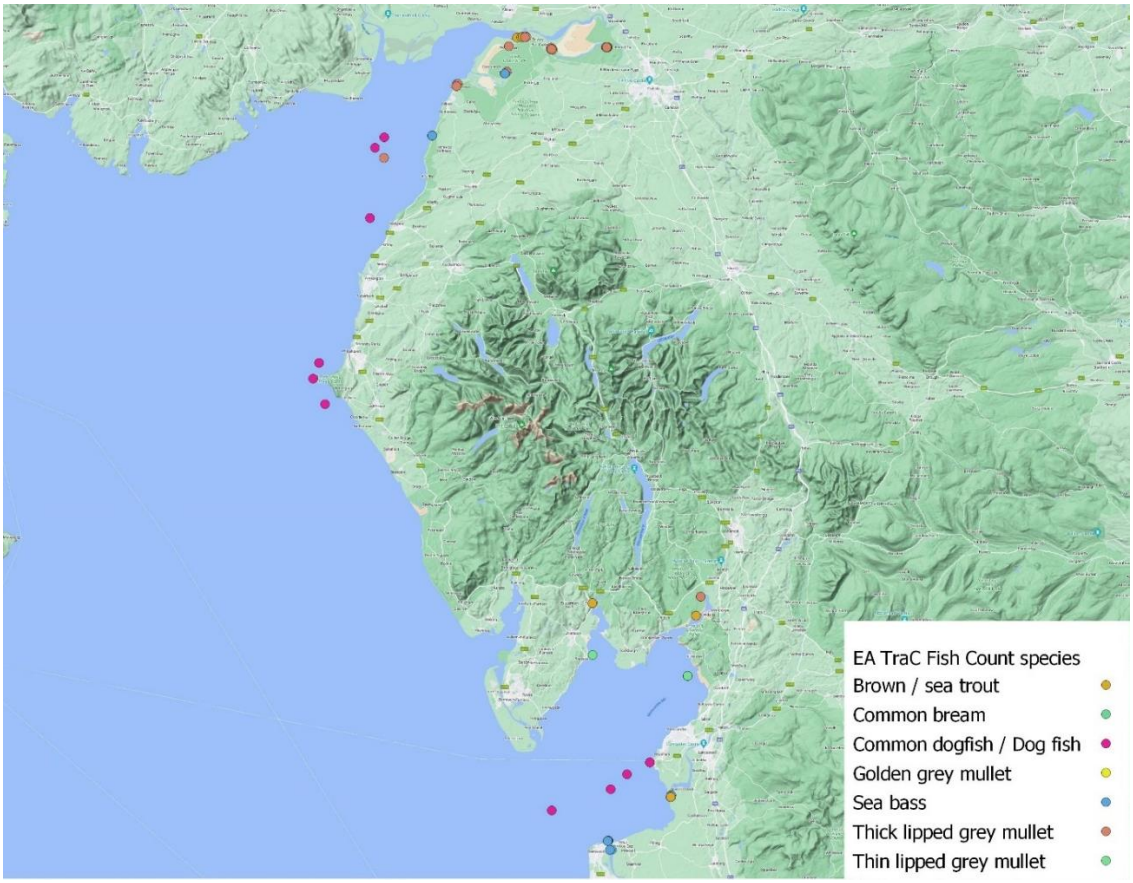

Figure 1: Environmental agency Transitional and Coastal fish survey locations and species caught (Data source: Environmental Agency 2018; Maps: Google 2023).

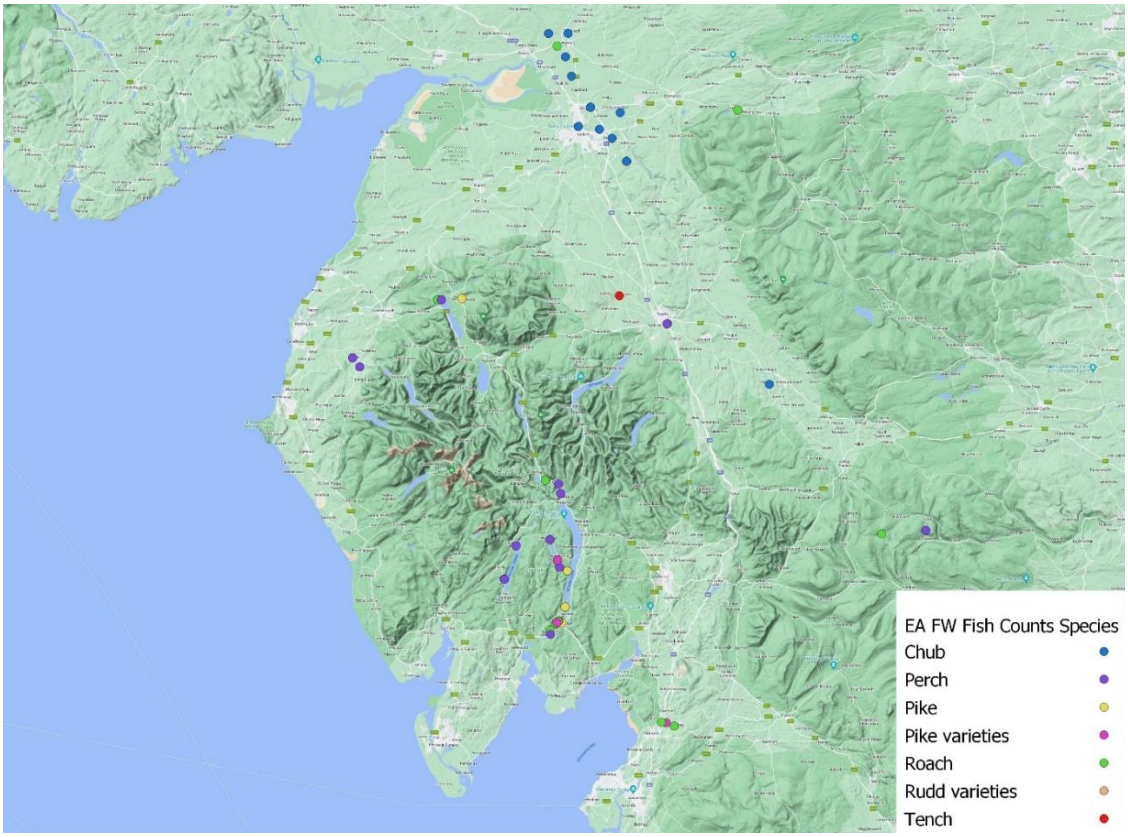

Figure 2: Environmental agency Freshwater fish survey locations and species caught (Data source: Environmental Agency 2022; Maps: Google 2023).

Table 5: Fish species recorded in the 20 waterbodies sampled as part of the Lakes Tour 2015 indicated as present (P), presumed locally extinct (E), and present in a tributary (T). Extent of knowledge in indicated as high (H), moderate (M) or low (L). (reproduced from: Winfield *et al.*, 2015).

