Comp. Biochem. Physiol. Vol. 103A, No. 3, pp. 579–595, 1992
Printed in Great Britain

0300-9629/92 $5.00 + 0.00

LIVE MASS, WATER CONTENT, NITROGEN AND MINERAL LEVELS IN SOME INSECTS FROM SOUTH-CENTRAL LOWER MICHIGAN

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(*Received* 16 *March* 1992; *accepted* 15 *April* 1992)

Abstract—1. Live and dry mass, water content, nitrogen, sodium, potassium, magnesium, calcium and total iron concentrations are reported (or are available from the authors or the Faculty/Staff Collection of The University of Michigan–Flint Library) for members of 16 orders (360 species) of mostly adult, flying insects from south-central lower Michigan.

2. Compared to published nutritional requirements (when meeting caloric requirements) for growth and reproduction in birds and mammals, insects are excellent sources of nitrogen, potassium and magnesium, highly variable sources of sodium and iron, and, very rarely, adequate calcium sources.

3. Elemental composition of some insects differs by size, sex, season and after culling.

INTRODUCTION

The question, 'why do animals eat what they eat?' has generated extreme interest among biologists. Such studies fall generally within the category of optimal foraging theory (for example, see Schoener, 1971, 1979; Krebs, 1978, 1980; Pyke *et al.*, 1977; Pyke, 1984), and include concepts of time-minimizing and energy-maximizing feeding strategies, of opportunistic and selective feeding habits, as well as generating and testing descriptive foraging models (for example, see Belovsky, 1981, 1984; Belovsky *et al.*, 1989; Clark, 1982; Vickery, 1984). Those studies are predicated on appropriate, or at least adequate, dietary nutrient self-selection and nutrient availability, and those assumptions have been questioned (Sullivan, 1988, 1989; Beck and Galef, 1989; Galef, 1991).

Insects are consumed as dietary items by an extremely wide variety of vertebrates, including bats (Gardner 1977; Whitaker, 1988) and birds (Ehrlich *et al.*, 1988). Estimation of nutritional budgets of animals requires quantification of amounts and composition of foods eaten and of resultant wastes. Estimates of energy (= caloric or carbon) demands or budgets and factors affecting those requirements have been reported for a wide variety of animals (for review, see Peters, 1983). The focus of most studies on caloric aspects of energy budgets seems reasonable, since growth and reproduction in individuals and populations require long-term maintenance of positive caloric budgets. Associated with the concentration of such caloric budgets, many reports are available concerned with energy content of foodstuffs, including insects (for example, see Cummins and Wuycheck, 1971; Schroeder, 1977; Slansky and Scriber, 1985).

Emphasis on examination of energy budgets implies that, in maintaining those budgets, animals automatically satisfy their remaining nutrient requirements. Except for the unlikely or unusual ingestion of "perfect" food that contains adequate levels of all other required macromolecules, water, vitamins, elements, etc., ingestion of enough calories to meet or slightly exceed energy demands would rarely provide sufficient intake of all nutrients. Within the perview of optimal foraging theory, some consideration has been given to dietary optimization when specific nutrient constraints are important (Pulliam, 1975; Stamps *et al.*, 1981). If intake of a specific nutrient impacts foraging strategies, then some dietary choices must be inadequate in concentration for such limiting nutrients and other selected dietary items must contain adequate or excessive levels of said nutrient.

Other than caloric content and associated measures of live mass and water content, rarity of published data on insect mineral composition (reviewed by Mattson and Scriber, 1987) precludes expansion of nutritional budget studies of insectivorous animals to include other nutrient budgets and application of optimal foraging models based on non-caloric nutrient constraints. Lack of published data, coupled with availability of new technology, has prompted the present study.

While data on caloric and water requirements are available for a wide variety of organisms (Peters, 1983), requirements for other nutrients, e.g. nitrogen and minerals, are restricted to commonly studied small laboratory mammals and commercially important birds (National Research Council, 1978, 1984).

Some insect-eaters, especially bats (Bell, 1982), cull food items, and limited data are reported here on nutritional composition of whole versus culled individuals of a few insect species. Limited mineral composition data on insects indicate possible differences with year, season, size, age and gender (Reichle *et al.*, 1969; Levy and Cromroy, 1973; Schowalter *et al.*, 1981; Bowden *et al.*, 1984) and possible effects of these variables are briefly investigated.

