An improved type of wire cage for the study of parental feeding behaviour in hole-nesting passerines

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Several techniques have been used to record details of feeding ecology in altricial birds. However, they often fail to provide the number, identity and size of prey, and/or the relative contribution of males and females. We designed and tested a handmade wire cage for filming nests in nest boxes (or natural holes) that allowed us to accurately (1) determine the sex and relative contribution of each parent and (2) identify each prey item and its size in a Great Tit *Parus major* population. The sex of adults was recorded successfully for all entries into the nest. The rate at which parents brought food and prey sizes were within the range obtained with other techniques in the same area. None of the nests were deserted and no detrimental effects on chick weight were found. A number of advantages compared to a previous design are discussed.

Key words: Great Tit, *Parus major*, parental feeding behaviour, orange groves, Sagunto.

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A number of different methods including direct behavioural observations (Karlsson 1994), automatic recorders (Kluijver 1950), video recording (Blondel *et al*. 1991), radiotelemetry (Licht *et al*. 1989) and passive integrated transponders (González-Solís *et al*. 2000) have been used in the past to assess parental feeding behaviour in birds. To register simultaneously the number and type of prey delivered to nestlings, however, requires direct observation or video recording (Barba & Monrós 1999). In species that readily occupy nest boxes filming can be done either from inside or outside the box: inside filming implies modifying the nest box to accommodate a video camera and to ensure adequate light conditions, which limits the number of nest boxes that can be filmed (Blondel *et al*. 1991). On the other hand, filming from outside does not require significant modifications to the nest box itself and many different nests can be recorded at once (see Currie *et al*. 1996). However, filming from outside may not always be suitable (e.g. in studies of nest predation rates) because the camera equipment may affect the behaviour of predators (Richardson *et al.* 2009).

A video camera placed outside a nest box does not usually allow the prey types brought to nestlings to be identified because adults tend to enter the box too fast. Currie *et al*. (1996) solved this problem by building a wire structure that momentarily stopped birds (Great Tits *Parus major* and Blue Tits *Cyanistes caeruleus*) before they entered the nest box, thereby allowing more time for observers to identify prey. This structure, however, had some disadvantages: (1) it only permitted filming from one direction, which may be a problem in unsuitable light conditions and (2) was inappropriate for identifying the sex of the parents since Currie *et al.* (1996) had to trap and mark birds prior to filming.

Our objective thus was to design a cage that would allow the prey brought to nestlings, the sex of the adults, and the rate at which parents visited the nest to be accurately identified and measured. We tested the performance of our cage by filming nesting Great Tits, a species for which previous data of nestling diet and feeding rates were available for the study area (Barba & Gil-Delgado 1990, Barba *et al.* 2009).

Material and methods

Our study site was an extensive orange plantation in Sagunto, eastern Spain (39°42'N, 0°15'W, 30 m a.s.l.). Wooden nest boxes available for Great Tits (e.g. Andreu & Barba 2006) were visited to assess laying dates (assuming that one egg was laid per day), clutch size and hatching dates (with visits every day or every other day around the expected hatching dates) as a means of determining a schedule for filming each nest. We filmed when nestlings were 10 days old (hatching date was day 0) since nestling age may affect parental feeding behaviour (Barba *et al.* 2009). Nestling weights were measured at day 14 using an electronic balance (± 0.1 g).

We hand-built 7.8 x 7.8 x 14.3 cm wire cages (1 mm thick, 1.1 cm mesh) with a front entrance to which we attached a wooden perch (6-cm long, Figure 1a). The cage had small wire 'wings' that were attached to the nest box with an elastic strap using the metal part of clothes peg as a hook, thereby keeping the cage in place (Figure 1b). The main difference between our cage and that of Currie *et al.* (1996) was that ours was designed to be attached to the front of the nest box so that the entrance was perpendicular to the direction of filming. Another important element was a wire 'fence' that we added to the cage entrance, which was one third of the height of the structure and kept birds on the perch (Figure 1a), thereby allowing for more observation time for sex determination and the identification and measurement of prey items. We strapped cages onto the nest boxes 2-4 days before filming so that birds could get used to them and removed them after filming.

