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WINTER DIET OF SOUTHERN BOOBOOKS *Ninox novaeseelandiae* IN CANBERRA 1997–2005

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There are few studies of Southern Boobook *Ninox novaeseelandiae* diet and only two major studies of winter (non-breeding) diet. In this analysis of winter diet in the Australian Capital Territory, Australia, prey remains and pellets were gathered from five adult males and five adult females wintering in nature parks and Canberra suburbs during 1997–2005. The study generated 496 prey items: 167 mammals, 33 birds, 0 reptiles, and 296 invertebrates. The analysis adds one new prey species to the known diet: Red-rumped Parrot *Psephotus haematonotus*. We compared our results to those from two other major studies of non-breeding diet from other areas, and one study of breeding diet from the same area. The diet in this study was similar to that found in a Victorian study also based on pellets, with the highest percentage of the biomass coming from vertebrates, but differed from a South Australian study based on gizzard contents, and from reviews of the literature that described Southern Boobooks as mainly insectivorous. These differences in results may relate to different methods of collection and analysis, and the misconception that Southern Boobooks are small owls.

INTRODUCTION

The Southern Boobook is the smallest of the eight owl species (four *Tyto* and four *Ninox*) that breed on mainland Australia (Pizzey and Knight, 2007). Although Olsen (1999) described the Southern Boobook as a small owl, 25–36 centimetres, with males *circa* 250 grams, and females *circa* 315 grams, the slightly smaller Brown Hawk-owl *Ninox scutulata,* 27–33 centimetres and 172–227 grams was described as a medium-sized owl. Olsen *et al.* (2006) argued that Australia has no small owls (defined here as 100 g or smaller), only medium-sized or large owls. For example, the recently discovered Little Sumba Hawk Owl *Ninox sumbaensis* from Indonesia, at 90 grams, is the smallest in mass for a *Ninox* (Olsen, Wink, Sauer-Gurth and Trost 2002). The Common Scops Owl *Otus scops* of Eurasia (mean 93 g) (Mikkola 1983), and the Elf Owl *Micrathene whitneyi* (mean 41 g) of North America are, respectively, about a third and a fifth the weight of Southern Boobooks, while Northern Hawk-owls S*urnia ulula* (male mean 282 g; female 324 g) and Long-eared Owls *Asio otus* (male mean 245 g; female mean 279 g) weigh about the same as Southern Boobooks and are described as medium-sized owls (Johnsgard 1988).

In studies of raptors mean predator weight has been positively correlated with prey size (Olsen *et al.* 2006; Kruger 2000; Newton 1979). Though Southern Boobooks are similar in mass to mammal specialists such as Northern Hawk-owls and Long-eared Owls, they are reported in Olsen (1999) to be mainly insectivorous. In contrast, Higgins (1999) stated that Southern Boobooks preyed mainly on birds and mammals. McNabb (2002) and Fitzsimons and Rose (2007) said they preyed mainly on mammals in Victoria. Some of the differences may relate to a misconception of Southern Boobooks as small owls, but also to methods of prey analysis, and methods of collecting prey remains e.g. from gizzard contents or estimating diet mainly from prey remains and pellets (see Marti 1987). Penck and Queale (2002) analysed gizzard contents from window-strike casualties and road-kills in South Australia, whereas McNabb (2002) collected pellets from roosts in southern Victoria. Penck and Queale found that invertebrates dominated in the non-breeding diet, whereas McNabb found that vertebrates dominated.

During the breeding season in the Australian Capital Territory (ACT) Southern Boobooks tend to hunt in woodland and forest (Olsen *et al*. 2006). In the non-breeding (autumn/winter) season some Southern Boobooks, which breed in nature parks in the ACT, move into suburban areas to live and hunt (Olsen, Trost and Hayes 2002; Olsen and Taylor 2001). Although Olsen *et al.* (2006) described the breeding diet of Southern Boobooks in the ACT, there is no published analysis of winter diet for the ACT. Here we present data on the non-breeding diet of ten Southern Boobooks wintering in Canberra (5 females and 5 males), and compare the results to two major studies on the non-breeding diet (McNabb 2002; Penck and Queale 2002), and a study of the breeding diet from the ACT (Olsen *et al.* 2006).