Since we are concerned with insects as prey of aerial insectivores, we present data on live and dry mass, water content, nitrogen, sodium, potassium, magnesium, calcium and total iron content of whole, primarily flying, insects found in south-central lower Michigan.

MATERIALS AND METHODS

Except for periodical cicadas (collected near Chicago, IL, and sent to us, alive, via air express by Dr Thomas Poulson), all insects were collected from Genesee, Livingston, Shiawasee or Lapeer Counties in south-central lower Michigan from March through October 1990. Although a wide variety of collection sites for day-active insects were utilized, most collections were made in two county parks in Genesee Co., MI. Most day collections were made with hand nets. Night-active insects were primarily collected at seven different sites; however, repetitive (at 1–2 week intervals) night collections were made at two sites located within 500 m of maternity roosts of big brown bats, *Eptesicus fuscus*. One site was in an uncut hay field in rural Livingston Co., MI, and the other site was adjacent to the Shiawasee River within the city limits of Byron, Shiawasee Co., MI. Night-active insects were attracted to one of three light traps (white bed sheets stretched over A-frames) containing incandescent, ultraviolet ("blacklight"), or mercury vapor lamps.

All insects were placed in air-tight plastic vials during or immediately after collection. Vials were placed on ice, returned to the laboratory and frozen until identification and analysis began. Except for eastern tent moth caterpillars, *Malacosoma americanum* (Studier *et al.*, 1991), no immature individuals of any species that exhibits complete metamorphosis were collected. Immature grasshoppers, crickets, box elder bugs and spittlebugs were deliberately collected to determine if any relationships exist between insect size and elements measured. Box elder bugs were collected in three months (March = spring, June = summer and October = fall) to determine if any measured elements varied with season. Finally, since bats often cull their prey before consuming it, some individuals of some abundant species (May beetles, periodic cicadas and one moth) were studied both whole and culled (legs, wings, elytra, if present, and heads removed).

Individuals were identified utilizing various sources (Blatchley, 1920; Cantrall, 1943, 1968; Needham and Westfall, 1955; Gurney and Brooks, 1959; Leonard and Leonard, 1962; Edmunds and Jensen, 1976; Milne and Milne, 1980; Pyle, 1981; McCafferty, 1981; White, 1983; Covell, 1984; Arnett, 1985), as well as local reference collections of some groups (obtained from The Museum, University of Michigan, Ann Arbor). Nomenclature generally follows Arnett (1985). Insects were sexed, whenever possible, aged as adults or immatures, and sex, if known, age, and collection data were recorded. Voucher specimens of all species collected in large numbers have been deposited at The Museum, University of Michigan, Ann Arbor, or retained by the authors.

Immediately upon thawing, individual or small groups of identified insects were weighed (to nearest 0.1 mg), placed in new aluminum weighing dishes and dried to constant weight at 50–60°C. Body water content was determined by difference. Although precautions were taken to prevent desiccation before initial weights were taken, some drying may have occurred and water content, especially of small insects, may be somewhat underestimated. In cases where collected insects were known to be partially desiccated, data on live weight and water content are omitted.

