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Foraging on human-derived foods by urban bird species

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Short title: Urban birds prefer peanuts

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Summary

Capsule: Providing peanuts on bird feeders was shown to attract more individuals and more species than providing cheese or bread.

Aims: To investigate how the provision of different human-derived foods affects visitation rates of urban birds at bird feeders.

Methods: A fully replicated study design was set up in parkland, offering a binary choice from three food types (peanuts, bread and cheese), on bird tables. Birds were observed using a scan-sample method.

Results: Peanuts attracted more visits and a greater diversity of species than cheese or bread. This preference was strongest for Blue Tits and Great Tits, whereas Robins visited all food types equally, and Blackbirds preferred cheese. Bread was the most consumed food type when measured in mass, but this could be linked to varying bite sizes.

Conclusion: Our results indicate that most birds preferred to visit the most protein- and energy-rich food, but that some birds still choose the carbohydrate-rich bread. The findings indicate that peanuts, rather than household scraps like bread and cheese, attract the highest number of bird species as well as individuals to bird tables. The findings are of interest to the public and to organisations providing information on bird feeding for recreational purposes.

Introduction

With increasing urbanisation comes habitat destruction and alteration, resulting in the loss of natural nesting and foraging habitats for wildlife, including birds (Evans et al. 2009). An estimated 48% of the UK population feed birds in their gardens (Davies *et al*. 2009), potentially impacting the birds' ecology and diet. Householders provide supplementary food to birds to nurture interest in the natural world or because feeding provides a connection to nature, or to assist birds through the winter (Jones & Reynolds 2008; Cox & Gaston 2016). Supplementary feeding is also a standard conservation intervention (e.g. Castro *et al*. 2003; Phipps *et al.* 2013; Mallord *et al*. 2010). Fuller *et al*. (2008) found that avian abundance increased with greater densities of feeders in an area. However, it is difficult to separate the effect of feeders on population abundance as opposed to feeders attracting birds, and another study in the same area found no effect of the presence of supplementary feeders on bird assemblages, leaving the actual effect uncertain. In fact, supplementary feeding can increase the risk of pathogen transmission or malnutrition (Murray *et al*. 2016; Galbraith *et al.* 2016), and so it is essential to take due care when feeding wild animals. Conservation organisations such as the Royal Society for the Protection of Birds (RSPB) and British Trust for Ornithology (BTO) strongly recommend bird feeding, and also suggest different food types to attract specific bird species, for example feeding mealworms to attract Robins *Erithacus rubecula* and Blue Tits *Cyanistes caeruleus* (RSPB 2009). However, there is little evidence to back up these suggestions. Although there are numerous studies on the foraging behaviour of individual species in laboratory environments (e.g. Diaz *et al*. 1990; Murray *et al*. 1993), there is very little *in situ* research into the supplementary food choices of garden birds (Jones & Reynolds 2008; but see Mckenzie *et al*. 2007).

The British Trust for Ornithology (2006) estimates that the total annual expenditure on outdoor bird feeding in the UK is £200 million. Despite the impressive scale of this industry, households maintain the provision of scrap foods to urban bird populations but minimal research has taken place to assess the food types and quantity provided, in addition to the ecological effects of providing such subsides. A broad range of food types are suggested for garden feeders including seeds, nuts and grated cheese, yet bread appears to be a contentious subject. RSPB (2012), BTO (2012) and Allison (2007) suggest the main negative attached to bread is that it is filling but has a low nutritional content (low fat, low protein), with suggestions that if bread makes up the vast majority of their diet then the bird will be subjected to critical vitamin deficiency or starvation (although the scientific evidence for this appears lacking).