Lake	Arctic charr	Atlantic salmon	Brown trout	Bullhead	Common bream	Crucian carp	Dace	Eel	Minnow	Perch	Pike	Rainbow trout	Roach	Ruffe	Schelly	Stone loach	Tench	Three-spined stickleback	Vendace	Extent of knowledge
Bassenthwaite Lake		P	P				P	P	P	P	P		P	P					P	H
Blelham Tarn			P							P	P		P							L
Brothers Water			P						P	P					P			P		M
Buttermere	P	P	P						P	P	P									M
Coniston Water	P	P	P						P	P	P		P							M
Crummock Water	P	P	P						P	P										H
Derwent Water		P	P				P	P	P	P	P		P	P					P	H
Elterwater			P							P	P					T				L
Ennerdale Water	P	P	P															P		M
Esthwaite Water			P		P			T	T	P	P	E	P			T				M
Grasmere			P	T	P					P	P		P			T				L
Haweswater	P		P					P	P	P	E				P					H
Lougrigg Tarn			P				P	P		P	P		P				P			L
Loweswater		T	P					T	P	P	P									M
Rydal Water			P			P		P		P	P		P	P		T				L
Thirlmere	P		P							P	P			P						M
Ullswater	E	P	P					P	P	P			P		P			P		M
Wastwater	P	P	P						P									P		M
Windermere North Basin	P	P	P	P	P			P		P	P		P					P		H
Windermere South Basin	P	P	P		P			P		P	P		P				P			H

4.6.2. Bird availability in Cumbria

The Cumbria coast and inland waterbodies attract large numbers of non-breeding and resident waterbirds. Tens of thousands of geese, ducks, waders, and gulls are recorded each year during the British Trust for Ornithology's (BTO) wetland bird surveys (WeBS; Table 6; full list in Appendix 2).

Key species in WTE diet are highlighted in Table 7. Coots were recorded in relatively small numbers during the WeBS surveys, however they are common and widespread residents, especially abundant in the south of the county (CBDC and CDC, 2015). Mallards were found in high numbers and are abundant and widespread residents (CBDC and CDC, 2015). Grebes were recorded in small numbers but both little grebe (*Tachybaptus ruficollis*) and great crested grebe (*Podiceps cristatus*) are fairly common residents and widespread across the county. *Mergus* species were recorded in relatively small numbers, however red breasted mergansers (*Mergus serrator)* are fairly common and widespread residents mostly around the Solway, the central Lakes and the Walney Island tip of the county, and goosanders (*Mergus merganser*) are also common and widespread residents. Geese visitors are abundant in the non-breeding season with greylag geese and Canada geese also widespread and common residents in the county (CBDC and CDC, 2015) as well as being summer visitors during moulting season (CBC, 2023) when they could be especially vulnerable to WTE.

Finally, eider were found in large numbers and are common residents in the south of the county around Walney island.

This review of WTE diet across Europe shows that they target a wide range of species. We have discussed availability of the key species, however many other waterbirds are present in large numbers in Cumbria as visitors or residents (Table 6; CBC, 2023) suggesting birds will be an important food source for WTE in the county.

Although large numbers of waterbirds are found across the county, key areas are the Cumbria coast, especially the Solway Estuary and Morecambe Bay, the River Eden which runs across the East to the Solway, some of the large lakes such as Derwentwater and Bassenthwaite Lake, as well as smaller waterbodies detailed in Table 8.

4.6.3. Mammal availability in Cumbria

European rabbit and brown hare are both widespread across Cumbria and likely to be consumed by WTE as live prey (Figures 3 and 4). Roe deer are also widespread across the county (Figure 5) and could be an important source of carrion. Mammal monitoring undertaken during the BTO Breeding Bird Surveys show an increase in brown hare and a decrease in rabbits in the North West of England since their monitoring started in 1995 (BTO, 2022). NBN Atlas data suggest that all three species are present in the area currently considered to host a release site, however recent data are limited, therefore localised surveys at the chosen release site to assess abundance of mammals in the area could be undertaken as young birds especially are likely to utilise that resource.

Table 6: Population size in Cumbria of the most numerous waterbird species (mean population estimates over the period 2017/18 to 2021/22). Table contains Wetland Bird Survey (WeBS) data from Waterbirds in the UK 2021/22 © copyright and database right 2023. WeBS is a partnership jointly funded by the BTO, RSPB and JNCC, with fieldwork conducted by volunteers and previous support from WWT.

			Total coastal	Total inland	Total Cumbria
Geese	*Anser anser*	Greylag Goose	1870	6863	8733
	Anser anser	Greylag Goose (British/Irish)	1748	3335	5083
	Anser anser	Greylag Goose (Icelandic)	285	4417	4702
	Anser brachyrhynchus	Pink-footed Goose	25087	7622	32709
	Branta canadensis	Canada Goose	1055	2757	3812
	Branta leucopsis	Barnacle Goose	28400	718	29118

	Branta leucopsis	Barnacle Goose (Svalbard)	28234	718	28952
Ducks	*Anas acuta*	Pintail	6385	123	6508
	Anas crecca	Teal	6194	3708	9902
	Anas penelope	Wigeon	12726	3254	15980
	Anas platyrhynchos	Mallard	2247	4736	6983
	Aythya fuligula	Tufted Duck	172	1251	1423
	Melanitta nigra	Common Scoter	5297	19	5316
	Somateria mollissima	Eider	5445	0	5445
	Somateria mollissima	Eider (except Shetland)	5445	0	5445
	Tadorna tadorna	Shelduck	8269	123	8392
Waders	*Arenaria interpres*	Turnstone	1732	13	1745
	Calidris alba	Sanderling	3692	1	3693
	Calidris alpina	Dunlin	41884	8	41892
	Calidris canutus	Knot	25637	0	25637
	Charadrius hiaticula	Ringed Plover	2675	20	2695
	Haematopus ostralegus	Oystercatcher	68117	651	68768
	Limosa lapponica	Bar-tailed Godwit	3899	0	3899
	Limosa limosa	Black-tailed Godwit	4261	90	4351
	Numenius arquata	Curlew	14107	576	14683
	Phalacrocorax carbo	Cormorant	2054	345	2399
	Pluvialis apricaria	Golden Plover	11157	333	11490
	Pluvialis squatarola	Grey Plover	1463	0	1463
	Tringa totanus	Redshank	13134	126	13260
	Vanellus vanellus	Lapwing	21459	4125	25584
Gulls / Terns	*Chroicocephalus ridibundus*	Black-headed Gull	16028	3374	19402
	Larus argentatus	Herring Gull	10139	1044	11183
	Larus canus	Common Gull	3885	2268	6153
	Larus fuscus	Lesser Black-backed Gull	3918	1227	5145
		Unidentified gull	1072	0	1072
	Sterna sandvicensis	Sandwich Tern	2513	5	2518

Table 7: Population size in Cumbria of the waterbird species that have been recorded in WTE diet in Europe (mean population estimates over the period 2017/18 to 2021/22). Highlighted in green are the key WTE dietary species identified in this literature review and proposed by experts. Table contains Wetland Bird Survey (WeBS) data from Waterbirds in the UK 2021/22 © copyright and database right 2023. WeBS is a partnership jointly funded by the BTO, RSPB and JNCC, with fieldwork conducted by volunteers and previous support from WWT.

