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Winter food of a small insectivorous bird, the Golden-crowned Kinglet.—Kinglets are the smallest passerine birds in the world, averaging 5–6 g. Since small body mass poses high energetic demands on thermoregulation, kinglets should face stringent problems of maintaining energy balance (Walsberg 1983). How they maintain energy balance in northern environments where temperatures routinely dip to −30°C and less, while on an insectivorous diet is not known. However, kinglets help reduce the extreme metabolic crunch imposed by their small size by huddling at night (Thaler 1990) or by at least sometimes sleeping in sheltered locations such as insulated squirrel (Blem and Pagels 1984) or bird nests (Farley 1993).

Most insectivorous birds of the northern forests solve the energy problem by migrating when insects become scarce at the end of the summer. Exceptions include birds that can access insects hidden inside wood (woodpeckers), or in bark crevices (parids, creepers, and nuthatches), and/or that can turn to alternative foods (suet and seeds) when available. Kinglets are unable to access insects hidden from view (Thaler 1990), and they never visit human-provided food in winter.

In the summer the Golden-crowned Kinglet (*Regulus satrapa*) subsists on a great variety of insects (Crawford and Jennings 1989, Galati 1991). However, their diet in the winter was previously unknown. The European winter kinglet the Goldcrest (*R. regulus*), is thought on the basis of its foraging mode to be a Collembolan specialist (Harrison 1969), and its main winter food is thought to be collembolans, genus *Entomobrya* (Schmidt 1968, Thaler 1990).

In the coniferous forests of western Maine, the site of this study, at least some (or all?) of the population of Golden-crowned Kinglets (*R. satrapa*) are year-round residents. The area is characterized by deep winter snows and temperatures that routinely dip to −30°C and sometimes to lower than −40°C (as in the winter of 1993–1994). The birds were present throughout all winters examined, although they seemed to be noticeably less common the winter of 1993–1994. (Curiously, 13 of our sample of 16 birds were males). They occurred in flocks of 2–4 individuals that moved rapidly through spruce-fir forests from dawn till dusk. Do they subsist on "snow fleas," the collembolan *Hypogastrura nivicola* (Hypogastruridae) that appear by the millions even on the deepest snow within hours of every thaw in the winter?

We examined the gizzard contents of 15 Golden-crowned Kinglets, all foraging in spruce-fir stands, from late November to mid-April, and one from mid-May, 1992–1994. Since our diet analysis is based on the hard exoskeletal remains, it may underestimate the contribution of soft-bodied prey. However, since the gizzard contents of the foraging birds were suspended in isopropyl alcohol within 1–2 min of collection (by 22 caliber rifle), digestion should have been stopped, and remains of the most recently ingested insects should have remained. Our emphasis, however, was in determining the *kinds* of prey. Thus, presence of prey was based on as little as a leg or a mandible fragment (spider) or several scales (moth), to almost wholly preserved specimens (two collembolans, many caterpillars). Unless two parts clearly came from two individuals (i.e., two right wings) we conservatively assigned them to one.

We made a "spot check" of prey availability by spreading a 5m^2 white sheet under small (8–15 cm diameter) trees or tree branches of similar size and hitting them twice each as hard as possible with the blunt side of an ax. On 13 October 1991 (following leaf fall and nightly frosts), a survey of five white pine (*Pinus strobus*), five red spruce (*Picea rubra*) vs five deciduous trees/branches (principally maple [*Acer*] and birch [*Betula*]) yielded 80, 122, and 11 arthropods, respectively. They were 119 spiders, 53 homopteran, 18 diptera, 13