Optimal foraging theory predicts that birds should prefer to eat high-energy food, especially in winter when food is scarce and thermoregulatory demands are high (MacArthur and Pianka 1966). As such, where a choice is available birds should select the food with the most energy yield for the energy expended in finding or processing it. However, energy is not the only requirement for bird survival. Nutrients, such as vitamins and minerals, are also necessary to reach a balanced, healthy diet (e.g. Klasing 1998; Ramsay & Houston 1998; Larcombe *et al*. 2008). If high-energy food is eaten in large amounts, this may lead to nutrient deficiencies, impacting on fitness related traits, such as immune function (Blount *et al*. 2003), locomotary performance (Larcombe *et al*. 2008) or offspring quality (Arnold et al. 2007). For example, Plummer *et al*. (2013a) reported that winter feeding with fat resulted in smaller egg yolks compared to feeding with fat plus Vitamin E. Their follow-up study documented lower productivity in Blue Tits after supplementary feeding compared with controls (Plummer *et al*. 2013b). Depending on the remainder of their diet, birds may need to choose the supplementary feeds which complement their existing food sources, which will differ among species. Several studies have analysed which types of food birds prefer to eat under laboratory conditions and compared these to the predicted optimal choices (e.g. Diaz *et al*. 1990; Murray *et al*. 1993; Glück 1985; Krebs *et al.* 1977; Willson 1971). However, these have been natural or semi-natural foods, such as mealworms or seeds. Human-derived food, on the other hand, is provided to wild birds throughout the world, but it is unknown whether urban birds exhibit optimal foraging behaviour with human-derived foods such as cheese and bread.

A number of environmental and social factors are predicted to affect the foraging behaviour and diet selection of birds. In winter, when food is scarce and thermoregulatory costs high, birds utilise supplementary feeders more often (Chamberlain *et al*. 2005; Herborn *et al*. 2014) and accrue body mass earlier in the day (Macleod *et al*. 2005) than under less harsh conditions. Moreover, when temperatures drop, food preferences may change to incorporate human-derived foods, higher-energy foods or larger food items to build up energy reserves (Diaz, 1990; Myton and Ficken 1967). Thus, birds may use air temperature as a cue to predict starvation risk, and hence optimise foraging rate (Fitzpatrick 1997), or food-type preferences. High wind speeds have been shown to lead to lower bird activity due to the high cost of movement, with impacts on foraging rates (Grubb 1978; reviewed in Wingfield & Ramenofsky 2011).

Clearly, the implementation of supplementary feeding as a management approach requires detailed knowledge on both food preferences and the effects of certain food types on individual species. The majority of this data has been collected by the wild bird food industry itself, consisting of preferences for food types, feeder design and location, time of day and season, food colour, taste and nutritional composition (Jones & Reynolds 2008). However, a negligible amount of information is available on the selection of one food type over another when offered simultaneously, in addition to the significance of such preference information and its role in conservation management. The three food types used in this experiment, bread, cheese and peanuts, were selected based on two surveys that we carried out in Hull (see Supplementary Online Material) and advice provided by avian conservation organisations (RSPB 2012; BTO 2012). The overall aim for this study was to investigate whether different human-derived foods can affect avian food choices at urban bird feeders. Specifically we addressed: 1) Do different food types attract different numbers of avian species? 2) Do urban birds show interspecific differences in their food preferences? 3) How do visit rates vary depending on weather conditions?

Methods

Seven observation sites were set up in similar habitats around the campus grounds of the University of York, UK and in adjacent green spaces. All sites were in a park-like, managed landscape, with lawns, hedges and a selection of native and non-native trees and shrubs similar to garden areas (see Fig. A1 in Supporting Information). Sites were positioned at least 200m apart, i.e. one minimum robin territory, with approximately half the sites at least 500m apart thus minimising the likelihood of individuals moving between sites on the same day. Two Gardman bird feeding tables with a brush roof were used at each site, placed at a reasonable distance apart from each other (420 cm ± 30 cm) and from surrounding vegetation (120 cm ± 90 cm) to control for distance to cover and perceived predation risk at the sites. The observation period ran from January to March in 2014. Observation periods did not take place when there was any precipitation. It was important that the birds were aware of the food before measurements begun. Therefore, tables were pre-baited with a mixed seed bird feed, ensuring that food was available for two consecutive days prior to an observation session.