			Total coastal	Total inland	Total Cumbria
Geese	*Anser anser*	Greylag Goose	1870	6863	8733
	Anser anser	Greylag Goose (British/Irish)	1748	3335	5083
	Anser anser	Greylag Goose (Icelandic)	285	4417	4702
	Anser anser	Domestic Greylag Goose	0	58	58
	Anser brachyrhynchus	Pink-footed Goose	25087	7622	32709
	Branta bernicla	Brent Goose	493	0	493
	Branta bernicla hrota	Brent Goose (Light-bellied - hrota)	274	0	274
	Branta bernicla hrota	Brent Goose (Light-bellied of Nearctic origin)	448	0	448
	Branta canadensis	Canada Goose	1055	2757	3812
	Branta leucopsis	Barnacle Goose	28400	718	29118
	Branta leucopsis	Barnacle Goose (naturalised)	166	0	166
	Branta leucopsis	Barnacle Goose (Svalbard)	28234	718	28952
Swans	*Cygnus cygnus*	Whooper Swan	442	395	837
	Cygnus olor	Mute Swan	297	527	824
Ducks	*Anas acuta*	Pintail	6385	123	6508
	Anas clypeata	Shoveler	315	161	476
	Anas crecca	Teal	6194	3708	9902
	Anas penelope	Wigeon	12726	3254	15980
	Anas platyrhynchos	Mallard	2247	4736	6983
	Anas platyrhynchos domesticus	Domestic Mallard	0	39	39
	Anas strepera	Gadwall	117	297	414
	Aythya ferina	Pochard	25	36	61
	Aythya fuligula	Tufted Duck	172	1251	1423
	Aythya marila	Scaup	376	4	380
	Bucephala clangula	Goldeneye	196	670	866
	Melanitta nigra	Common Scoter	5297	19	5316

	Mergus merganser	Goosander	229	439	668
	Mergus serrator	Red-breasted Merganser	275	58	333
	Somateria mollissima	Eider	5445	0	5445
	Somateria mollissima	Eider (except Shetland)	5445	0	5445
	Tadorna tadorna	Shelduck	8269	123	8392
	Gavia stellata	Red-throated Diver	130	0	130
Grebes	*Podiceps cristatus*	Great Crested Grebe	88	46	134
	Tachybaptus ruficollis	Little Grebe	59	278	337
Waders	*Ardea cinerea*	Grey Heron	140	139	279
	Arenaria interpres	Turnstone	1732	13	1745
	Calidris alpina	Dunlin	41884	8	41892
	Egretta garzetta	Little Egret	563	29	592
	Fulica atra	Coot	152	556	708
	Gallinula chloropus	Moorhen	76	361	437
	Gulosus aristotelis	Shag	17	0	17
	Haematopus ostralegus	Oystercatcher	68117	651	68768
	Phalacrocorax carbo	Cormorant	2054	345	2399
	Pluvialis apricaria	Golden Plover	11157	333	11490
	Rallus aquaticus	Water Rail	10	12	22
	Tringa totanus	Redshank	13134	126	13260
	Vanellus vanellus	Lapwing	21459	4125	25584
Gulls	*Chroicocephalus ridibundus*	Black-headed Gull	16028	3374	19402
	Larus argentatus	Herring Gull	10139	1044	11183
	Larus canus	Common Gull	3885	2268	6153
	Larus fuscus	Lesser Black-backed Gull	3918	1227	5145
	Larus marinus	Great Black-backed Gull	631	49	680
	Larus melanocephalus	Mediterranean Gull	94	4	98
	Rissa tridactyla	Kittiwake	226	0	226
Terns	*Sterna sandvicensis*	Sandwich Tern	2513	5	2518

Table 8: Key sites for waterbirds in Cumbria. Table contains Wetland Bird Survey (WeBS) data from Waterbirds in the UK 2021/22 © copyright and database right 2023. WeBS is a partnership jointly funded by the BTO, RSPB and JNCC, with fieldwork conducted by volunteers and previous support from WWT.

	Geese	Swans	Ducks / Divers	Grebes	Waders	Gulls	Terns	Total
Solway Estuary	72251	346	14953	21	63584	12606	262	164023
St Bees Head to Mawbray	42	49	501	5	8766	1029	600	10992
Drigg Point to St Bees Head	0	8	232	0	951	589	25	1805
Irt and Mite and Esk Estuary	681	5	1240	1	1218	1065	9	4219
Duddon Estuary	2761	60	4796	18	15465	2319	973	26392
Morecambe Bay	12406	275	32197	103	127527	18572	806	191886
Bassenthwaite Lake	621	18	573	21	37	88	0	1358
Cardew Mires Quarry	1049	7	354	13	406	998	0	2827
Castle Carrock Reservoir	658	2	262	3	10	101	0	1036
Derwent Water	1700	18	600	10	96	59	0	2483
Haweswater Reservoir	884	1	76	2	25	69	0	1057
Holme Dub	1381	5	969	0	952	268	0	3575
Longtown Ponds and River	685	38	1189	25	363	495	0	2795

Mockerin Tarn	415	8	173	2	38	488	0	1124
River Eden - Grinsdale to Sandsfield	830	25	456	13	588	0	0	1912
River Eden - Little Salkeld	1186	21	14	1	352	0	0	1574
River Eden - Newby to Scotby	727	68	156	4	59	200	0	1214
River Eden - Scotby to Rickerby Rocks	1814	63	824	5	947	99	0	3752
Rivers Eamont and Eden	1954	26	181	5	71	478	0	2715
RSPB North Plain Farm	736	2	641	1	524	123	0	2027
Tarns Dub	209	1	513	1	20	603	0	1347
Thurstonfield Lough	24	33	690	22	86	165	0	1020
Ullswater	854	15	310	24	67	32	0	1302
Wedholme Flow	3561	117	619	0	131	67	0	4495
Wet Sleddale Reservoir	1447	0	164	1	91	37	0	1740

