Earthworms in the diet of breeding Herring Gulls (*Larus argentatus*) on Lady Isle, Firth of Clyde, Scotland

Tom W. Pennycott, Browncarrick Drive, Ayr, KA7 4JA, Scotland.

David Grant, University of the West of Scotland, Ayr Campus, Ayr, KA8 0SX, Scotland.

Ruedi G. Nager, Graham Kerr Building, IBAHCM, University of Glasgow, G12 8QQ, Scotland.

Short title: Earthworms and Herring Gulls

Key words (in addition to those in title): regurgitated pellets; terrestrial vegetation; nutrition, rainfall

Email of correspondence author: pennycott740@btinternet.com

Summary

To have a better understanding of the diet of a declining species, three hundred and fourteen pellets of indigestible material regurgitated by Herring Gulls (*Larus argentatus*) breeding on Lady Isle in the Firth of Clyde, Scotland, were collected in 2018 and 2019 and examined for the presence of earthworm chaetae. Large numbers of chaetae were detected in 31.2% of pellets examined and a further 34.4% of pellets contained smaller numbers of chaetae, indicating that over half (65.6%) of the pellets came from gulls that had consumed earthworms. There was considerable variation in frequency of pellets with earthworm chaetae between sampling occasions. During chick rearing, significantly fewer pellets contained earthworm chaetae in 2018, a relatively dry season, than in 2019, and in 2019 pellets from the chick rearing period were more likely to contain earthworm chaetae than pellets from the incubation period.There were highly significant associations between the presence of large quantities of terrestrial vegetation in the pellet and the detection of large numbers of earthworm chaetae

and/or fragments of terrestrial arthropods, suggesting that recent consumption of these food items should be suspected when pellets contain large quantities of vegetation.

Earthworms in the diet of Herring Gulls (*Larus argentatus*) breeding onan offshore island

The Herring Gull population in the UK is currently in decline and has been since the 1970s, warranting its red-listed status (Eaton *et al.* 2015). The exact reason for this population decline is unknown but changes in food resources could be one possible explanation (Mitchell *et al*. 2004). Any advances in the understanding of the diet of this species are therefore to be regarded as positive.

Information about the diet of Herring Gulls in southwest Scotland and nearby Northern Ireland, based on analysis of regurgitated pellets, has been provided by Melville (1974), Nogales et al. (1995) and O'Hanlon *et al*. (2017). However, the methodology used in these studies did not include examination for the remains of earthworms (Class Oligochaeta, Family Lumbricidae), which have been identified as important food source elsewhere (Sibly & McCleery 1983; Coulson & Coulson 2008). Earthworms were recognised as a source of food for gulls as long ago as the 1900s by Portielje (1928) and O'Mahony (1935), and are potentially highly nutritious (Edwards 1985). Most parts of an earthworm are easily digested after being eaten by a bird or mammal, but the chaetae (bristle-like structures found in their hundreds on the outer surface of earthworms) are not digested and are passed out in the faeces or regurgitated in pellets where they can be detected using appropriate methodology (Coulson & Coulson 2008).

Within southwest Scotland, the Clyde Basin is an important area for breeding Herring Gulls in Scotland, and Lady Isle (55.53°N, 4.73°W), a very small (4.4 hectares) unpopulated island within the Clyde Basin and 5.6 km off the Ayrshire coast, hosts one of the most important Herring Gull colonies, with approximately 1000 breeding pairs (DG unpubl data). Lady Isle also has significant breeding populations of Lesser Black-backed Gulls *L. fuscus* and Great Black-backed Gulls *L. marinus* (Grant *et al*. 2013). Determining whether Herring Gulls on Lady Isle consume earthworms is important in studies looking at resource use by gulls in this area