Three different food types were used: grated cheese (Heritage Mild Cheddar), chopped peanuts (Gardman Peanut Bites for Wild Birds), and crumbled pieces of white bread (Warburton's Medium White). Peanuts and bread were found to be commonly provided by households to garden birds in a preliminary survey (Supplementary Online Material). Cheese, although not included in the survey, was chosen because it has been recommended for bird feeding (RSPB, 2009) without there being much evidence that this is a preferred feed for birds. The food types also differ in their nutritional content (Molokwu *et al*. 2011; SELF Nutrition Data 2013; Table 1). For each observation period, 50 grams of one food type was put on each of the two tables, allowing us to record bird choice between these two food types. All combinations of the three foods were observed across all sites and both tables to control for spatial preferences, leading to 42 observation sessions. There were no observations where the same food was provided on both tables. Birds tend to be most active in the morning (Farine and Lang 2013; Rollfinke and Yahner 1990), so a maximum of two observation sessions were carried out within three hours of sunrise (sunrise times from Timeanddate.com, as recommended by The Royal Observatory Edinburgh). The sampling was based on a strategic sampling schedule so that food types and sites were not repeatedly observed at the same time of day. The observer was positioned approximately 15 m from the nearest table, and a timer was started when the observer was in the correct position after leaving the food on the tables. The observer then applied a scan-sample method for one hour, with a bird count every 60 seconds (i.e. 60 counts per one hour observation period and 42 observation sessions in total). The number of individuals on the feeders was recorded at every count as well as which species they were. One "visit" was defined as one individual being present on one feeder at the point of a 60-second scan. This sampling method was used as this was considered the best way of collecting data on what could be a highly dynamic situation involving birds that were not individually marked. It should be noted that there is no way of knowing how many individuals visited the feeders, and it is also possible (although in our opinion unlikely) that the same individuals were observed at several sites, so these data should be treated with some caution. After each observation session, the remaining food was removed and weighed to calculate the amount of eaten food.

Data on weather conditions for each observation day were collected from the University of York campus weather station, using a Vaisala WXT520. This included average air temperature, average wind speed and total rainfall from the previous day. Data from the day prior to the observation period were used, because the same-day weather data would largely measure weather that occurred after the morning observations, and the weather in the previous 24 hours determines the energetic status of a bird in the morning. Ground conditions at the observation site were also recorded (snow/frost/wet/dry), because changes in conditions such as snow cover can impact foraging behaviour and access to food (Brotons 1997).

Ethical Note

Care was taken to ensure that hard or stale bread and whole peanuts were not used during observations, as these may cause birds to choke. Tables were also wiped after the observation period with a bird safe disinfectant (Chapelwood wildlife care, Droitwich, UK), as the congregation of birds at feeders has been implicated in disease transmission particularly with platform feeders (Brittingham & Temple 1986). After completion of the experiment, the tables were allowed to empty naturally for five days so that individuals could make a gradual transition to alternative food sources. All experiments were carried out in accordance with ASAB/ABS's Guidelines for the Treatment of Animals in Research: http://asab.nottingham.ac.uk/ethics/guidelines.php.

Statistical analysis

All analyses were conducted using R statistical software (R Core Development Team 2011), using the packages 'Stats', 'lme4' and 'nlme'. The visit count data were transformed into presence/absence data for each minute. This was done to avoid the statistical problem of zero inflation which would occur with count data, and it had minimal impact on the dataset which largely consisted of 0s and 1s. This data is thus the probability of presence of a bird of any species on the bird table at any given minute. This variable was then the response variable of a Generalised Linear Mixed Model (GLMM), with food type as a fixed factor, table (A or B) nested within observation session (1-42) within site (1-7) as random effects, and a binomial distribution. In addition, it was necessary to control for the temporal autocorrelation in the data. We created a variable that consisted of the presence/absence of birds in the previous minute, and added this to the model. Although not a perfect statistical method, this improved the model fit and worked better than any of the more complex methods to control for temporal autocorrelation (most of which are made for normally distributed data). It is useful to note that the conclusions from the model remained the same regardless of which correction was used, and so we consider the results to be fairly robust despite the challenging structure of the dataset. The same procedure was run for each of the five most common species, with the response variable being presence/absence of the species of interest.

Weather conditions were assessed with the same model structure as above, using presence/absence of birds as the response variable and weather conditions (rainfall, temperature and wind speed from the previous day and ground conditions from the same day) as fixed effects, with each weather variable analysed in a separate model.