Weighed, identified, dry, whole insects were wet oxidized in a cleaned volumetric flask in boiling, concentrated H_2SO_4, followed by addition of a mixture of 30% H_2O_2:concentrated H_2SO_4 (2:1 v/v). After digestion was complete, cooled samples were diluted to flask volume. Amounts used were dependent on original dry sample weight. Dry samples weighing from 10 to 35 mg were digested in 25 ml volumetric flasks with 0.25 ml concentrated H_2SO_4 and 0.75 ml of mixture; dry samples weighing between 35 and 150 mg were digested in 100 ml volumetric flasks with 1 ml of concentrated H_2SO_4 and 3 ml of mixture; and, dry samples weighing more than 150 mg were digested to 250 ml volumetric flasks with 2.5 ml H_2SO_4 and 7.5 ml of mixture. For very small insects, individuals were grouped to obtain minimum 10 mg samples. Each diluted sample was kept in a new, non-sterile, leakproof, 120 ml capacity, clear, polypropylene, screw-capped container (Fisher Scientific, Itasca, IL). One milliliter aliquots of diluted samples were analysed for nitrogen content by Nesslerization (Treybig and Haney, 1983). Additional aliquots, after appropriate dilution and preparation, were analysed for sodium, potassium, magnesium, calcium and total iron concentrations following standard procedures using a Varian Spectra AA-20 atomic absorption spectrophotometer (analytical methods for flame spectroscopy, Varian Techtron Pty. Ltd, Springvale, Australia). Sodium and potassium levels were determined by flame emission and all other minerals by atomic absorption. Required dilutions of each sample were performed with the aid of an Eppendorf Digital Pipette (Brinkmann Instruments Co., Westbury, New York) and FISHERbrand Adjustable Dispensers (Fisher Scientific, Pittsburg, PA) into new, non-sterile, 12 × 75 mm, clear, polystyrene tubes and covered with PARAFILM (American National Can, Greenwich, CT). All diluted samples were analysed within 48 hr of dilution and all samples were mixed by inversion just prior to measurement. Water used throughout the determinations was purified by a reverse osmosis system and further purified with a Barnstead NANOpure II water purifying system (Barnstead/Thermolyne Corp., Dubuque, IA). Volumetric flasks used in digestions were rinsed three times and dried at 50–60°C between use. These precautions were necessary due to the extreme sensitivity of atomic absorption spectrophotometry to contaminants.

Values for nitrogen are expressed as per cent (%) dry weight and all minerals are expressed as parts per thousand (ppt) dry weight. With the weight:volume ratios used in the digestion process in this study, the lower limit of detection for sodium was about 0.001 ppt dry mass and samples that read below that limit are reported as 0 (<0.001 ppt). Minimum detection limit for total iron was about 0.01 ppt dry mass and samples with lower total iron levels are reported as 0 (<0.01 ppt). Levels for sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}) include only those valence states; however, levels for iron include both common valence states (Fe^{2+} and Fe^{3+}) and are, therefore, reported as total iron.

Data were stored in Lotus files. Data analyses were performed using SYSTAT (Wilkinson, 1987).

RESULTS AND DISCUSSION

Live weights and water content

Live (wet) and dry mass, per cent body water, collection dates, sex and element levels for selected species studied are shown in Appendix 1. Complete data sets are available from the authors or from the Faculty/Staff Collection of The University of Michigan–Flint Library in hard copy. Water content in all insects tested is consistent in the 60–70% range of live weight. Regression analyses of per cent body water vs individual dry weight for *Melanoplus* spp., *M. bivittatus*, *Gryllus pennsylvanicus*, *Hippiscus rugosa*, *Leptocoris trivittatus* and *Philaenus spumarius* show significant relationships only in the melanoplines (in *M. bivittatus*, $F = 31.33$, $df = 1$ and 30, $r^2 = 0.511$, $P < 0.001$; and, in other melanoplines, $F = 18.65$, $df = 1$ and 168, $r^2 = 0.100$, $P < 0.001$).

Relations between live mass (LM in mg) and per cent body water (% BW) in *M. bivittatus* and other melanoplines, respectively, are:

$$\% \text{ BW} = -0.022(\pm 0.004)\text{LM} + 74.97(\pm 0.75)$$

and

$$\% \text{ BW} = -0.017(\pm 0.004)\text{LM} + 72.47(\pm 0.43)$$

where values in parentheses are standard errors of the means. The group designated *Melanoplus* spp. includes, at least, *M. confusus*, *M. borealis* and *M. femurrubrum*. Some of the variation in percentage body water may be explained by a slight tendency toward decrease in relative water content with increasing size related to the associated decrease in surface area: mass ratio with increasing size. Since all insects were analysed whole, gut fullness and percentage water of gut contents would also contribute to variability in percentage body water. High levels of body fat, especially in large, gravid females, would contribute to variability by reducing water content and probably contribute to the negative relation found for water content as a function of size in melanoplines. As can be calculated from the data in Appendix 1, significant differences in live weight and percentage body water exist by sex for many species, e.g. among the Emphemeroptera, for *Baetis* spp., live males are heavier than females (t = 6.57, df = 34, $P < 0.001$), while for *Stenonema pulchellum*, live females are heavier than males (t = 2.20, df = 20, $P < 0.05$).