During 2005 and 2006 breeding seasons, we used video cameras (Sony DCR-DVD 203), which were placed on a tripod about 1 m from the nest a couple of hours prior to filming. Each nest was filmed for about 1 hour and the recordings were played and analyzed frame-by-frame on a computer. For each visit, we recorded the time when the parent entered and left the nest box, the sex of the parent, and prey type and size. The hourly provisioning rate was calculated by dividing the number of visits by the time elapsed from the first visit to the end of the filming separately for both the total number of visits and for each sex. If the time and angle of observation is adequate, the width of the black breast patch (tie) and the black neck-band, both of which are narrower in females (Cramp & Perrins 1993), can be used for sex identification. We measured the size of prey (length and width, ignoring appendages) using graph paper on a

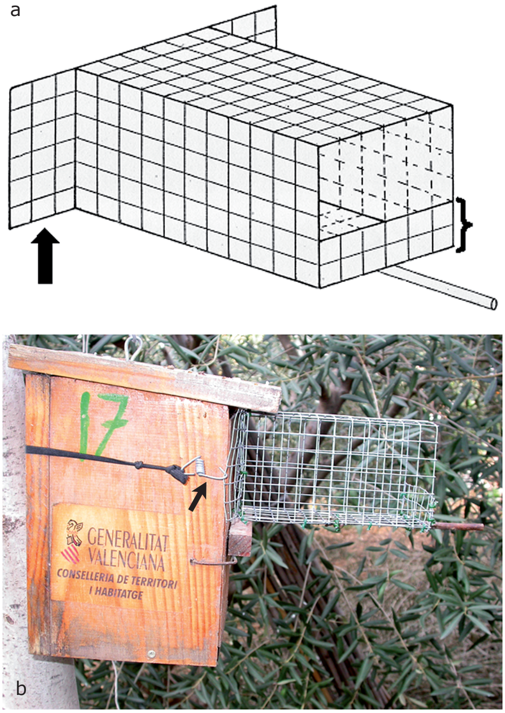

Figure 1. Front-lateral view (a) of the wire cage used for filming Great Tits. The arrow shows one of two 'wings'. The bracket gives an idea of the height of the fence. Fig. 1b. shows the cage attached on the front of the nest box. The arrow shows the cloth peg used to attach the cage to the nest box.

(a) Visió frontolateral de l'estructura metàl·lica emprada per filmar les Mallerengues Carboneres. La fletxa mostra una de les dues "ales" de l'estructura metàl·lica. El claudàtor dóna una idea sobre l'altura de la tanca. (b) Aspecte de l'estructura metàl·lica col·locada en una caixa niu. La fletxa mostra el ganxo emprat per fixar l'estructura a la part frontal de la caixa niu.

computer screen. The mean bill length of this Great Tit population (mean 11.94 mm, SD 0.78, $n = 17$; authors' unpublished data) was used to scale prey measurements on the screen. Only the measurements for the main prey items brought to nests are reported here.

The percentage of visits of each sex to the nest and the percentage of prey items brought by each sex were analyzed with tests based on χ^2 values. The possible effects of the absence of one or both members of the pair feeding the chicks were tested using an ANCOVA, with brood size and hatching date as covariates, and year as fixed factor.

Table 1. Percentage of prey brought by males (n = 73) and females (n = 85).
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	Male	Female
Lepidoptera (adult)	67.12	48.24
Lepidoptera (larvae)	16.44	17.65
Pupae	4.11	3.53
Spiders	2.74	4.71
Coleoptera	0.00	1.18
Hymenoptera	1.37	16.47
Miriapoda	0.00	1.18
Pieces of orange	6.85	2.35
Not identified	1.37	4.71

Results

In ten out of the 28 nests filmed both adults entered the box during the filming period. In 14 nests only one member of the pair entered and there was no significant tendency for it to be either the male (43% of nests) or the female (57% of nests; $\chi^2_{0.05,1} = 0.29$; $p > 0.05$). Neither of the adults entered in the remaining four nests. All sampled nests were successful (i.e. at least one chick fledged). On the basis of plumage dimorphism, the sexes were identified successfully in 100% of the entries for all nests in which at least one adult entered.