STUDY AREA AND METHODS

We collected pellets and prey remains from nine Southern Boobook roosts inside the Canberra city limits: four with single females, four with single males, and one with a pair. Five roosts were in Canberra nature parks and four roosts in suburbs.

Five of the owls were trapped using wire bal-cha-tri traps (Olsen and Woollard 1975) baited with a House Mouse *Mus musculus*, a noose mounted on the end of a surf-casting rod, and fishing nets on extended poles. The adults were sexed (Olsen and Trost 1997), fitted with a stainless steel, numbered Australian Bird and Bat Banding Scheme band, and a plastic colour-band sealed with 'Super Glue' (n = 5 adults) or with coloured aluminium bands attached with two rivets. They were fitted with back-pack style Sirtrack single-stage transmitters attached to a string harness with a weak link designed to break if the bird became entangled by its transmitter and harness (Karl and Clout 1987). Radios weighed 5.4 grams and harnesses 1.0 grams, making 6.4 grams on a 270 gram male (2.4% of body weight) and on a 340 gram female (1.9% of body weight). The batteries lasted 10 to 12 months.

Study area

The study area was located in the Australian Capital Territory.

Canberra Nature Parks Roosts.

Except for the grazing land, the area was primarily open forest and tall woodland, with dominants of Scribbly Gum *Eucalyptus rossii*, Brittle Gum *E. mannifera*, Red Stringybark *E. macrorhyncha*, Blakely's Red Gum *E. blakelyi* woodland with Red Box *E. polyanthemos* and Yellow Box *E. melliodora* in more open areas (NCDC 1988). The understorey had abundant tussock grasses (*Poa* spp.), with the shrub *Cassinia longifolia* dominating areas that were more open. Wildfire had been largely absent and a regime of prescription fires had created a mosaic effect on the understorey. The nearby suburbs of Cook and Aranda had retained a significant element of eucalypt overstorey of large Brittle Gums and Yellow Box with a mix of native and non-native understorey elements along roadsides, bushland corridors, and backyards. A common tree in all areas was the Native Cherry *Exocarpus cupressiformis*, which contained dense foliage that was favoured as daytime roosts by the owls.

Suburban-based Roosts.

One pair was located in a backyard in Melba. One female was in a front yard in Weston, one female in a school playground in Kaleen, and one female in suburban Barton, which included a combination of offices, a school, and residential property (see Olsen and Taylor 2001).

Collections

We searched for roosting owls during the non-breeding season, defined here as 1 March to 1 October, when adult females often leave the breeding territory for a separate winter home range, but males remain in their breeding territories (see Olsen and Trost 1997; Olsen, Trost and Hayes 2002; Olsen and Trost 2003). Thirty minutes before dusk we located the owls by radio receiver, or from previous knowledge of the roost and, if it did not disturb the owls, collected regurgitated pellets and prey remains from under the roost in daylight. If there was any danger of flushing the owls, we waited until the owls left the roost then searched the ground by torch. Pellets from the Weston roost were collected by the house-holders. A total of 229 regurgitated pellets was collected between 1 March to 1 October each year from 1997 and 2005 (see Olsen, Trost and Hayes 2002).

Prey analysis

ABR identified prey from pellets and prey remains, counting body parts to estimate the minimum number of prey items (MNI) in a pooled sample of pellets and prey remains, in order to minimise biases in the food estimations (Collopy 1983; Marti 1987; Seguin *et al.* 1998; Simmons *et al.* 1991). We did not assume that one pellet represented one individual prey item. Collected materials were then sorted and analysed in the laboratory by ABR. Feathers were identified by comparison with feather collections and museum specimens when necessary. Bones, hair, and scales were identified by microscopy (following Brunner and Coman (1974) for mammalian hair) and by comparison with museum reference material.