Elemental composition

Elemental composition of insects studies (summarized by order in Table 1 and by species in Appendix 1) agrees well with the limited data summarized by Mattson and Scriber (1987). Minimal requirements for growth and reproduction in birds for the elements measured are: iron, 0.08–0.10 ppt dry mass (DM); calcium, 6.5–12.0 ppt DM; magnesium, 0.3–0.5 ppt DM; sodium, 1.5–1.7 ppt DM; potassium, 4.0–7.0 ppt DM; and nitrogen, 3.5–4.8% DM as ideal or complete protein (National Research Council, 1984). In mammals, these requirements are: iron, 0.025–0.140 ppt DM; calcium, 4.0–8.0 ppt DM; magnesium, 0.4–1.0 ppt DM; sodium 0.5–1.5 ppt DM; potassium, 2.0–7.2 ppt DM; and nitrogen, 1.9–2.09% DM as protein (National Research Council, 1978). These values represent concentrations of nutrients required in a calorically adequate diet.

As sources of iron, megalopterans appear to be inadequate (small sample size makes this a very tentative conclusion), while walking sticks (Phasmatodea), mantids (Mantodea), lepidopterans and, perhaps even hemipterans and coleopterans, probably provide marginally adequate dietary iron. As previously stated, the procedure used measures total iron (both Fe^{2+} and Fe^{3+}). Iron is assimilated primarily as ferrous ion (Fe^{2+}) and, since iron is poorly assimilated (Charlton and Bothwell, 1983), insect species (Appendix 1) containing less than 0.2 ppt may not provide sufficient iron to meet needs for growth and reproduction.

On average, only stone flies (plecopterans) provide sufficient dietary calcium to meet needs for growth and development of birds and mammals. The female *Perlesta decipiens* studied were gravid and show body calcium concentrations which are significantly higher than in males (t = 27.64, df = 22, $P < 0.001$). Hemipterans may be marginally adequate as calcium sources for mammals. All other insects represent inadequate sources of calcium. The possibility that dietary calcium intake may be a limiting nutrient in insectivorous birds has received some attention based on both nutritional models (Turner, 1982) and observations of the consumption of bone or grit during reproductively active periods (Maclean, 1974; Jones, 1976; Repasky *et al.*, 1991). Based on quite limited data, some other arthropods, e.g. millipedes and isopods, may be excellent dietary calcium sources (Reichle *et al.*, 1969; Carter and Cragg, 1976).

All insects tested are adequate sources of dietary magnesium for birds and mammals except for hymenopterans, which may be marginal for mammals.

As sources of dietary sodium for birds, phasmatids, orthopterans, mantids, homopterans, neuropterans, trichopterans, hymenopterans and lepidopterans are inadequate and coleopterans are marginal. For mam-