Since for some nests we only had data for the male or the female we checked whether prey types brought to the nest differed between sexes at the ten nests for which we had data for both parents. There were no differences in the percentage of the two main prey types brought by males or females ($\chi^2_{0.05,1} = 0.66$; $p = 0.414$; Table 1) and so we were able to use data from all nests in diet analyses. For those ten nests, the hourly provisioning rate was 12.70 visits·h^{-1} (SD 4.03) and when only one member of the pair entered, this rate was 7.39 visits·h^{-1} (SD 3.73). Feeding rates for each sex did not vary (females 5.22 visits·h^{-1}, SD 2.76; males 7.05 visits·h^{-1}, SD 4.74) between nest boxes in which either one or both members of the pair entered, and the interaction was also non-significant ($p > 0.05$). The time elapsed between the installation of the camera and the first visit by a parent was 11.39 min (SD 4.74), showing that birds became quickly accustomed to its presence.

Of 158 prey items observed at the 24 nest boxes, 56.9% were moths (adult nocturnal Lepidoptera), 17.1% caterpillars, 3.8% pupae, 3.8% spiders and 15.2% other prey, including Coleoptera, Hymenoptera, Miriapoda and pieces of oranges (see Table 1). We failed to identify only 3.2% of the prey items. All identified prey items were measured and data on the main prey types are shown in Table 2.

There were no differences in the nestling weight in the nests in which both parents entered and those in which only one or none entered during the filming period (ANCOVA: $F_{1,21} = 0.20$, $p = 0.659$, brood size (covariate):

Table 2. Measurements (length and width) of the main prey types delivered by parents to ten-day-old Great Tit nestlings.
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	Length (mm)		Width (mm)		
	Mean	SE	Mean	SE	n
Lepidoptera (adult)	22.44	0.68	4.27	0.37	89
Lepidoptera (larvae)	19.12	1.58	4.11	0.47	27
Pupae	14.56	3.43	5.24	1.46	6
Spiders	10.87	4.44	2.37	0.93	6

$F_{1,21}$ = 0.02, p = 0.969, hatching date (covariate): $F_{1,21}$ = 0.06, p = 0.816, year: $F_{1,21}$ = 0.31, p = 0.583). Additionally, mean nestling weight was similar in filmed to that of unfilmed nest boxes (ANCOVA: $F_{1,35}$ = 0.02, p = 0.901, brood size (covariate): $F_{1,35}$ = 0.03, p = 0.856, hatching date (covariate): $F_{1,35}$ = 0.10, p = 0.749, year: $F_{1,35}$ = 0.09, p = 0.762).

Discussion

Because the study site was open to the public, we could not leave the video camera (or even a tripod with a dummy camera) unattended for any length of time before filming as a means of allowing birds to get used to its presence; this may have caused some birds to refuse to enter the nest box during the filming period. We based this conclusion on two facts. Firstly, wire cages were placed on nest boxes a couple of days before filming and so if one or both parents had avoided entering the nest during this period we would expect to have detected detrimental effects on the nestling weight. However, no significant differences were observed on nestling weight between nests and no nest box was deserted. Secondly, as part of another study, we attempted to trap both parents at the nest box a few days after filming and in 98% (n = 56 individuals) of the cases both the male and the female were trapped, thus indicating that neither had abandoned the brood as a consequence of the wire structure. As well, the hourly provisioning rate obtained with the video cameras at the nests in which both parents were feeding was within the range of that registered in another study of the same population where we used mechanical counters (12-16 visits per hour; Barba *et al.* 2009). Thus, the rate of visits to the boxes was seemingly unaffected by the wire structure.

The sex of the bird entering the nest box could be determined in all cases on the basis of plumage dimorphism. This is very advantageous and meant that trapping and marking birds prior to filming, as reported by Currie *et al.* (1996), was not necessary. In those nests in which both parents entered, their contribution in terms of feeding visits and prey types was similar and in accordance with that expected in monogamous birds (Perrins 1979).

Nestling diet and prey size obtained with the video cameras agreed with those previously reported for this population using neck collars (see e.g. Barba & Gil-Delgado 1990, Iglesias *et al.* 1993). Barba & Gil-Delgado (1990) studied the whole breeding season and included prey brought to nestlings of different ages (2-13 days old) in contrast with our study, in which all nestlings sampled were 10 days old and only from first clutches. Nevertheless, both studies agree that moths were the most abundant prey (50% in Barba & Gil-Delgado 1990, 57% here), followed by caterpillars (24% vs. 17%). We also identified here other prey items such as pupae, spiders and even pieces of orange that also appear in the study by Barba & Gil-Delgado (1990), even though our sample size was much lower (158 vs. 566 prey items) and more restricted in terms of time and range of nestling ages. We therefore conclude that the results obtained with the video cameras provide a good overview of nestling diet in these Great Tits since most items were successfully identified.