TABLE 1
FOOD ITEMS IDENTIFIED IN THE GIZZARDS OF 16 GOLDEN-CROWNED KINGLETS

	Kinglets 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Seeds	0	0	0	0	0	0	0	0	0	0	0	0	10	3	17	3	33
RFM	0	0	+	0	+	+	0	0	0	0	0	0	0	0	0	0	—
Diptera																	
Adult	0	0	0	1B 1Ce	0	0	0	0	0	2	0	0	0	1	0	0	7
Pupae	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Larvae	24A	1S+ 6T	1S+ 13T	2S+ 8T	1S+ 14T	2S+ 17T	0	1T	0	1	0	1T	0	0	0	0	93
Homoptera	0	0	0	0	1P	1Ap	1Ap 1Ci	0	0	0	0	0	0	0	0	2Ap	6
Plecoptera	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Heteroptera	0	0	0	0	0	0	>1N	0	0	0	0	0	0	0	0	0	1
Neuroptera	0	0	0	0	0	0	1H	0	0	0	0	0	0	0	0	0	1
Hymenoptera	0	1Br	0	0	0	0	1	0	0	1	0	0	0	0	0	0	3
Lepidoptera																	
Pupae	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	3
Larvae	30G	16G	1G 12oth.	29G	38G 1oth.	10G	6G	19G	8G	2G	26G	17G	6G	23G 1oth.	6G	35G 1oth.	272G 15oth.
Adults	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Arthropod eggs	0	3	3	0	0	7	0	0	1	0	0	0	2	0	3		21
Arachnida	1Sp	1Sp	1Sp	1Sp	1Sp	0	1Sp 1Mi	1	0	0	0	1	0	0	0	2 0	9
Coleoptera	0	0	0	0	0	0	3E 1M	0	1C	0	0	2Ca	0	0	1	 0	8
Collembola	4(2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4

[a] The top row identifies the 16 kinglets. Dates of capture were as follows: 1, Jan. 25, 1992; 2–4, Dec. 1992; 3–7, March–May 11, 1993; 8–12, April 14, 1994; 13–16, Nov. 24–26, 1994. Numbers in body of table show minimum number of prey items of indicated category. Letters refer to type of prey items: A = Agromyzidae (Diptera) larvae, Ap = Aphidae (Homoptera), B = Bibio sp. (Bibimidae, Diptera) adult, Br = Braconidae (Hymenoptera) adult, C = Curculionidae (Coleoptera) adult, Ca = Cantharidae (Coleoptera) larvae, Ce = Cecidomyidae, Lestreminae (Diptera) adult, Ci = Cicadellidae (Homoptera), E = Elateridae (Coleoptera) adult, Geo = Geometridae (Lepidoptera) larvae, H = Hemerobiidae (Neuroptera) larvae, M = *Mulsantina hudsonica* (Csy.) (Coccinellidae, Coleoptera) adult, Mi = mites (Arachnida), N = *Nabis americoferus* Caragon (Heteroptera) adults, oth. = larvae other than Geometridae (Lepidoptera), P = *Paratrioza* sp. (Psyllidae, Homoptera) adult, Pu = pupae (Lepidoptera), RFM = unidentified red flocculant material, S = Syrphidae (Diptera) larvae, Sp = spiders (Arachnida), T = Tachinidae (Diptera) larvae parasitizing lepidopteran caterpillars.