Table 1. Element composition of some insects from south-central lower Michigan

Order	Sp	*N* (*)	DM (mg)	Fe (ppt)	Ca (ppt)	Mg (ppt)	Na (ppt)	K (ppt)	N (%)
Ephemeroptera	16	126 (324)	15.2 ± 1.6	0.332 ± 0.038	1.024 ± 0.036	1.211 ± 0.042	2.698 ± 0.071	10.15 ± 0.23	18.04 ± 0.32
Odonata	20	120 (153)	34.8 ± 4.9	0.407 ± 0.039	0.869 ± 0.021	1.630 ± 0.125	3.015 ± 0.112	9.75 ± 0.21	18.25 ± 0.21
Plecoptera	5	39 (124)	17.8 ± 3.8	0.581 ± 0.106	11.515 ± 1.273	2.572 ± 0.190	1.920 ± 0.121	7.25 ± 0.20	17.14 ± 0.42
Phasmatodea	1	5	83.7 ± 7.6	0.100 ± 0.019	2.634 ± 0.443	2.952 ± 0.128	0.125 ± 0.050	14.89 ± 0.57	14.66 ± 0.63
Orthoptera	18	269 (300)	99.4 ± 6.2	0.211 ± 0.023	1.876 ± 0.063	1.340 ± 0.031	0.659 ± 0.054	12.30 ± 0.18	16.32 ± 0.17
Mantodea	1	7	113.6 ± 14.6	0.143 ± 0.055	1.815 ± 0.157	1.366 ± 0.073	1.336 ± 0.107	9.23 ± 0.22	14.34 ± 0.51
Dermaptera	1	14 (14)	15.4 ± 1.0	0.702 ± 0.042	1.595 ± 0.101	1.284 ± 0.063	1.757 ± 0.100	9.52 ± 0.27	16.71 ± 0.50
Hemiptera	10	82 (185)	46.9 ± 21.7	0.191 ± 0.024	3.126 ± 0.183	2.736 ± 0.120	2.406 ± 0.394	13.27 ± 0.79	18.70 ± 0.36
Homoptera	6	94 (192)	160.8 ± 28.7	0.563 ± 0.034	2.271 ± 0.045	1.804 ± 0.046	0.581 ± 0.056	9.43 ± 0.28	14.40 ± 0.44
Neuroptera	1	6 (13)	5.6 ± 0.5	0.385 ± 0.168	2.018 ± 0.575	1.072 ± 0.310	0.118 ± 0.108	13.69 ± 1.07	16.60 ± 0.91
Megaloptera	1	2	76.8	0.034	1.721	1.710	2.285	9.03	13.08
Coleoptera	43	194 (236)	47.7 ± 8.2	0.188 ± 0.020	1.050 ± 0.052	1.523 ± 0.043	1.660 ± 0.096	9.01 ± 0.22	16.84 ± 0.21
Trichoptera	13	74 (173)	15.6 ± 1.9	0.338 ± 0.039	1.793 ± 0.110	1.149 ± 0.065	1.412 ± 0.102	7.12 ± 0.28	16.77 ± 0.27
Hymenoptera	21	135 (161)	51.6 ± 4.4	0.270 ± 0.025	0.759 ± 0.036	0.956 ± 0.023	0.556 ± 0.051	9.21 ± 0.30	16.88 ± 0.26
Lepidoptera	181	546 (597)	45.1 ± 2.1	0.145 ± 0.009	1.221 ± 0.041	2.308 ± 0.068	0.544 ± 0.055	9.40 ± 0.13	16.61 ± 0.13
Diptera	20	108 (474)	10.2 ± 1.2	0.576 ± 0.069	1.471 ± 0.114	1.275 ± 0.070	2.217 ± 0.118	8.69 ± 0.18	17.81 ± 0.23

Values for elements are arithmetic means ± standard errors, Sp = number of species tested, *N* = number of samples, (*) = number of individuals tested, if different from number of samples and DM = dry matter. Units for minerals are parts per thousand (ppt) dry mass and for nitrogen are per cent (%) dry mass. For Orders in which only one species was tested, those species are: in Phasmatodea, *Diapheroma femorata* [two females (F), three males (M)]; in Mantodea, *Mantis religiosa* (seven F); in Dermaptera, *Forficula auricularia* (10 F, four M); in Neuroptera, *Chrysopa ornata* (six, sexes combined); in Megaloptera, *Chauliodes rastiicornis* (two, sexes unknown).

Table 2. Significant linear relationships for body element (E) levels

E	Slope	Intercept	r^2	F	d.f.	P
Melanoplus spp. (DM range = 2.9–597.3 mg)						
N	−0.014 ± 0.002	17.91 ± 0.28	0.195	33.25	1,137	<0.001
K	−0.005 ± 0.002	12.66 ± 0.26	0.037	5.32	1,137	0.023
Mg	−0.002 ± 0.001	1.517 ± 0.06	0.107	16.39	1,137	<0.001
Ca	−0.002 ± 0.001	2.028 ± 0.101	0.043	6.18	1,137	0.014
Fe	−0.002 ± 0.000	0.371 ± 0.044	0.127	19.95	1,137	<0.001
Melanoplus bivittatus (DM range = 11.5–489.7 mg)						
N	−0.010 ± 0.003	17.58 ± 0.54	0.284	11.92	1,30	0.002
K	−0.011 ± 0.004	13.80 ± 0.69	0.210	7.99	1,30	0.008
Mg	−0.002 ± 0.001	1.749 ± 0.125	0.211	8.05	1,30	0.008
Hippiscus rugosa (DM range = 17.0–540.7 mg)						
N	−0.013 ± 0.002	17.47 ± 0.52	0.683	36.55	1,17	<0.001
K	0.005 ± 0.002	10.62 ± 0.53	0.230	5.08	1,17	0.038
Fe	−0.001 ± 0.000	0.419 ± 0.087	0.380	10.41	1,17	0.005
Leptocoris trivittatus (DM range = 1.1–20.5 mg)						
N	−0.107 ± 0.041	19.40 ± 0.49	0.193	6.71	1,28	0.015
K	−0.134 ± 0.034	13.00 ± 0.41	0.352	15.19	1,28	0.001
Mg	−0.065 ± 0.015	4.313 ± 0.176	0.404	18.98	1,28	<0.001
Philaenus spumarius (DM range = 0.6–3.8 mg)						
Fe	−0.016 ± 0.006	0.073 ± 0.015	0.376	8.44	1,14	0.012