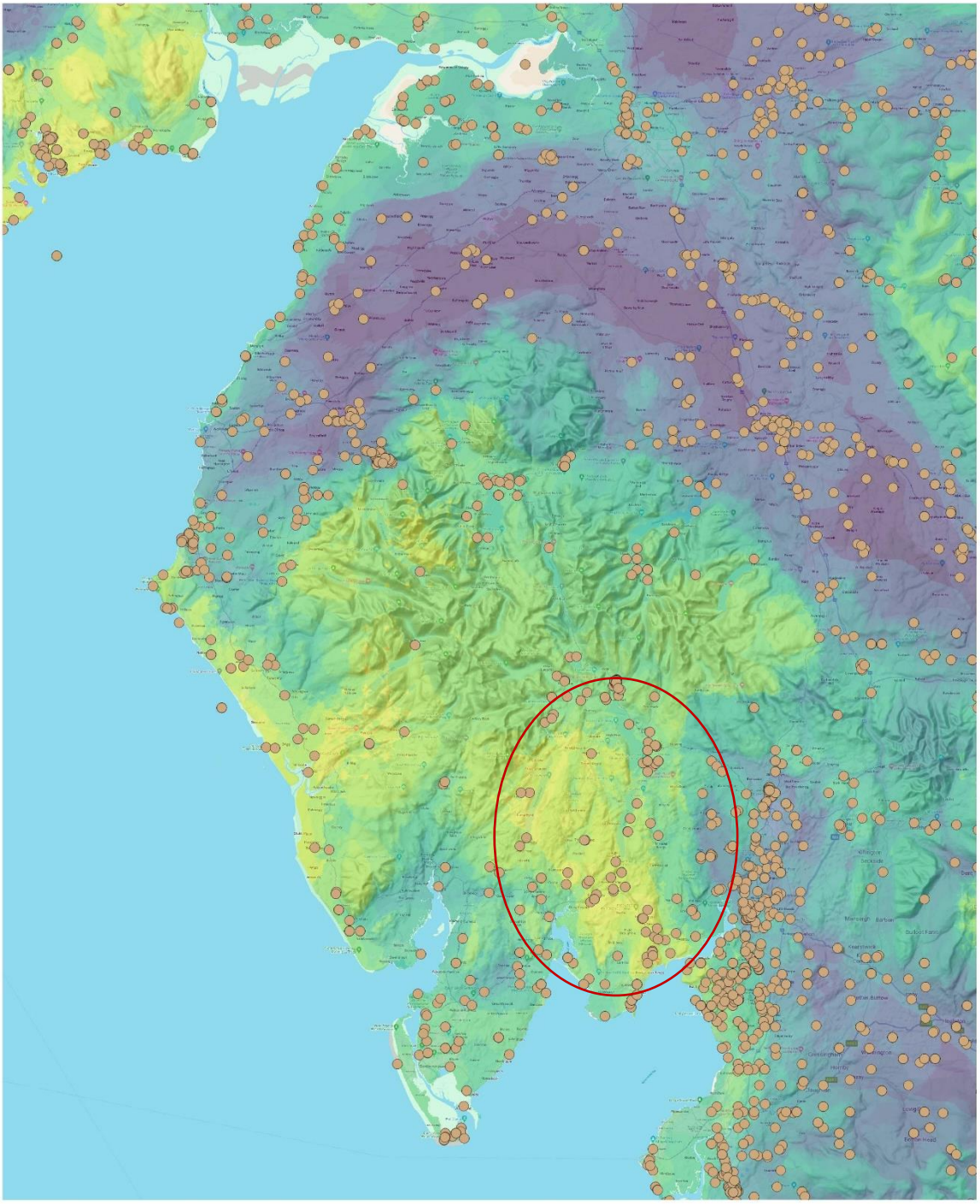

Figure 1: Records of rabbit in Cumbria between 2014 and 2023 in relation to habitat suitability mapping. Potential release sites currently being considered are within the red circle. Data suggest rabbit prey could be available in low numbers in the vicinity of the release site (Data source: NBN Atlas occurrence download at https://nbnatlas.org accessed on 23 May 2024; Maps: Google 2024).

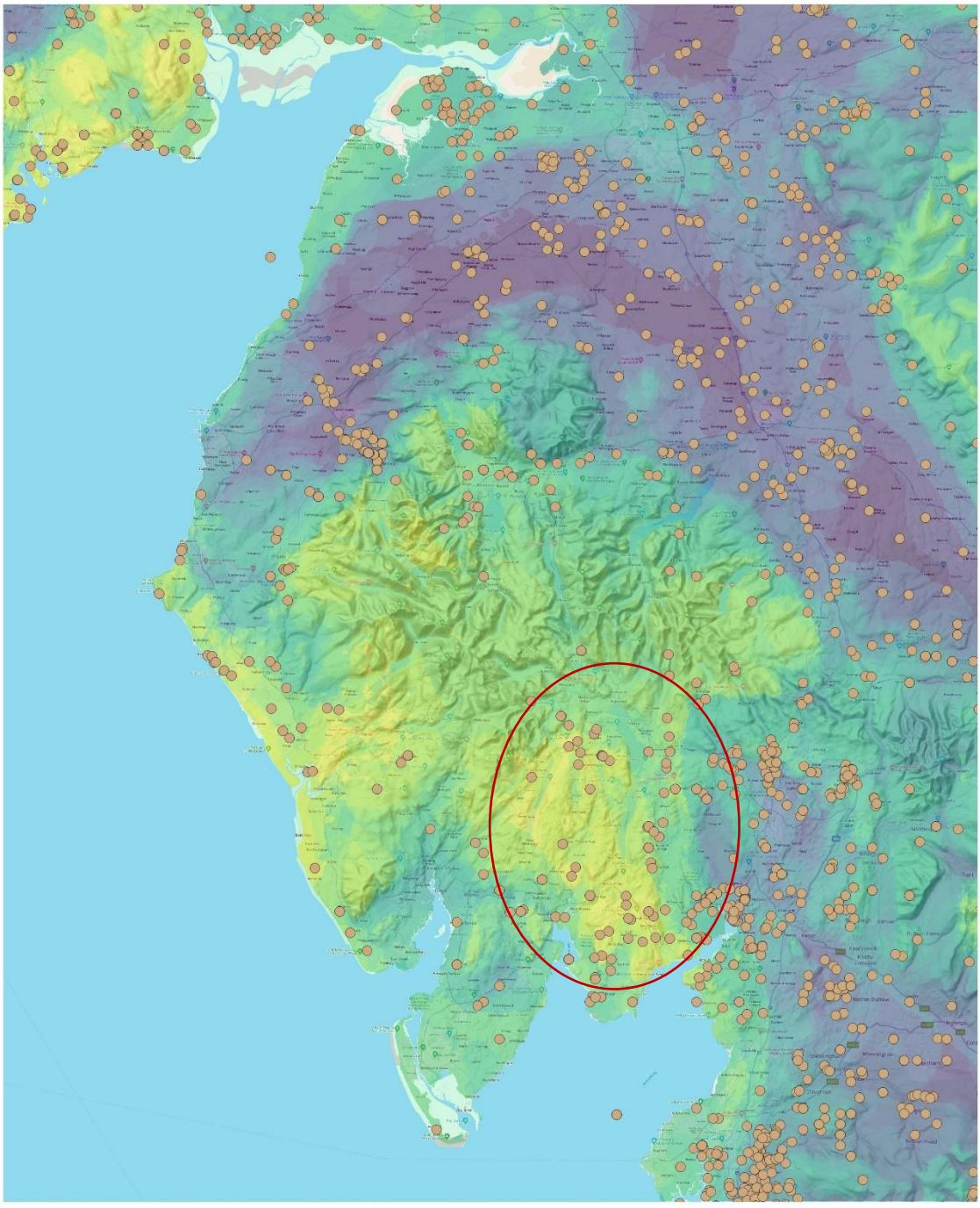

Figure 2: Records of brown hare in Cumbria between 2014 and 2023 in relation to habitat suitability mapping. Potential release sites currently being considered are within the red circle. Data suggest brown hare prey could be available in low numbers in the vicinity of the release site (Data source: NBN Atlas occurrence download at https://nbnatlas.org accessed on 23 May 2024; Maps: Google 2024).