We calculated the numeric frequency and biomass of prey items, and compared the proportion of vertebrate to invertebrate prey for two seasons (autumn versus winter) using Chi-square tests (Zar 1984). These results were compared to two studies of non-breeding Southern Boobook diet: the numeric frequencies from Penck and Queale (2002) in South Australia, based on analysis of gizzard contents, and the biomass estimates from McNabb (2002), based on regurgitated pellets collected in the Dandenong Ranges in Victoria.

RESULTS

Just over half the Southern Boobook prey items (n=496, Table 1) were invertebrates (n=296, 59.7%). Of the invertebrates, wolf spiders (n=73, 14.7%), grasshoppers (Order Orthoptera, n=47, 9.5%), and lepidopterans (n=44, 8.9%) were the most abundant. However, vertebrates provided 97.2 per cent of the total biomass. Mammals contributed 61.1 per cent. The dominant mammal was the House Mouse (n=154, 40.6% of biomass). Birds provided 36.1 per cent, of which most were Common Starlings *Sturnus vulgaris* (n=12, 17.1% of biomass). Invertebrates provided only 2.8 per cent (n=296) of the total biomass.

There was a difference in diet between autumn and winter, with a higher proportion of vertebrates in winter (Table 2). In autumn the diet by number consisted of 25.4 per cent (n=80) vertebrates and 74.6 per cent (n=235) invertebrates, compared to 66.3 per cent (n=120) vertebrates and 33.7 per cent (n=61) invertebrates in winter (χ^2 = 78.22; p<0.0001).

Although Penck and Queale (2002) did not statistically compare their autumn and winter food (gizzard contents), a Chi-square analysis of data extracted from their Table 1 showed no significant difference between the number of vertebrates and invertebrates by number for these two seasons (χ^2 = 3.45, p=0.06). When the results of our study are compared to Penck and Queale (2002) there was a difference between the two studies in the number of vertebrate and invertebrate prey items for each season (Table 2). For autumn, this study reported 25.4 per cent vertebrates, whereas Penck and Queale reported 9.5 per cent, and for winter, this study reported 66.3 per cent vertebrates, compared to 5.1 per cent in Penck and Queale (Table 2).

No specific numbers were given for vertebrate versus invertebrate prey in McNabb (2002). However, a broad comparison of the combined autumn/winter diet in this study and that found by McNabb (2002), based on estimated percentages of biomass in his graphs showed a difference in the contribution of invertebrates and vertebrates; 2.8 per cent invertebrates in this study, 4.2 per cent in McNabb (Table 3). There was also a difference in the biomass contribution for mammals: 61.1 per cent in this study, 81.8 per cent in McNabb, and for birds, 36.1 per cent in this study, 13.1 per cent in McNabb.

The percentage of biomass contribution from vertebrates and invertebrates in this study was similar to that reported from the same area, Black Mountain and Aranda Bushland, during the breeding seasons in 1993–1994 (Olsen *et al.* 2006) (97.2% vertebrates versus 95.1%, respectively).

TABLE 1

Number (n) and percentage of prey items and biomass from nine Southern Boobook roosts 1997-2005.