Previous data on prey size in this population consisted only of caterpillar length (mean 18.5 mm, SD 4.10 mm, n = 118; Iglesias *et al.* 1993). The mean caterpillar length found here (Table 2) did not differ from that previously found (t_{145} = 0.57, p > 0.05). Measurements of the rest of the prey items were within the range reported for other habitats (Cramp & Perrins 1993; see also Monrós *et al.* 1997). We therefore conclude that this method allows accurate prey measurements to be made.

Further advantages of the wire cage used here include the fact that (a) it is easy to move from one nest box to another, thereby allowing a number of nest boxes to be sampled without any prior preparation or modification, that (b) filming could be done from both sides of the box, and that (c) because of the elastic strap the cage may be easily adapted for use on natural tree cavities. That filming could be done from both sides of the box is important for obtaining good quality films, since we were able to choose the direction of filming when we placed the camera once birds had got used to the wire structure. This allowed us to make a better use of the light conditions at the time of filming. The wire cage design used by Currie *et al.* (1996) established the direction of filming once the cage was placed on the nest box at least one day before filming and there were problems with prey identification when birds entered opposite the camera. Other factors may make our device even more attractive for future studies. Firstly, the material used is cheap and it does not require much time to make the cages and as many as necessary can be built without problems of cost. Secondly, the design of the cage prevents small mammals reaching either the adults or chicks from outside the nest box. Thirdly, this type of cage may be used for other hole nesters and indeed we have used it (authors' unpublished data) on the nests of Coal Tits *Periparus ater*, Crested Tits *Lophophanes cristatus* and Blue Tits *Cyanistes caeruleus* breeding in Aleppo Pine *Pinus halepensis* and Holm Oak *Quercus ilex* forests and have found no effects on parental behaviour.

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Resum

Una estructura metàl·lica per estudiar l'alimentació parental en passeriformes que nien en cavitats

Hi ha diferents tècniques per enregistrar l'ecologia tròfica en aus nidícoles, però sovint fracassen a l'hora d'identificar les preses i mesurar-ne la seva mida amb precisió. En aquest estudi es mostra el disseny i aplicació d'una estructura metàl·lica per a la filmació de nius de la Mallerenga Carbonera *Parus major* que permet (1) identificar el sexe dels individus adults, la seva contribució relativa a l'alimentació dels polls, i (2) la identificació del tipus i mida de les preses. El sexe fou identificat en tots els casos. La taxa de becada i la mida de les preses es va situar dins de l'interval obtingut mitjançant d'altres tècniques a la mateixa població. No hi va haver abandonament en cap dels nius on es va provar l'estructura metàl·lica ni tampoc efectes sobre la condició corporal dels polls, fets que suggereixen que les mallerengues s'acostumen perfectament a l'estructura dissenyada. Es discuteixen els avantatges sobre d'altres dissenys previs.

Resumen

Una estructura metàlica para estudiar la alimentación parental en paseriformes que nidifican en cavidades

Existen diferentes técnicas para el estudio de la ecología alimenticia en aves nidícolas que, sin embargo, fallan a la hora de identificar y medir las presas con precisión. En este estudio se muestra el diseño y aplicación de una estructura metálica para la filmación de nidos de Carbonero Común *Parus major* que permite (1) identificar el sexo de los individuos adultos, su contribución relativa al aprovisionamiento de los pollos, y (2) la identificación del tipo y medida del tamaño de las presas. El sexo se identificó en todos los casos. La tasa de ceba y el tamaño de las presas estuvieron dentro del rango normal obtenido mediante otras técnicas utilizadas previamente en la misma población. No hubo abandono en ninguno de los nidos en donde se probó la estructura metálica, ni tampoco hubo efectos sobre la condición corporal de los pollos, lo que sugiere que los carboneros se habitúan perfectamente a la estructura diseñada. Se discuten las ventajas del nuevo diseño creado sobre diseños previos.

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