of Scotland. In addition, many previous researchers (Harris 1965; Vernon 1970; Melville 1974; Nogales *et al.* 1995; Coulson & Coulson 2008; Lindborg *et al*. 2012; O'Hanlon *et al.* 2017) have reported the presence of large quantities of terrestrial vegetation in pellets produced by different species of gulls. In most of these studies no attempts were made to look for earthworm chaetae and the significance of the vegetation was unclear. Coulson & Coulson (2008) did, however, propose that such terrestrial vegetation was accidentally consumed when gulls were foraging for earthworms and insects. Here we explored the importance of earthworms in the diet of Herring Gulls breeding in a coastal colony using pellets and how variable earthworm consumption is between years and breeding stages. Furthermore, we tested for a possible association between the presence of large quantities of terrestrial vegetation in Herring Gull pellets and the detection of earthworm chaetae in pellets.

We collected pellets from Lady Isle during the 2018 and 2019 breeding seasons (139 in May – July 2018, 175 in May – July 2019, Table 1). Pellets were collected from rocks, nests or the vicinity of nests from where Herring Gulls breed on the island (Grant *et al*. 2013) and were stored in a deep freeze prior to testing. The methodology used for pellet analysis is presented in Appendix 1. The presence of pellets containing earthworm chaetae (0 if absent, 1 if present) was compared between breeding stages and years using a binomial general linear model. The proportion of pellets containing earthworm chaetae are presented with 95% confidence intervals using the Jeffrey interval from package *binom* (Dorai-Raj 2014) in R version 3.6.1 (R Core Team 2019).

We collected and analysed a total of 314 pellets (Table 1). The commonest items making up at least 25% of the bulk of a pellet were anthropogenic debris such as waste food, plastic, paper, aluminium foil and glass (xx% of pellets), cereal husks and/or kernels (xx%) and marine items such as fragments of fish, crabs and langoustines (xx%). In xx pellets (xx%), coarse terrestrial vegetation comprised at least 40% of the bulk of the pellet, and fragments of terrestrial arthropods, although never comprising 25% of the bulk of the pellet, were found in xx pellets (xx%).

Earthworm chaetae were present in 206 out of 314 (65.6%) pellets and of these 94 pellets (31.2% of all pellets) contained large numbers (>50 in 300 µl of sediment) of chaetae. The presence of earthworm chaetae in pellets varied between breeding stages and years (stage-by-year interaction: χ_1^2=19.16, p<0.001; Table 2). During the incubation stage, the frequencies of pellets with earthworm chaetae present were similar between the two years (mean (confidence interval); 2018: 0.59 (0.46, 0.71), n=83; 2019: 0.65 (0.56, 0.74), n=100), but in the chick stage more pellets contained earthworm chaetae in 2019 than in 2018 (2018: 0.11 (0.04, 0.20), n=56; 2019: 0.60 (0.49, 0.71), n=75). Proportion of pellets containing large numbers of chaetae also varied between years and stages (χ_1^2=10.64, p=0.001), and in particular during chick rearing in 2019 most Herring Gull pellets (0.60 (0.49,0.71), n=75) contained large numbers of earthworm chaetae, whereas the proportion of pellets contained large numbers of earthworm chaetae were lower at other times (<0.31 (0.22,0.40)). Variation between sampling dates within the same breeding stage were also apparent, both for presence of chaetae (χ_1^2=16.08, p<0.001) and frequency of pellets with large number of chaetae (χ_1^2=5.22, p=0.022). During chick rearing in 2018, more pellets contained chaetae on June 26th than 16 days later, and the same trend was noted during incubation in 2018 on two sampling dates four days apart (Table 2).