PREY SPECIES		Weight (g)	n	% by Number	% by Mass
MAMMALS					
House Mouse [i]	*Mus musculus*	18	83	16.7	28.4
House Mouse (juvenile)	*Mus musculus*	9	71	14.3	12.1
Black Rat	*Rattus rattus*	180	3	0.6	10.3
Black Rat (juvenile)	*Rattus rattus*	50	8	1.6	7.6
Bush Rat	*Rattus fuscipes*	125	1	0.2	2.4
Gould's Wattled Bat	*Chalinolobus gouldii*	14	1	0.2	0.3
Subtotal			**167**	**33.6**	**61.1**
BIRDS					
Red-rumped Parrot[n]	*Psephotus haematonotus*	61	1	0.2	1.2
White-browed Babbler	*Pomatostomus superciliosus*	39	1	0.2	0.7
Red-browed Finch	*Neochmia temporalis*	11	6	1.2	1.3
House Sparrow	*Passer domesticus*	27	5	1.0	2.6
Common Myna	*Acridotheres tristis*	116	3	0.6	6.6
Common Blackbird	*Turdus merula*	95	1	0.2	1.8
Common Starling [i]	*Sturnus vulgaris*	75	12	2.5	17.1
Birds undetermined		63	4	0.8	4.8
Subtotal			**33**	**6.7**	**36.1**
INVERTEBRATES					
Huntsmen Spider	Heteropdidae	0.5	14	2.8	0.13
Wolf Spider	Araneae. Lycosidae	0.5	73	14.8	0.7
Spider undetermined	Fam. Aranaea	0.5	11	2.2	0.1
Grasshopper	Order Orthoptera	0.5	47	9.5	0.44
Locust	Order Orthoptera	0.5	7	1.4	0.07
Cricket	Order Orthoptera	0.5	8	1.6	0.08
Gryllids	Order Orthoptera	0.5	6	1.2	0.06
Phoracantha semipunctata	Cerambycidae	0.5	18	3.6	0.17
Longicorn Beetle	Cerambycidae	0.5	4	0.8	0.04
Scarab Beetles	Fam. Scarabaeidae	0.5	4	0.8	0.04
Weevil	Curculionidae	0.5	1	0.2	0.01
Other Beetles undetermined	Order Coleopter	0.5	41	8.3	0.4
Cockroach	Blattodea	0.5	9	1.8	0.08
Moth undetermined	Order Lepidoptera	0.5	44	8.9	0.4
Insects undetermined		0.5	9	1.8	0.08
Subtotal			**296**	**59.7**	**2.8**
TOTAL			**496**	**100**	**100**

[i] Introduced species.

[n] Species not previously reported (Higgins 1999; Penck and Queale 2002; McNabb 2002).

TABLE 2

Comparison of diet for autumn versus winter, based on number of prey items from pellets (this study) and gizzard contents (Penck and Queale 2002). Results from differences between the number of vertebrate and invertebrate prey items for autumn and winter are: Penck and Queale χ^2 3.45 p = 0.06 ns; this study χ^2 78.22 p.<0.001.

Prey Items	This Study n = 496		Penck and Queale (2002) n = 558	
	Autumn	Winter	Autumn	Winter
Mammal	23.5%	51.4%	7.6%	2.7%
	(n=74)	(n=93)	(n=20)	(n=8)
Bird	1.9%	14.9%	1.1%	2.4%
	(n=6)	(n=27)	(n=3)	(n=7)
Reptile	0.0%	0.0%	0.8%	0.0%
	(n=0)	(n=0)	(n=2)	(n=0)
% Total vertebrates	25.4%	66.3%	9.5%	5.1%
	(n=80)	(n=120)	(n=25)	(n=15)
% Total invertebrates	74.6%	33.7%	90.5%	94.9%
	(n=235)	(n=61)	(n=238)	(n=280)
Total prey items	n=315	n=181	n=263	n=295

In this study, there was a difference in the relative biomass contributions for mammals and birds for those owls that roosted in suburban areas compared to those that roosted in forest/woodland. Mammals contributed 65.8 per cent and birds 34.2 per cent for owls roosting in the suburbs, compared with 26 per cent mammals and 74 per cent birds for owls roosting in forest/woodland.

DISCUSSION

Our results differ from those of Penck and Queale (2002), and statements made by Olsen (1999) that the Southern Boobook is mainly insectivorous, but are similar to Higgins (1999), König *et al.* (1999) and McNabb (2002) who reported that Southern Boobooks preyed mainly on birds and mammals, not insects. Penck and Queale's (2002) analysis of gizzard contents found that Southern Boobooks in the non-breeding season ate mainly invertebrates.