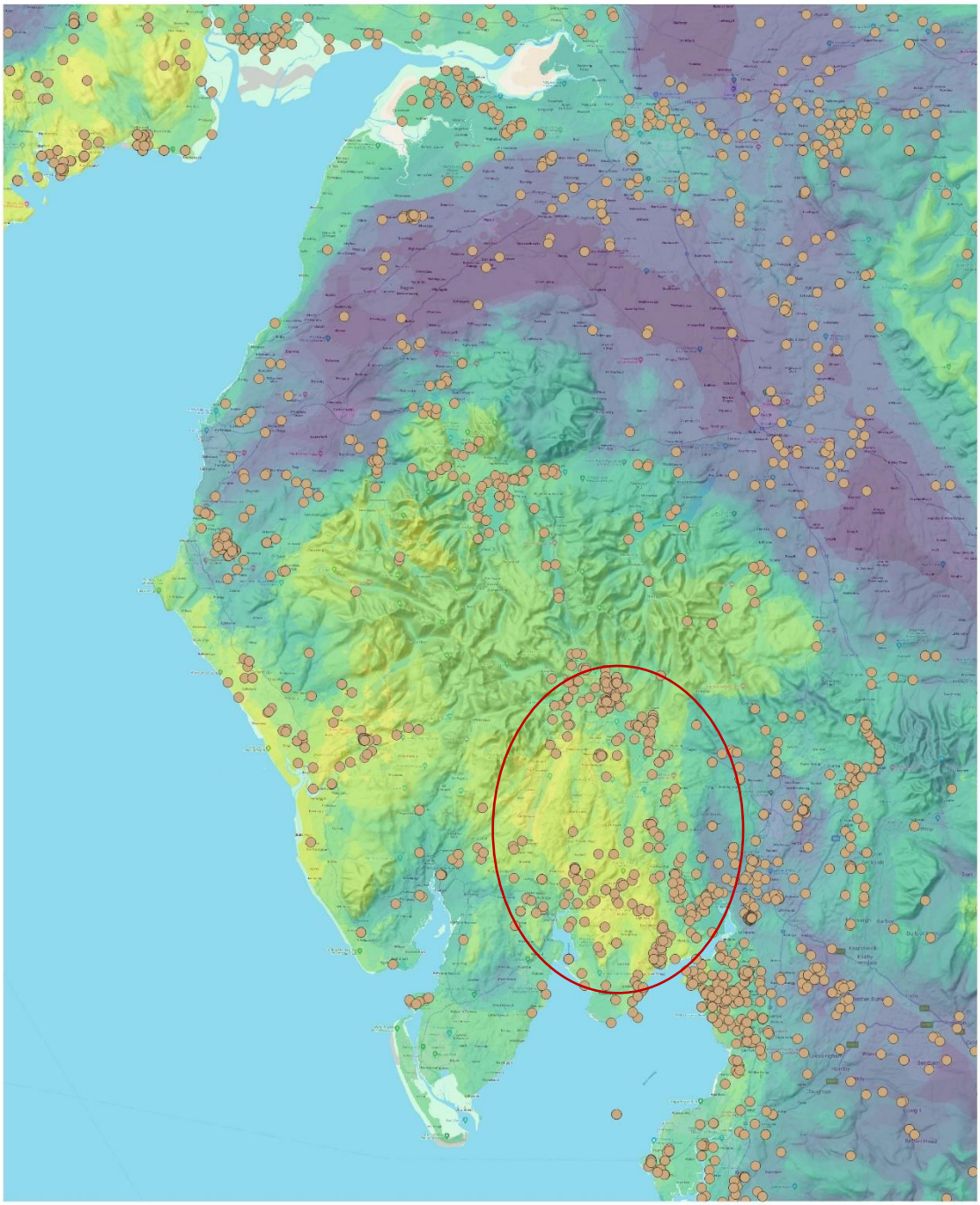

Figure 3: Records of roe deer in Cumbria between 2014 and 2023 in relation to habitat suitability mapping. Potential release sites currently being considered are within the red circle. Data suggest roe deer carrion should be available in the vicinity of the release site (Data source: NBN Atlas occurrence download at https://nbnatlas.org accessed on 23 May 2024; Maps: Google 2024).

5. CONCLUSION

This literature review confirms that the main food sources utilised by WTE across their UK and European range are fish, birds, and mammals. Evidence shows that WTE prey on a wide range of species with variations linked to habitat, season, and age, as well as specific to individuals. WTEs are an adaptable species able to best utilise the food sources available.

Although time consuming and difficult for established WTE populations that are not GPS tagged, monitoring diet using visual observations could provide more accurate data and eliminate the limitation of some food remains not showing up in pellets. Most studies collect remains in and around nests therefore the focus is on breeding pairs' and nestlings' diet only and restricted to early summer. Visual observations could therefore provide more insight into seasonal variations and diet patterns of younger birds. This method is being used to monitor the diet of the GPS tagged reintroduced population on the Isle of Wight and has allowed around 100 prey species to be recorded from over 400 observations (S. Egerton-Read 2023, *pers. comm*.). Webcams and visual observation have also been used to monitor WTE diet in the Netherlands (Van Rijn *et al*. 2010).

Prey availability in Cumbria appears to be good, with many of the key species across food groups present in the county. Key bird prey species are likely to be geese as they are present throughout the year and in very large numbers during the non-breeding season. Many other waterbird species are likely to be predated with several species of visitors and residents widespread across the country. Pike, which was identified as the main fish prey in Europe, is also widespread in Cumbria. Several other potential fish prey are present in Cumbria, both in freshwater and marine habitat, however recent data are sparse and abundance is not well known. Important mammal species are present in Cumbria and are likely to be consumed as live prey and carrion, although recent presence and abundance data are lacking.

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7. APPENDIX 1: Detailed prey species lists identified in literature review

Appendix 1.1 - Fish species found in WTE diet

		Bounas *et al.* (2023)	Dementavičius *et al.* (2020)	Ekblad *et al.* (2016)	Ekblad *et al.* (2020)	Mirski and Komar (2023)	Nadjafzadeh *et al.* (2013)	Nadjafzadeh *et al.* (2015)	Randla and Tammur (1996)	Sándor *et al.* (2015)	Sulkava *et al.* (1997) Aland	Sulkava *et al.* (1997) Quark	Sulkava *et al.* (1997) Lapland	van Rijn *et al.* (2010)	Yurko (2016)	Reid *et al.* (2023)
		% of all items	% of all items	% of all items	% of all items	% of all items	% of all items	proportion by food group	% of fish	% of all items	% of all items	% of all items	% of all items	n	% of all items	n
Abramis brama	Common bream		9.9	6.7		2.14		0.816	8.4	1.15				2	22	
Alosa fallax	Twait shad		0.1													
Anguilla anguilla	European eel		0													1
Balistes capriscus	Triggerfish															1
Belone belone	Garfish		1													1
Blicca bjoerkna	White bream		1.1			0.8		0.014							1.6	
Carassius auratus	Goldfish														0.8	
Carassius carassius	Crucian carp					1.2									3.9	
Carassius gibelio	Prussian carp									8.08						
Carassius spp.	Mostly carp spp.		6.4													
Clupea harengus	Herring															
Conger conger	European conger															2
Ctenopharyngodon idella	Grass carp		0.1			0.67										36
Cyclopterus lumpus	Lumpsucker															22
Cyprinidae spp.	Minnows and carps	1	7.1		1.2	6.28	54.7			10					31.5 (not in addition to above)	
Cyprinus carpio	Common carp	10.6	2.6			38.18				11.54				18		
Esox lucius	Northern pike	0.5	18.7	13.9	49.8	8.95	3.17	0.046	59	6.15	19.1	25.4	53	4	10.2	2