Species richness was defined as the total number of species recorded during an observation session. A GLMM used species richness as the response variable, food type as the fixed factor and table nested within site as a random effect, with a Poisson error structure.

The amount of food eaten in each observation session was analysed with a linear mixed effects model, where the response variable was the amount of food eaten from each table in grams, log-transformed after adding 1. Food type was the fixed effect and table was nested within site as a random effect.

Results

Impact of food type on bird presence

There was a significantly higher probability of presence of birds of any species at tables providing peanuts than those providing bread (GLMM, $Z = 5.46$, $p < 0.001$; Fig. 1), and no significant difference between those with cheese and bread (GLMM, $Z = 1.81$, $p = 0.07$).

Impact of weather on visit rates

None of the weather variables (rain, wind, temperature or ground conditions) had any effect on the probability of the presence of birds (GLMM, all $p > 0.2$). However, the relatively steady weather might mean we did not see sufficient variation to conclude in this respect.

Species-specific food preferences

There was a higher probability of seeing Great Tits *Parus major* (Fig. 2a) and Blue Tits (Fig. 2b) at tables with peanuts than those with bread (GLMM, $Z = 4.35$, $p < 0.001$ and $Z = 4.40$, $p < 0.001$ respectively). Robins (Fig. 2c) and Dunnocks *Prunella modularis* (Fig. 2d) did not show a particular preference (GLMM, all $p > 0.05$), whereas Blackbirds *Turdus merula* (Fig. 2e) were more likely to be seen on tables with cheese (GLMM, $Z = 2.22$, $p = 0.03$).

Species richness

We observed a total of nine species (Eurasian Robin *Erithacus rubecula*, Great Tit *Parus major*, Blue Tit *Cyanistes caeruleus*, Blackbird *Turdus merula*, Common Moorhen *Gallinula chloropus*, Dunnock *Prunella modularis*, Coal Tit *Periparus ater*, Long-tailed Tit *Aegithalos caudatus* and House Sparrow *Passer domesticus*). Species richness was significantly higher on bird tables with peanuts than tables with bread (GLMM, $Z = 3.11$, $p < 0.01$; Fig. 3), and there was no difference between tables with bread and cheese (GLMM, $Z = 1.37$, $p = 0.17$).

Weight of eaten food

There was no difference between the food types when measured in total weight eaten per observation session (GLMM, all $p > 0.20$, Fig. 4). In total across the entire study period, bread was consumed the most (104 g), followed by peanuts (79 g) and cheese (75 g).

Discussion

Urban birds showed a preference for feeding on peanuts instead of cheese or bread. Peanuts also attracted the highest number of bird species. This could be useful information when planning supplementary feeding for increased urban biodiversity and human engagement with biodiversity (Cox & Gaston 2016). Goddard *et al.* (2010) emphasise the importance of urban green spaces for biodiversity, encouraging wildlife-friendly management which enhances the potential of gardens and parks (see also Evans *et al*. 2009). However, only nine species were observed, and a number of species were observed only rarely. From our experimental design we cannot determine whether this was due to the low abundance of some species in urban areas, aversion to the food types provided or a neophobic response to the food delivery method (Echeverría & Vassallo 2008; Herborn *et al*. 2010). Thus, there is a possibility that supplementary feeding for urban birds only benefits certain types of species (e.g. granivores and/or generalists) (Chamberlain *et al*. 2009).

Peanuts attracted more visits in total to the feeders as well as attracting higher numbers of species. Considering the high energy content of peanuts, it is economical for the birds to forage on this food type, so this supports the optimal foraging theory (MacArthur and Pianka 1966). Birds have been shown to selectively choose higher-energy foods in earlier studies with natural food types (Glück 1985; Krebs *et al.* 1977; Willson 1971). This aspect of our results indicates that this preferential selection for high quality foods also occurs for urban birds feeding on human-derived foods.