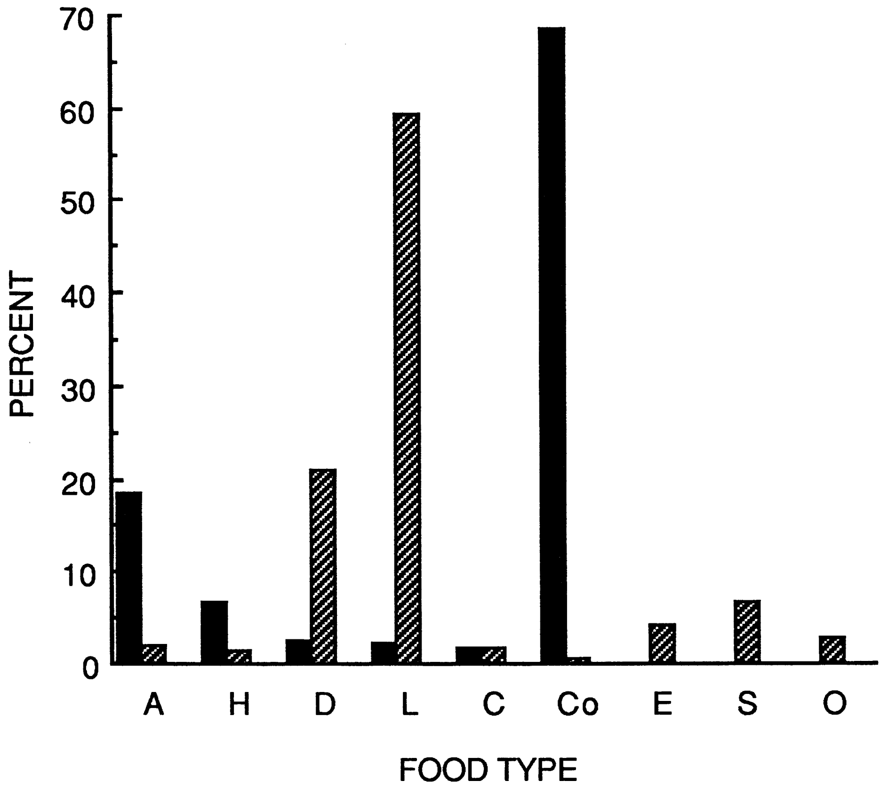

FIG. 1. The relative percentage of the most common types of arthropods (N = 795) retrieved from winter tree branches (filled bars) vs the most common types of prey items (N = 483) found in the kinglets' stomachs (hatched bars). A = Arachnida, H = Homoptera, D = Diptera, C = Coleoptera, L = Lepidoptera (caterpillars), Co = Collembola, E = Arthropod eggs, S = seeds, O = other.

coleoptera, and 13 caterpillars. On 1 December, 1991, 10 conifer branches yielded 532 collembolans (*Hypogastrura nivicola*), 27 spiders, two geometrids, one homopteran, and one fly, while 10 red (*Acer rubrum*) and sugar maple (*A. saccharum*) trees/branches yielded only 13, one, two, zero and zero of the same arthropods, respectively. An additional sampling occurred on 10 January, 1995, during a thaw following several days when temperatures had dipped to at least −30°C. Fifteen each of 5–8cm diameter red spruce, balsam fir (*Abies balsamea*), red maple and American beech (*Fagus grandifolia*) were sampled as before (on snow). The total arthropods taken was 25 spiders, 13 geometrid caterpillars, one beetle, one fly, and >50 *H. nivicola.* Three of the caterpillars were on the balsam fir, the other ten were on the maple and beech. Thus collembolans were present on winter conifer branches, which also consistently had many more arthropods than deciduous branches of similar thickness. By far (>99%) the most numerous collembolan were the "snow fleas," *Hypogastrura nivicola* (Hypogastruridae). They peppered the deep snow by the millions within hours of every thaw, and then retreated primarily into the bark crevices of thick trees during the intervening cold periods. However, in contrast to our expectations that these insects would be the kinglet's primary food, given previously-published accounts of the foraging specializations of kinglets, our study pointed to a different conclusion.

Out of a total of 483 identified prey items in the gizzards of the 16 Golden-crowned Kinglets in winter, 287 (or 59%) were lepidopterous caterpillars (of which 60 were parasitized by Tachinid fly larvae), and of all these caterpillars, 95% were geometrids (Table 1). Small (5–10 mm) lepidopterous larvae were the only consistent diet items found in all 16 birds, with a mean of 18 per bird (range = 6–39). Additionally, remains of numerous other (Table 1) kinds of arthropod food items were retrieved, but all appeared only sporadically among the different individuals. Four individuals had eaten small seeds, and three had red flocculant (presumably fruit) in their gizzards. In the 11 birds from late November to April, any one bird had recently fed on 3–7 kinds of food items, while the one bird from mid-May had fed on ten. Noticeably absent in the diet, despite their abundance in the environment, were collembolans. Only one of the 16 birds had collembolans, and the four it had eaten were of at least two species, neither one being *H. nivicola,* the hyperabundant "snow flea." We were surprised that so many caterpillars were apparently hibernating in the open treetops in the depth of winter.

We conclude that the kinglets' foraging in evergreens may reflect prey abundance there, but that they do not prey on the there very abundant *H. nivicola.* The diet of the kinglets appears to be varied and highly opportunistic. Furthermore, although the birds include some species of *Collembola* in their winter diet, they appear to subsist primarily on geometrid caterpillars. Our estimate of primary reliance on lepidopterous caterpillars (Fig. 1) is a conservative one because we tabulated only numbers of items, and the volume of individual caterpillars was far greater than the volume of most of the other prey items such as aphids, arthropod eggs, seeds, etc. that we tabulated. This study was done under State of Maine Collecting Permit No. 75-1743.

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