Esox/ Stizostedion	Pikes/zander														1		
Gadus morhua	Cod																35
Gadidae spp.	Cod spp.																44
Hypophthalmichthys spp.	Carp spp.		0.3			1.87											
Labridae spp.	Wrasses spp.																29
Leuciscus cephalus	Chub		0.1														
Leuciscus idus	Ide			5.6	5.5						4.3	3.8	4.4		1.6		
Lophius piscatorius	Anglerfish																26
Lota lota	Burbot		2.1		2.8	0.4											
Melanogramnus aeglefinus	Haddock																14
Merluccius merluccius	European hake																62
Molva molva	Ling																21
Mugilidae sp.	Grey mullet																1
Myoxocephalus scorpius	Bullrout																14
Oncorhynchus mykiss	Rainbow trout					0.27											
Osmerus eperlanus	European smelt		0														
Pelecus cultratus	Ziege		0.1														
Perca fluviatilis	European perch	2.5	3.5	1.3	1.2	0.93		0.011	9.	0.38					1.6		
Percidae spp.	Inc. perches and darters						1.71										
Platichthys flesus	Flounder																3
Pleuronectidae	Flounders		0.1														20
Pollachius virens	Saithe																5
Raja clavata	Thornback ray																3
Raniceps raninus	Tadpole-fish																1
Rutilus rutilus	Common roach		1.6			2.67		0.075							1		
Salmo salar	Atlantic salmon																12
Salmo trutta	Trout																11
Salmonidae spp	Salmonids					0.13											

Sander (Lucioperca) lucioperca	Zander	5.3				0.38	1.6	
Sardina pilchardus	Pilchard							1
Scardinius erythrophthalmus	Common rudd	0.6			0.038			
Scomber scombrus	Mackerel							15
Scophthalmus maximus	Turbot							1
Scyliorhinus canicula	Lesser-spotted dogfish							86
Silurus glanis	Catfish	0.1		0.27		0.77	3.1	
Taurulus bubalis	Long-spined sea scorpion							1
Tinca tinca	Tench	0.8		4.81			1.6	
Trachurus trachurus	Scad							3
Triglidae sp.	Gurnard							2
Trisopterus luscus	Bib							2
Trisopterus sp.	Small cod sp.							1
Vimba vimba	Vimba bream	0.1						
Zeus faber	John dory							17

Appendix 1.2. Bird species found in WTE diet

		Bounas *et al.* (2023)	Dementavičius *et al.* (2020)	Ekblad *et al.* (2020)	Ekblad *et al.* (2016)	Mirski and Komar (2023)	Nadjafzadeh *et al.* (2013)	Nadjafzadeh *et al.* (2015)	Randla and Tammur (1996)	Sándor *et al.* (2015)	Sulkava *et al.* (1997) Aland	Sulkava *et al.* (1997) Quark	Sulkava *et al.* (1997) Lapland	van Rijn *et al.* (2010)	Yurko (2016)	Reid *et al.* (2023)
		% of all items	% of all items	% of all items	% of all items	% of all items	% of all items	proportion by food group	% of birds	% of all items	% of all items	% of all items	% of all items	n	% of all items	n
Accipiter nisus	Sparrowhawk															2
Actitis hypoleucos	Common sandpiper															3
Alca torda	Razorbill															165
Alectoris rufa	Red-legged partridge															4
Anas (Mareca) penelope	Eurasian widgeon		1.4											2		1
Anas (Mareca) strepera	Gadwall		0							2.69						
Anas acuta	Northern pintail		0.2													
Anas clypeata	Northern shoveler													10		
Anas crecca	Common teal		0.6	1.6										14		7
Anas platyrhynchos	Mallard	2.5	4	2.8		0.93			16.5	3.08	5.2	3.7	4.1	10	5.5	135
Anas spp.	Dabbling ducks							0.227						3		2
Anatidae	Ducks									3.46	4.2	9.5	3.3			
Anser albifrons	White-fronted goose		1.1							0.77						
Anser anser	Greylag goose		0.4			4.01				3.08				55		201
Anser fabalis	Bean goose		0.2													
Anser/Branta spp.	Geese		1.3	1.1	1.9			0.142								
Anseriformes	Waterfowl						7.17									
Apus apus	Common swift		0													
Ardea cinerea	Grey heron	1.5	0.4				0.14			1.92					1.6	107
Arenaria interpres	Turnstone															1

Asio flammeus	Short-eared owl																20
Asio otus	Long-eared owl					0.4											1
Aythya ferina	Common pochard		0.1							2.31							
Aythya fuligula	Tufted duck		0.3														
Aythya nyroca	Ferruginous duck									0.38							
Aythya spp.	Diving ducks							0.059			5.2	0.9	10.3				
Botaurus stellaris	Eurasian bittern		0.1							0.53							
Branta canadensis	Canada goose																15
Bucephala clangula	Goldeneye		0.4	1.6	5.7						5.1	0.4	1.9				
Buteo buteo	Common buzzard		1.6			1.74											2
Calidris alpina	Dunlin																1
Calidris pugnax	Ruff		0.1														
Casmerodius albus	Great egret															1.6	
Cepphus grylle	Black guillermot																26
Charadriiformes	Shorebirds	0.5					1.53			0.38							
Chlidonias spp.	Terns					0.8											
Ciconia ciconia	White stork		0.3			2.94										6.3	
Ciconia nigra	Black stork															12.6	
Circus cyaneus	Hen harrier																2
Clangula hyemalis	Long-tailed duck		0.1														1
Coloeus monedula	Western jackdaw		0.1														5
Columba livia f. domestica	Domestic pigeon	2	0.2														20
Columba palumbus	Common wood pidgeon		0.4							0.96							16
Columba spp.	Pigeons		0.1			0.53	0.7										
Coracias garrulus	European roller									0.06							
Corvidae	Corvids		0.2	2.1													102

Corvus corax	Common raven		0.2			0.13								0.8	63
Corvus cornix	Carrion crow	0.5	0			0.53				0.87					
Corvus frugilegus	Rook		0.4							0.4					
Cuculus canorus	Common cuckoo		0												6
Cygnus columbianus	Tundra swan		0												
Cygnus olor	Mute swan		0.1							1.15					
Cygnus spp.	Swans				1	0.13		0.038							
Dendrocopos major	Great spotted woodpecker						0.2								
Dendrocopos syriacus	Syrian woodpecker	0.5													
Egretta garzetta	Little egret	1													
Falco peregrinus	Peregrine														1
Falco tinnunculus	Common kestrel		0.1												4
Fratercula arctica	Puffin														100
Fringilla coelebs	Chaffinch														1
Fulica atra	Eurasian coot	15.6	6.9		0.7	4.54		0.139	31.3	8.52			35	5.5	
Fulmarus glacialis	Northern fulmar														4347
Gallinago gallinago	Common snipe		0.1												4
Gallinula chloropus	Common moorhen	4								0.27				0.8	1
Gallus domesticus	chicken		0.4			0.93									3
Garrulus glandarius	Eurasian jay		0.1												2
Gavia arctica	Black-throated diver														3
Gavia stellata	Red-throated diver		0												7
Grus grus	Common crane		0.3	2.4		0.53									
Haematopus ostralegus	Eurasian oysteratcher													0.8	54
Haliaeetus albicilla	White-tailed eagle													2.4	