Great Tits had a particularly strong preference for peanuts, which has been observed in an earlier study (Cowie and Hinsley 1988). Blue Tits showed the same preference. On the other hand, Robins and Dunnocks appeared to have no preference for any particular food type, and Blackbirds selected cheese more often than any other species. Due to the variation in energy content between the foods, choosing cheese appears to not support the optimal foraging theory. There might be a hidden cost to selecting peanuts for these species, for example due to differences in beak morphology between insectivores and seed/nut eaters (Lederer 1975), they might be limited in some nutrient found mostly in cheese (such as calcium or phosphorous; Reynolds & Perrins 2010), or they may be foraging sub-optimally (Matsumura *et al.* 2010). Further study is needed to find the reasons behind this choice, possibly looking into taste preferences in these species. Note that there were only observed eleven Dunnock visits throughout the study period, so the data is less robust for this species, and the trend was for them to prefer peanuts. This trend might have been significant with more data.

It is interesting to note that a different pattern emerged when considering how much food was eaten in grams. In fact, when looking at the total amount of food eaten by the birds, there was more bread consumed in weight than cheese or peanuts. Considering the calorie content of the food types, the total amount of food eaten across the observation period equates to 448 kcal for peanuts, 276 kcal for bread, and 301 kcal for cheese. Thus, in total, the birds visited the peanut feeder more often, but ate less in weight, yet ultimately gained more calories from it. This means peanuts should be the optimal choice if choosing only based on calories. It appears that some birds did, in fact, not forage optimally, as they chose bread over peanuts. It is possible that they required more carbohydrates in their diet, as white bread is high in carbohydrates, that they found it easier to digest, or that it had higher palatability.

Our data, however, is likely confounded by the size of the bites of food provided to the birds. Despite our attempts to provide equally sized bites for all food types, this was not possible to completely standardise, and in practice the size of each bite of food varied, both between and within each food type. Bread bites tended to be more variable in size, and it could be hypothesised that the birds, when they did choose bread, chose the bigger pieces so they could minimise the number of flights required, and therefore were able to visit the bread feeders less often. If so, it is possible that birds received, in total, a similar amount of calories from the food types – either from few trips to fetch big chunks of calorie-poor bread, or many trips to fetch small bits of calorie-rich peanuts. Indeed, there are a number of factors that can influence the choice of prey size, for example handling time, difficulty in discriminating between sizes, and availability of prey items (see for example Krebs *et al*. 1977, Naef-Daenzer 2000, Turner 1982). Unfortunately, it is impossible to draw any firm conclusions with our data, as we would need data on both the bite sizes and the flight distances for this analysis. The implication, however, remains – providing small bites of peanuts means the birds have to visit more often, and so will be more desirable if the preferred outcome is to observe as many birds as possible (i.e. for recreational bird feeding in gardens).

Conclusions and implications

In our study, birds mostly chose to forage most frequently on peanuts, the most energy-rich food type. This indicates that the optimal foraging theory not only applies to captive birds foraging on natural foods, but might also apply to urban birds feeding on human-derived foods. This applied especially for Great Tits and Blue Tits, whereas the Blackbird appeared to prefer cheese. However, overall birds consumed a higher mass of bread than other food types, which could be explained by the variable bite sizes of the food provided. The most robust and important conclusion from our results is that providing small bites of peanuts as supplementary feeding to urban birds will attract higher numbers of individuals, as well as higher numbers of species, than providing bread or cheese. Feeding peanuts will tend to attract Tit species in particular, whereas cheese can be fed if the Blackbird is a desired visitor. This information can be useful for the enjoyment of individual garden owners, but also be useful for conservation when using supplementary feeding to increase biodiversity in urban areas.

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Table 1. Nutritional content for 100 g of unsalted peanuts, mild cheddar and white bread, used for bird feeding. Nutritional data from SELF Nutrition Data; http://nutritiondata.self.com.

	Peanuts (unsalted)	Mild cheddar	White bread
Energy, kcal	567	403	266
Protein, g	25.8	24.9	7.6
Fat, total lipid, g	49.2	33.1	3.3
Carbohydrate, g	16.1	1.3	50.6
Fibre, total dietary, g	8.5	0	2.4
Sugars, total, g	4	0.5	4.3
Calcium, mg	92	721	151
Magnesium, mg	168	28	23
Phosphorous, mg	376	512	99

Figure legends

Figure 1. Probability estimates for observing a bird of any species at a table with each of the food types. Back-transformed estimates from the output of the GLMM model, presented with +/- 1 standard error.