Nitrogen in % dry weight; potassium, calcium, magnesium and total iron in part per thousand dry weight, and dry mass (DM) in mg. Values are means ± standard errors. No significant relationships were found for *Gryllus pennsylvanicus*.

mals, since their sodium needs are less than those of birds, only phasmatids and lacewings (neuropterans) are inadequate sodium sources and the other groups just listed for birds are all marginal sodium sources for mammals. Among the night-flying geometrid, arctiid and, especially, noctuid moths, which are consumed readily by bats, sodium levels are essentially bimodal with many species containing immeasurably low sodium concentrations while others exhibit extremely high body sodium levels. Some of those moths, therefore, provide no nutritional sodium while others are superb nutritional sodium sources. The extreme variability in sodium level may relate to puddling behavior reported for some lepidopterans (Arms *et al.*, 1974).

With the possible exception of trichopterans, all insects tested provide sufficient dietary potassium to meet the nutritional needs of birds and mammals. Dietary sodium requirements increase with increasing potassium intake in herbivores (Meyer *et al.*, 1950; Weeks and Kirkpatrick, 1978; Staaland *et al.*, 1980) and insects high in potassium, e.g. phasmatids, orthopterans, hemipterans and neuropterans, may, therefore, increase the nutritional minimum for sodium.

Avian and mammalian nitrogen requirements for growth and reproduction given above are values for complete or ideal protein, i.e. all amino acids present. While many plant proteins are incomplete, most proteins of animal origin are complete. Insects, therefore, would seem to be excellent and adequate sources of dietary protein for birds and mammals. Since much of the total nitrogen present in insects, however, is unavailable, e.g. as aminated polysaccharides in the exoskeleton, much of the total nitrogen cannot be assimilated. Dry nitrogen levels, however, exceed dietary requirements by at least a factor of three and it seems unreasonable that less than one-third of the total measured nitrogen is available. Consequently, even with these caveats, insects almost certainly provide adequate required dietary nitrogen.

Significant linear regression relationships found with size for nitrogen and minerals are given in Table 2. Of the species tested, only the crickets, *Gryllus pennsylvanicus*, showed no relationships of mass to any of the elements tested. That lack of relationships in crickets may well be attributed to the considerable variability in crop fullness found in the individuals tested. The observance of a significant relationship for just one element (Fe) to size in spittlebugs may relate to the small size range available for testing. No relationship was found for Na^+ level and body mass in any species tested, and Ca^{2+} was significantly related to size in only the melanoplines. Relationships to size were found for at least half of the species tested for the remaining elements (N, K, Mg and Fe). Nearly all significant linear relationships have negative slopes which, again, imply a surface area:mass decrease with size phenomenon; however, most relationships have quite low coefficients of determination (r^2) which indicates that although elemental variation is related to body size, characteristics other than size have marked influence on elemental variation. Factors other than crop fullness, which might explain the observed variability in elemental composition, include combining species during classification of the melanoplines, gender differences, differences in collection sites or seasons which modify available foodstuffs for insects, and ages of tested insects which show incomplete metamorphosis. Elemental composition of insects that exhibit complete metamorphosis has also been reported to differ with developmental stage (Levy and Cromroy, 1973; Studier *et al.*, 1991).

The possible importance of sex and season on mass and elemental composition are demonstrated by data on box elder bugs (*Leptocoris trivittatus*) shown in Table 3. The high coefficients of determination suggest that, at least in this species, both sex and season strongly affect elemental composition. Such seasonal and gender composition differences have been previously reported for a few insects (Reichle *et al.*, 1969; Bowden *et al.*, 1984).