In 89 pellets (28.3%), coarse terrestrial vegetation comprised at least 40% of the bulk of the pellet, and of these 85 (95.5%) pellets contained large numbers of earthworm chaetae whereas of the remaining 225 pellets with moderate, little or no coarse terrestrial vegetation only 13 (5.8%) pellets contained large numbers of earthworm chaetae (Pearson's χ^2 test with Yates' correction, χ_1^2=234.99, p<0.01). This supports earlier suggestions that terrestrial vegetation had been accidentally picked up with other food (Harris 1965; Vernon 1970; Coulson & Coulson 2008), or maybe deliberately ingested to help nest maintenance or pellet formation and the expulsion of small fragments of insects Nogales *et al*. 1995; Lindborg *et al*. (2012). Based on the strong association between terrestrial vegetation and large numbers of earthworm chaetae we recommend that, in future studies, pellets with large quantities of

coarse terrestrial vegetation be examined for the presence of earthworm chaetae using appropriate methodology. We adopted a simple and inexpensive methodology that can be followed after minimal training, and does not require specialised equipment (Appendix 1). The only essential pieces of equipment were a microscope capable of delivering a magnification of at least x100 (x10 eyepiece and x10 objective lens). The technique also detected other structures such as the microscopic remains of food items and the eggs of parasitic helminths, including syngamid roundworms, hairworms and flukes. The trade-off for simplicity was reduced sensitivity. It is highly unlikely that all the earthworm chaetae were initially recovered from each pellet, and subsequent dilution factors further reduced the sensitivity. However, the level of sensitivity was considered acceptable as earthworm typically have eight chaetae for each of their 100-150 segments (Edwards & Bohlen 1996) and thus a single earthworm can have many hundreds of chaetae.

Earthworms have been inconsistently reported as food source of Herring Gulls. Sibly & McCleery (1983) found that earthworms were one of the 4 most important food sources for a coastal colony close to an agricultural landscape and cited other studies where earthworm in samples from gulls had probably been missed or underestimated. Earlier studies on the diet of Herring Gulls in the Firth of Clyde did not detect earthworm chaetae in pellets from Ailsa Craig, approximately 16 km off the coast of Ayrshire and 40 km from Lady Isle (Nogales *et al*. 1995), nor from several coastal colonies including Lady Isle (O'Hanlon *et al*. 2017) whereas we found earthworm chaetae in two-thirds of pellets. This is probably an overestimate of the frequency of earthworms in the diet as chaetae could be detected in the faeces of Choughs *Pyrrhocorax pyrrhocorax* for at least twelve faecal evacuations after consumption of an earthworm (Meyer *et al*. 1994) and detection of small numbers of chaetae probably reflected carry-over of chaetae from an earlier meal. Thus, the frequency of pellets with larger numbers of chaetae (31.2%) better reflects the contribution of earthworms to the diet of Herring Gulls, although our threshold of >50 chaetae in 300 µl of sediment was arbitrarily chosen and requires further study. Coulson & Coulson (2008) also found a high frequency of pellets

containing earthworm chaetae (55.2%) in Lesser Black-backed Gulls breeding in an inland urban colony in southwest Scotland. This variation in presence of earthworms in diet samples may be due to differences in accessibility to areas rich in earthworms and/or methodological differences between studies. The findings from the current study on Lady Isle demonstrate that the prevalence of pellets containing chaetae is much greater than previous research into the diet of Herring Gulls in Scotland and Northern Ireland had suggested and supports the conclusion of Coulson & Coulson (2008) that the methodology employed is key to determining the presence or absence of earthworm chaetae in gull pellets.