Some of the differences found in different studies and reviews may relate to the methods of prey collection, and analysis. Our study, and McNabb (2002) estimated diet from prey remains and pellets. In contrast, Penck and Queale (2002) analysed gizzard contents in South Australia, mainly road-kills and window-strikes. They concluded that invertebrates made up 95.9 per cent of the diet (90.5% in autumn and 94.9% in winter), and that estimates from pellets alone might underestimate the invertebrates that had no hard, indigestible parts to persist in castings. Rose (1996) analysed both gizzard contents and pellets from Southern Boobooks and found proportionally more invertebrates in the gizzards, and proportionally more vertebrates in the pellets. He argued that pellets comprised of invertebrates may not reflect numbers of invertebrates because these pellets break down more quickly, but gizzard contents may not reflect numbers of vertebrates caught by breeding owls because samples of Boobook gizzards from road-kills and window-strikes probably come mainly from juveniles forced into marginal areas. These owls are more at risk of mortality through collision, and they eat proportionally more invertebrates compared to breeding adults (Rose 1973; Olsen *et al.* 2006). The majority of the owls in this study were owls that we knew were successful breeders, holding territories, breeding before the winter season when we collected pellets and prey remains.

Our field observations support this argument. Breeding adults brought birds, reptiles, and mammals to the nest, and to fledged broods, but fledged owls, after they reached independence, only hunted invertebrates (S. Trost and J. Olsen unpubl. data). Photographic evidence of prey brought to nestlings and fledglings during 2002–03 showed that certain soft-bodied invertebrates, like caterpillars did not show in subsequent analysis of castings, but soft-bodied vertebrates, like geckos, or larger vertebrates like rosellas, did not show either (Trost, Olsen and Rose unpubl. data). Both the analysis of gizzards from vehicle and collision-killed owls, and analysis of castings and prey remains from breeding owls, have biases, but most evidence, for example, this study, and McNabb (2002), shows that the winter (non-breeding) diet of Southern Boobooks in south-eastern Australia is, by biomass, primarily vertebrates, particularly birds and mammals, not insects as suggested by Olsen (1999).

Although we found species of spider in this study to be the largest category of invertebrates, and McNabb (2002) did not report spiders, McNabb did not search specifically for them. A separate analysis of winter diet from the Dandenong Ranges analysed by an invertebrate specialist may show they take spiders.

TABLE 3

Comparison with McNabb (2002) of percentage dietary biomass (based on pellets) for autumn and winter. Note: the McNabb figures have been based on estimates from the graphs of biomass for three sites.

Prey items	This Study n = 229	McNabb (2002) n = 113
Mannal	61.1%	81.8%
Bird	36.1%	13.1%
Invertebrate	2.8%	4.2%

n = number of pellets

Further studies need to be done, comparing the breeding and non-breeding diets of Southern Boobooks to determine if these patterns are the rule. The comparison of the breeding season diet of owls from the same area (Olsen *et al.* 2006) showed no difference in vertebrates and invertebrates. The data support the conclusion that these owls are not predominantly insectivorous.

An analysis of the vertebrate prey in the diet showed that females that wintered in suburban areas had a higher percentage of biomass from mammals (particularly mice and rats), whereas males and females wintering in forest/woodland showed a higher percentage of biomass from birds. It is possible that female Southern Boobooks move during winter to the suburbs where more rats and mice are likely to be found.

The diet for Southern Boobooks indicated that most of the biomass in the autumn/winter period came from vertebrates. Invertebrates provided the major items based on number, but contributed only 2.8 per cent of the biomass. This analysis of Southern Boobooks in the ACT supports the conclusions of McNabb (2002) that most biomass is from vertebrates.

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