Figure 2. Probability estimates for observing a a) Great Tit, b) Blue Tit, c) Robin, d) Dunnock and e) Blackbird at a table with each of the food types. Back-transformed estimates from the output of the GLMM models, presented with +/- 1 standard error.

Figure 3.

Estimates of species richness for each of the food types. Back-transformed estimates from the GLMM model, presented with +/- 1 standard error.

Figure 4. Mass of food consumed in grams during each observation session, for each of the three food types. The bold line shows the median value, the boxes show first and third quartile, and whiskers show the extreme data still within 1.5 IQR of the lower/upper quartile.

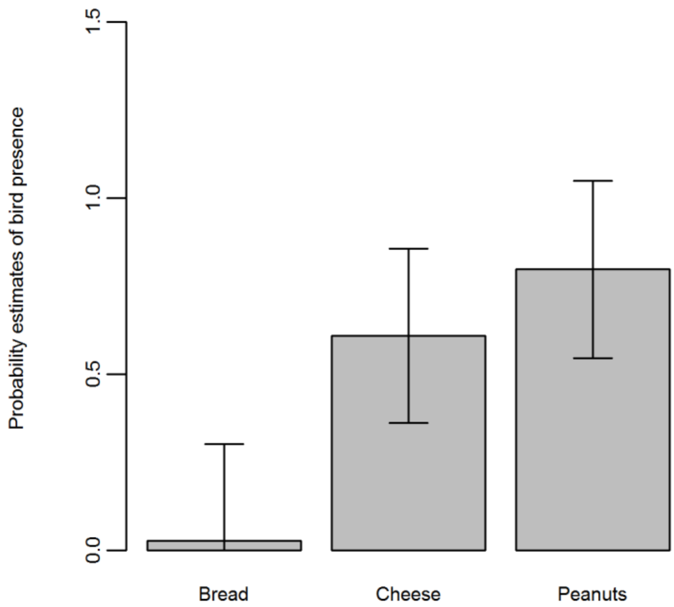
Probability estimates of bird presence
0.0
0.5
1.0
1.5
Bread
Cheese
Peanuts