Frequency of pellets with earthworms varied between sampling dates and breeding stages, although the later differed between years. These differences may reflect the effect of weather conditions on earthworm numbers and accessibility with earthworms more available under rainy conditions (Kruuk 1978). Total rainfall recorded at Prestwick (approximately 6.5 km from Lady Isle) for May-July 2018 was 135 mm (the driest May-July recorded at Prestwick between 2010 and 2019), whereas total rainfall for May-July 2019 was 215 mm, close to the ten-year Prestwick May-July mean of 212 mm (Scottish Environment Protection Agency https://apps.sepa.org.uk/rainfall/data/index/344764 Accessed 26/08/19). Vernon (1972) noted that gull numbers on farmland substantially increased after heavy rain because earthworms (especially *Lumbricus* spp.) came to the surface and became more accessible. Thus, the wetter weather in 2019 could explain the higher proportion of pellets with earthworm chaetae in that year. Diet switches between incubation and chick rearing, triggered by chick hatching, had also been observed in other gull populations (Annett & Pierotti 1989; Isaksson *et al*. 2016). Incubating parents may select for food that is more predictable in time and space rather than of high quality (Annett & Pierotti 1989). Once chicks hatched, however, they require energy-rich and readily digestible food. Typically gull diets switch from rather terrestrial food to chicks being provided more likely with marine invertebrates and fish (Annett & Pierotti 1989; Isaksson et al. 2016). Thus a switch to more frequent terrestrial foraging trips after chick hatching as reflected by a higher frequency of

pellets with earthworm chaetae during chick rearing, at least in 2019, was unexpected. This might reflect a poor availability of alternative prey within the foraging range of Herring Gulls breeding on Lady Isle. Alternatively, foraging habitat choice, and thus diet, may also be related to time costs incurred by foraging gulls that vary with chick age; Lesser Black-backed Gulls in Belgium shifted from predominantly marine foraging trips that were shorter, but energetically more expensive to cheaper but more time consuming terrestrial foraging trips when chicks were older and required less time at the nest (Sotillo *et al*. 2019). A combination of time management, food quality and weather conditions may contributed to the observed temporal variation in the frequency of earthworm chaetae in pellets of Herring Gulls.

Acknowledgements

SAC Consulting Veterinary Services, Auchincruive, Ayr, kindly provided access to the Olympus binocular microscope. Roselle Smith, Klaudyna Maniszewska and James Scralett and the University of the West of Scotland assisted in the collection of some of the pellets.

References

Annett, C., & Pierotti, R. 1989. Chick hatching as a trigger for dietary switching in the Western Gull. *Colonial Waterbirds* **12**: 4-11.

Coulson, J.C. & Coulson, B.A. 2008. Lesser black-backed gulls *Larus fuscus* nesting in an inland urban colony: the importance of earthworms (Lumbricidae) in their diet. *Bird Study* **55:** 297-303.

Dorai-Raj, S. 2014. Binomial Confidence Intervals For Several Parameterizations. https://CRAN.R-project.org/package=binom

Eaton, M., Aebischer, N., Brown, A., Hearn, R., Lock, L., Musgrove, A., Noble, D., Stroud, D. & Gregory R. 2015. Birds of Conservation Concern 4: the population status of birds in the UK, Channel Islands and Isle of Man. *British Birds* **108:** 708–746

Edwards, C.A. 1985. Production of feed protein from animal waste by earthworms. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences,* **310:** 299-307

Edwards C.A. & Bohlen P.J. 1996. *Biology and Ecology of Earthworms*. Chapman & Hall, London.

Grant, D., Robertson, D., Nager, R. & McCracken, D. 2013. The status of breeding gulls on Lady Isle, Ayrshire. 2012. *Scottish Birds* **33:** 298-307.

Harris, M.P. 1970. The food of some *Larus* gulls. *Ibis* **107:** 43-53

Isaksson, N., Evans, T.J., Shamoun-Baranes, J.& Åkesson, S. 2016. Land or sea? Foraging area choice during breeding by an omnivorous gull. *Movement Ecology* **4**: 11.

Kruuk, H. 1978. Foraging and spatial organization of the European badger, *Meles meles* L. *Behavioral Ecology and Sociobiology* **4**, 75–89.

Lindborg, V.A., Ledbetter, J.F., Walat, J.M. & Moffett, C. 2012. Plastic consumption and diet of Glaucous-winged Gulls (*Larus glaucescens*). *Marine Pollution Bulletin* **64:** 2351-2356.