Hydrocoloeus minutus	Little gull		0										
Lagopus lagopus	Willow ptarmigan			1.3									
Lagopus lagopus scotia	Red grouse												240
Laridae	Gulls								5	2.9	15		
Larus (Chroicocephalus) ridibundus	Black-headed Gull	6	1.8			0.8						1	12
Larus argentus	European herring gull		0.1										146
Larus canus	Common gull		0.2										66
Larus fuscus	Lesser black-backed gull												13
Larus marinus	Greater black-backed gull												70
Larus michahellis	Yellow-legged gull	3.5											
Larus spp.	Gulls		0.7	2.1	7.3								70
Limosa limosa	Black-tailed godwit		0										
Mareca/Anas/Spatula spp.	Genus of ducks		3.5										
Melanitta fusca	Velvet scoter		0		4.4								
Melanitta nigra	Common scoter												1
Melanitta spp.	Scoters								5.9		1.9		
Mergus merganser	Goosander		0.3		5.6		0.114						
Mergus serrator	Red-breasted merganser				5.3								38
Mergus/Mergellus spp.	Mergansers			2.8	12				10.3	2.4	8.9		
Morus bassanus	Northern gannet												31
Numenius arquata	Eurasian curlew		0										40
Numida meleagris	Guinea fowl												2

Passeriformes		0.5	0											2.4	
Perdix perdix	Grey partridge		0.1												
Phalacrocorax aristotelis	Shag														354
Phalacrocorax carbo	Great cormorant	2	0.3		0.9		1.77	0.046		1.96				0.8	20
Phalacrocorax pygmeus	Pygmy cormorant									2.32					
Phasianus colchicus	Pheasant									0.38					85
Pica pica	Magpie		0							0.56					
Plegadis falcinellus	Glossy ibis	0.5													
Pluvialis apricaria	Golden plover														4
Podiceps cristatus	Great crested grebe	15.6	2.2							3.24	2.8		2.1	1	
Podiceps grisegena	Red-necked grebe									0.7					
Podiceps nigricollis	Black-necked grebe									0.26					
Podicipediformes	Grebes						2.16	0.235	9.3		0.7		0.6		
Porzana porzana	Spotted crake		0												
Puffinus puffinus	Manx shearwater														32
Rallidae	Rails	0.5					7							1	
Rissa tridactyla	Kittiwake														43
Scolopacidae	Waders			1.2											
Scolopax rusticola	Eurasian woodcock		0.1											1	17
Somateria mollissima	Common eider				23.7						14.8		3.6		104
Spatula clypeata	Northern shoveler		0.2												
Spatula querquedula	Garganey		0.4												
Stercorarius skua	Great skua														1
Sterna sandvicensis	Sandwich tern														1
Sterna sp.	Terns				0.6										13

Streptopelia decaocto	Collared dove	0.5														2
Strix aluco	Tawny owl		0.1			0.13										2
Sturnus vulgaris	Common starling		0.1			0.13			0.1					1		3
Tachybaptus ruficollis	Little grebe		0			0.13			0.54							
Tadorna tadoma	Shelduck	5														23
Tetrao (Lirurus) tetrix	Black grouse			1.3											0.8	2
Tetrao urogallus	Capercaillie			2.5												
Tetraonidae	Grouse									1.3	3.5	2.6				
Tringa glareola	Wood sandpiper		0													
Tringa sp	Genus of waders	0.5	0.1													
Tringa totanus	Common redshank													1		3
Turdus iliacus	Redwing													1		
Turdus merula	Common blackbird		0.2													2
Turdus philomelos	Song thrush		0.1													
Turdus viscivorus	Mistle thrush															3
Turdus sp.	Trush family					0.13										
Tyto alba	Barn owl															7
Uria aalge	Guillemot															501
Vanellus vanellus	Northern lapwing		0.5											1		17

Appendix 1.3. Mammal species found in WTE diet

	Bounas *et al.* (2023)	Dementavičius *et al.* (2020)	Ekblad *et al.* (2016)	Ekblad *et al.* (2020)	Mirski and Komar (2023)	Nadjafzadeh *et al.* (2013)	Nadjafzadeh *et al.* (2015)	Randla and Tammur (1996)	Sándor *et al.* (2015)	Sulkava *et al.* (1997) Aland	Sulkava *et al.* (1997) Quark	Sulkava *et al.* (1997) Lapland	van Rijn *et al.* (2010)	Yurko (2016)	Reid *et al.* (2023)

		% of all items	% of all items	% of all items	% of all items	% of all items	% of all items	proportion by food group	% of mammals	% of all items	% of all items	% of all items	% of all items	n	% of all items	n
Avricola terrestris	Water vole		0.2													
Bovidae	Bovids						0.33									
Canidae	Canids						2.38									
Canis lupus familiaris	Dog					0.13										
Capra hircus	Goat															1
Capreolus capreolus	Roe deer		0.7			0.67		0.239						20	0.8	25
Castor fiber	Beaver		0.1			0.27									1.6	
Cervidae sp.	Deer			0.6			6.27									
Cervus dama	Fallow deer							0.172								1
Cervus elaphus	Red deer													1		95
Equus verus	Konik													1		
Erinaceus europaeus	Hedgehog															42
Erinaceus roumanicus	Northern white breasted hedgehog	1														
Felis catus (domesticus)	Domestic cat		0.1				0.14									8
Lepus europaeus	Brown hare		0.4			0.53			36.4	1.15						42
Lepus sp.	Hares		0.3		1.8						1.7	1.4	0.8			
Lepus timidus	Mountain hare			0.7												353
Oryctolagus cuniculus	Rabbit															1102
Lepus/Oryctolagus	Hare/rabbit													2		
Martes martes	Pine Marten					0.13										
Meles meles	Badger															2
Mustelidae	Mustelids		0.1				0.41									3
Mustela erminea	Stoat															1

Neovison vison	American mink														5
Nyctereutes procyonoides	Raccoon dog		0			0.2	0.03	0.38						0.8	
Ondatra zibethicus	Muskrat		2.1	1.8				1.92	4.5	5.6	0.3	9			
Ovis aries	Domestic sheep	1						1.15							1350
Phoca vitulina	Common seal														8
Phocoena phocoena	Harbour porpoise							0.77							
Rangiger tarandus	Reindeer				4.2										
Rattus norvegicus	Brown rat		0.1												18
Rattus/Microtus	Rat/vole											2			
Rodentia	Rodents					1.34									
Sciurus vulgaris	Red squirrel					0.41									
Suidae	Pigs					4.2									
Sus scrofa	Wild boar	1.5	0		0.13		0.418							7.1	
Sus scrofa/domesticus	Boar/pig				0.13										
Talpa europaea	Mole											1			
Vulpes vulpes	Red fox		0				0.141								13

8. APPENDIX 2: Wetland bird species recorded in Cumbria

Appendix 2.1: Full list of species recorded by the WeBS survey in Cumbria and 5-year average peak counts (Contains Wetland Bird Survey (WeBS) data from Waterbirds in the UK 2021/22 © copyright and database right 2023. WeBS is a partnership jointly funded by the BTO, RSPB and JNCC, with fieldwork conducted by volunteers and previous support from WWT)