Figure 1

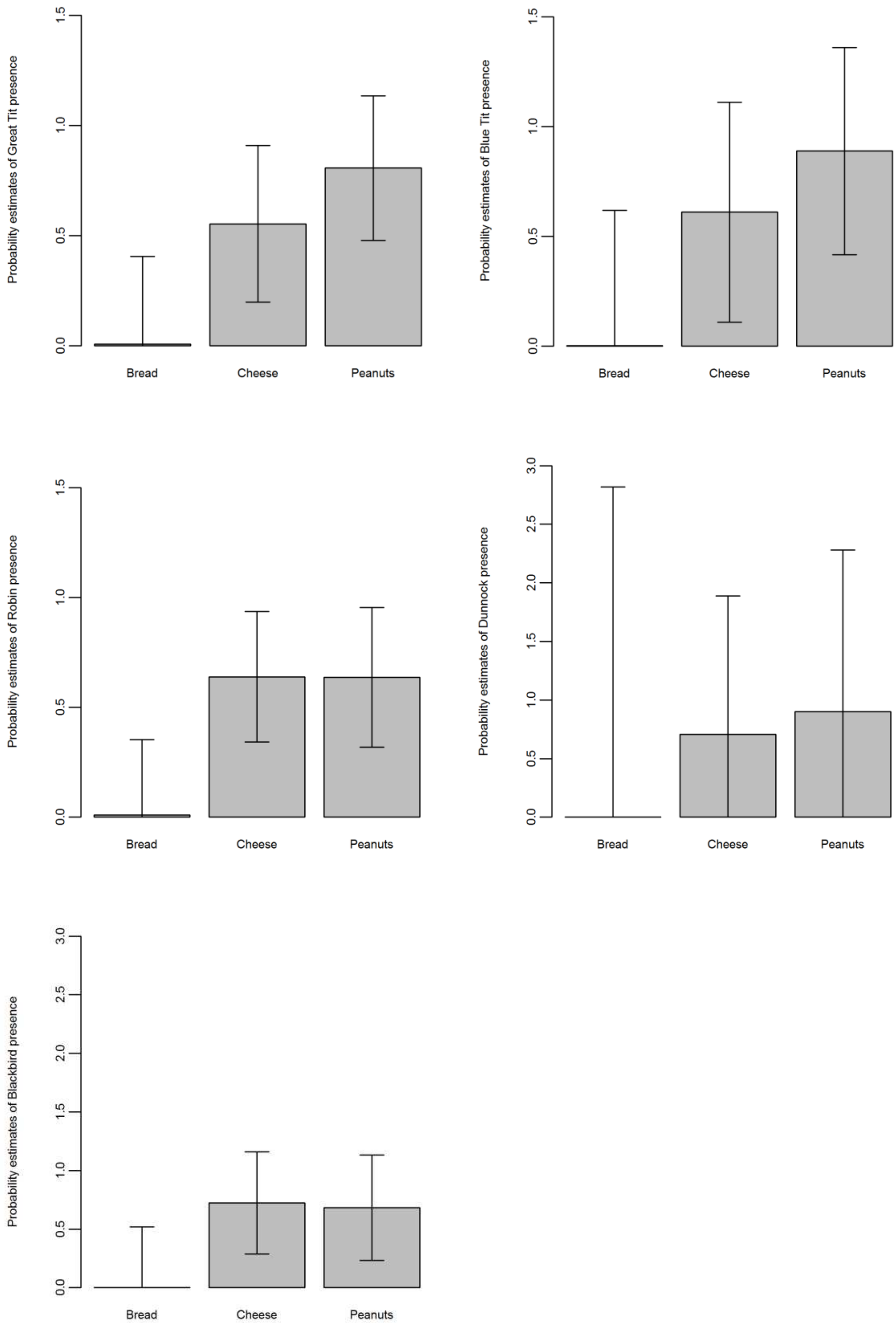
Probability estimates of Great Tit presence
0.0
0.5
1.0
1.5
Bread
Cheese
Peanuts
Probability estimates of Blue Tit presence
0.0
0.5
1.0
1.5
Bread
Cheese
Peanuts
Probability estimates of Robin presence
0.0
0.5
1.0
1.5
Bread
Cheese
Peanuts
Probability estimates of Dunnock presence
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Bread
Cheese
Peanuts
Probability estimates of Blackbird presence
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Bread
Cheese
Peanuts

Figure 2

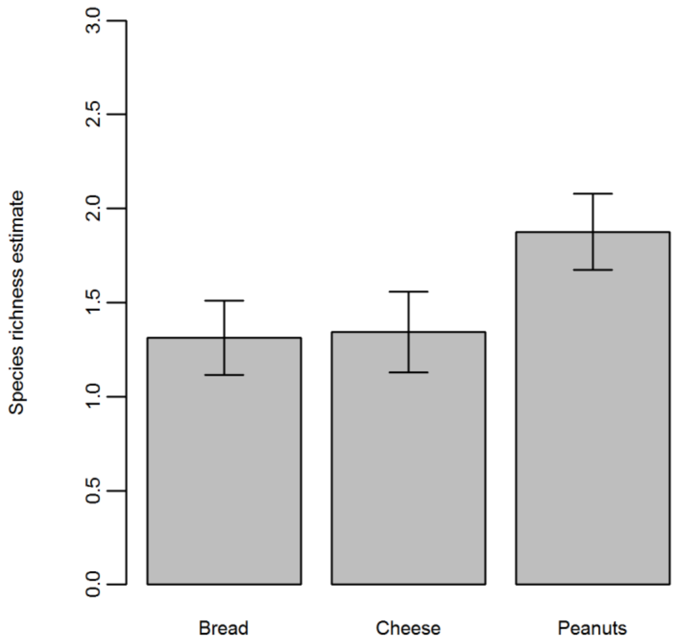
Species richness estimate
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Bread
Cheese
Peanuts

Figure 3