Melville, D. 1974. Analysis of herring gull pellets collected in Co. Antrim. *Seabird Report 1972-1974*, pp40-46

Meyer R.M., Buckland P.C. & Monaghan P. 1994. The diet of the chough *Pyrrhocorax pyrrhocorax* as indicated by analysis of digested prey remains. *Avocetta* **18:** 95-106.

Mitchell, P.I., Newton, S.F., Ratcliffe, N. & Dunn, T.E. 2004. Seabird populations of Britain and Ireland. T. & AD Poyser, London

Nogales, M., Zonfrillo, B. & Monaghan, P. 1995. Diets of adult and chick Herring Gulls *Larus argentatus argenteus* on Ailsa Craig, south-west Scotland. *Seabird* **17:** 56-63.

O'Hanlon, N.J., McGill, R.A.R. & Nager, R.G. 2017. Increased use of intertidal resources benefits breeding success in a generalist gull species. *Marine Ecology Progress Series* **574:** 193-210.

O'Mahony, E. 1935. Herring Gull Eating Earthworms. *The Irish Naturalists' Journal* **5**: 309.

Portielje, A.F.J. 1928. Zur Ethologie bzw. Psychologie der Silbermowe, *Larus a. argentatus*. Pontopp. *Ardea,* **17:** 112-149

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Sibly, R.M. & McCleery, R.H. 1983. Increase in weight of herring gulls while feeding. *Journal of Animal Ecology* **52:** 35-50.

Sotillo, A., Baert, J.M., Müller, W., Stienen, E.W.M., Soares, A.M.V.M. & Lens, L. 2019. Time and energy costs of different foraging choices in an avian generalist species. M*ovement Ecology* **7**: 41

Vernon, J.D.R. 1970. Food of the Common Gull on grassland in autumn and winter. *Bird Study* **17:** 36-38

Vernon, J.D.R. 1972. Feeding habitats and food of the Black-headed and Common Gulls. Part 2 – Food. *Bird Study* **19:** 173-186

248 Table 1: Composition of gull pellets collected in two breeding seasons from Lady Isle

Species and stage	Sampling dates	Prey remains in pellet (> 25% by volume)				
		Earthworms	Refuse	Cereal	Mam/Avian	Marine
2018						
Herring Gull Incubation	14/05/2018 (n=69) 18/05/2018 (n=14)					
Herring Gull Chicks	26/06/2018 (n=26) 12/07/2018 (n=30)					
Black-backed Gull Incubation	14/05/2018 (n=21)	38.1%	28.6%	61.9%	9.5%	9.5%
2019						
Herring Gull Incubation	17/05/2019 (n=100)					
Herring Gull Chicks	25/07/2019 (n=75)					

249

250

Table 2: Proportion of gull pellets with presence of at least some earthworm chaetae and containing large numbers of earthworm chaetae (> 50 chaetae in 300 µl of sediment) in two breeding seasons from Lady Isle. Numbers give mean proportions with 95% confidence intervals using the Jeffrey interval in brackets, and n = number of pellets examined.

		Presence of earthworm chaetae in pellets	Frequency of large numbers of earthworm chaetae in pellets
2018			
Incubation	14/5/2018	0.64 (0.52, 0.75, n=69)	0.22 (0.13, 0.32, n=69)
	18/5/2018	0.36 (0.14, 0.60, n=14)	0.07 (0.01, 0.25, n=14)
Chick rearing	26/6/2018	0.81 (0.65, 0.98, n=26)	0.19 (0.07, 0.35, n=26)
	12/7/2018	0.33 (0.18, 0.50, n=30)	0.03 (0.01, 0.12, n=30)
2019			
Incubation	17/5/2019	0.65 (0.56, 0.74, n=100)	0.31 (0.22, 0.40, n=75)
Chick rearing	25/7/2019	0.81 (0.72, 0.89, n=100)	0.60 (0.49, 0.71, n=75)