			Total coastal	Total inland	Total Cumbria
Geese	*Anser albifrons*	White-fronted Goose	0	1	1
	Anser albifrons	White-fronted Goose (European - albifrons)	0	1	1
	Anser anser	Greylag Goose	1870	6863	8733
	Anser anser	Greylag Goose (British/Irish)	1748	3335	5083
	Anser anser	Greylag Goose (Icelandic)	285	4417	4702
	Anser anser	Domestic Greylag Goose	0	58	58
	Anser brachyrhynchus	Pink-footed Goose	25087	7622	32709
	Anser canagicus	Emperor Goose	2	0	2
	Anser cygnoides	Swan Goose	0	5	5
	Anser indicus	Bar-headed Goose	3	1	4
	Branta bernicla	Brent Goose	493	0	493
	Branta bernicla bernicla	Brent Goose (Dark-bellied - bernicla)	73	0	73
	Branta bernicla hrota	Brent Goose (Light-bellied - hrota)	274	0	274
	Branta bernicla hrota	Brent Goose (Light-bellied of Nearctic origin)	448	0	448
	Branta canadensis	Canada Goose	1055	2757	3812
	Branta canadensis x Anser anser	Canada x Greylag Goose	0	2	2
	Branta leucopsis	Barnacle Goose	28400	718	29118
	Branta leucopsis	Barnacle Goose (naturalised)	166	0	166
	Branta leucopsis	Barnacle Goose (Svalbard)	28234	718	28952
	Branta leucopsis x Anser anser	Barnacle x Greylag Goose	0	1	1

	Branta leucopsis x Branta canadensis	Barnacle x Canada Goose	0	1	1
		Hybrid goose	1	0	1
		Unidentified goose	1	0	1
Swans	*Alopochen aegyptiaca*	Egyptian Goose	1	0	1
	Cygnus columbianus	Bewick's Swan	4	0	4
	Cygnus cygnus	Whooper Swan	442	395	837
	Cygnus olor	Mute Swan	297	527	824
Ducks	*Aix galericulata*	Mandarin Duck	0	10	10
	Anas acuta	Pintail	6385	123	6508
	Anas clypeata	Shoveler	315	161	476
	Anas crecca	Teal	6194	3708	9902
	Anas penelope	Wigeon	12726	3254	15980
	Anas platyrhynchos	Mallard	2247	4736	6983
	Anas platyrhynchos domesticus	Domestic Mallard	0	39	39
	Anas querquedula	Garganey	3	0	3
	Anas strepera	Gadwall	117	297	414
	Aythya collaris	Ring-necked Duck	0	1	1
	Aythya ferina	Pochard	25	36	61
	Aythya fuligula	Tufted Duck	172	1251	1423
	Aythya marila	Scaup	376	4	380
		Aythya hybrid	0	1	1
	Bucephala clangula	Goldeneye	196	670	866
	Cairina moschata	Muscovy duck	0	5	5
	Clangula hyemalis	Long-tailed Duck	1	1	2
	Melanitta fusca	Velvet Scoter	1	0	1
	Melanitta nigra	Common Scoter	5297	19	5316

	Mergus merganser	Goosander	229	439	668
	Mergus serrator	Red-breasted Merganser	275	58	333
	Somateria mollissima	Eider	5445	0	5445
	Somateria mollissima	Eider (except Shetland)	5445	0	5445
	Tadorna tadorna	Shelduck	8269	123	8392
		Hybrid duck	1	1	2
		Unidentified duck	69	3	72
Divers	*Gavia immer*	Great Northern Diver	1	0	1
	Gavia stellata	Red-throated Diver	130	0	130
Grebes	*Podiceps cristatus*	Great Crested Grebe	88	46	134
	Podiceps grisegena	Red-necked Grebe	0	2	2
	Tachybaptus ruficollis	Little Grebe	59	278	337
		Unidentified grebe	1	0	1
Waders	*Actitis hypoleucos*	Common Sandpiper	60	70	130
	Actitis macularius	Spotted Sandpiper	1	0	1
	Ardea alba	Great White Egret	11	0	11
	Ardea cinerea	Grey Heron	140	139	279
	Arenaria interpres	Turnstone	1732	13	1745
	Botaurus stellaris	Bittern	2	0	2
	Calidris alba	Sanderling	3692	1	3693
	Calidris alpina	Dunlin	41884	8	41892
	Calidris canutus	Knot	25637	0	25637
	Calidris ferruginea	Curlew Sandpiper	2	0	2
	Calidris maritima	Purple Sandpiper	35	1	36
	Calidris melanotos	Pectoral Sandpiper	0	1	1
	Calidris minuta	Little Stint	1	0	1

Charadrius dubius	Little Ringed Plover	4	16	20
Charadrius hiaticula	Ringed Plover	2675	20	2695
Ciconia ciconia	White Stork	0	2	2
Egretta garzetta	Little Egret	563	29	592
Fulica atra	Coot	152	556	708
Gallinago gallinago	Snipe	366	261	627
Gallinula chloropus	Moorhen	76	361	437
Gulosus aristotelis	Shag	17	0	17
Haematopus ostralegus	Oystercatcher	68117	651	68768
Limnodromus scolopaceus	Long-billed Dowitcher	0	1	1
Limosa lapponica	Bar-tailed Godwit	3899	0	3899
Limosa limosa	Black-tailed Godwit	4261	90	4351
Lymnocryptes minimus	Jack Snipe	9	3	12
Numenius arquata	Curlew	14107	576	14683
Numenius phaeopus	Whimbrel	185	7	192
Phalacrocorax carbo	Cormorant	2054	345	2399
Philomachus pugnax	Ruff	13	6	19
Platalea leucorodia	Spoonbill	16	0	16
Pluvialis apricaria	Golden Plover	11157	333	11490
Pluvialis squatarola	Grey Plover	1463	0	1463
Rallus aquaticus	Water Rail	10	12	22
Recurvirostra avosetta	Avocet	75	0	75
Scolopax rusticola	Woodcock	0	2	2
Tringa erythropus	Spotted Redshank	3	0	3
Tringa nebularia	Greenshank	86	4	90
Tringa ochropus	Green Sandpiper	2	10	12

	Tringa totanus	Redshank	13134	126	13260
	Vanellus vanellus	Lapwing	21459	4125	25584
		Unidentified wader	410	0	410
		Unidentified large wader	1	0	1
Gulls	*Chroicocephalus ridibundus*	Black-headed Gull	16028	3374	19402
	Hydrocoloeus minutus	Little Gull	1	1	2
	Larus argentatus	Herring Gull	10139	1044	11183
	Larus canus	Common Gull	3885	2268	6153
	Larus fuscus	Lesser Black-backed Gull	3918	1227	5145
	Larus glaucoides	Iceland Gull	0	1	1
	Larus marinus	Great Black-backed Gull	631	49	680
	Larus melanocephalus	Mediterranean Gull	94	4	98
	Larus michahellis	Yellow-legged Gull	1	0	1
	Rissa tridactyla	Kittiwake	226	0	226
		Unidentified gull	1072	0	1072
		Unidentified large gull	185	2	187
Terns	*Sterna hirundo*	Common Tern	66	0	66
	Sterna paradisaea	Arctic Tern	45	0	45
	Sterna sandvicensis	Sandwich Tern	2513	5	2518
	Sternula albifrons	Little Tern	47	0	47
		Unidentified tern	4	0	4
Other	*Alcedo atthis*	Kingfisher	5	23	28