Culling generally removes body parts which contain slightly lower water content, such as elytra, wings, legs and the head; and culled individuals may, therefore, have a slightly higher percentage of water

Table 3. Dry mass (DM, mg), N (% DM) and mineral (ppt DM) levels in box elder bugs, *Leptocoris trivittatus*, by sex and season

Mo	S	N	DM	Fe	Ca	Mg	Na	K	N
Mr	F	5 (15)	16.3 ± 0.9	0.158 ± 0.024	1.339 ± 0.042	3.061 ± 0.081	0.916 ± 0.181	21.22 ± 1.75	19.74 ± 0.74
Mr	M	4 (16)	8.2 ± 0.3	0.189 ± 0.024	1.907 ± 0.027	3.425 ± 0.140	0.663 ± 0.164	13.00 ± 0.52	22.42 ± 0.50
Jn	F	5	14.7 ± 1.4	0.016 ± 0.004	3.348 ± 0.265	3.486 ± 0.357	0.663 ± 0.084	11.60 ± 0.56	17.84 ± 0.38
Jn	M	5	8.7 ± 0.2	0.034 ± 0.004	2.526 ± 0.313	3.296 ± 0.188	0.955 ± 0.083	10.35 ± 0.29	17.85 ± 0.50
Oc	F	11 (12)	11.0 ± 0.5	0.284 ± 0.016	4.053 ± 0.349	2.147 ± 0.204	0.715 ± 0.089	14.83 ± 0.78	20.51 ± 0.93
Oc	M	6 (12)	5.8 ± 0.4	0.311 ± 0.010	4.540 ± 0.463	2.177 ± 0.275	0.829 ± 0.054	16.18 ± 0.90	21.77 ± 1.56
F			14.76	114.8	23.29	14.12	NS	15.47	5.199
P			<0.001	<0.001	<0.001	<0.001		<0.001	0.012
r^2			0.793	0.887	0.628	0.504		0.662	0.294

F = female, S = sex, M = Male; Mo = Month; (Mr = March, Jn = June, Oc = October), *N* = samples analysed, while values in parentheses are numbers of individuals used, if different from sample size. Values shown are arithmetic means ± standard errors. Results of a two-way ANOVA (by season and sex) are given at the bottom of the table for season only. For each analysis, df for season = 2, sex = 1, season × sex interaction = 2 and error = 30. There were no significant season × sex interactions. Sex is only significant for potassium level and DM (F = 9.189, $P = 0.005$; and F = 90.55, $P < 0.001$, respectively).

than whole insects, e.g. *Phyllophaga rugosa* ($t = 3.58$, df = 24, $P < 0.01$) as shown in Table 4. Table 4 also shows element composition data in some other whole and culled insects. Although culling reduces biomass consumed/insect, no differences in elemental composition were found for periodical cicadas, *Magicicada septemdecim*, of either sex. In the moth, *Crambus laqueatellus*, culling increases the nutrient density of Fe, Ca and Na. In June beetles, *Phyllophaga rugosa*, culling increases the nutrient density of Mg, Na and K. No pattern of nutrient modification is observable in the few species studied, except for the possibility that culling increases nutrient density for some elements.

Nutritional value of insects

Data reported here may have certain nutritional implications for insectivorous birds and mammals. These implications are based on the assumption that minimal nutritional requirements for growth and reproduction reported for birds (National Research Council, 1984) and mammals (National Research Council, 1978) are typical for all birds and mammals. Requirements for less than a dozen species of birds and mammals are summarized in those references and none of the species studied are primarily insectivorous. Ongoing research (as yet, unpublished) in our laboratory with nestling eastern bluebirds (*Sialia sialis*) suggests that their requirements for Na^+ are slightly higher, K^+ are typical, iron and Mg^{2+} are slightly less, and N and Ca^{2+} are markedly less than reported previously for larger, non-insectivorous birds (National Research Council, 1984). We must also assume that data on composition of the insects reported here are typical for all insects. Although data on a wide variety of adult, flying insects are reported in this study, considering the massive numbers of known insect species, acceptance of this second assumption must be tentative.

Subject to the above assumptions, adult flying insects are excellent sources of nitrogen, potassium and magnesium and should readily exceed minimal requirements for growth and reproduction in birds and mammals. For iron and sodium, the extreme variability of levels of those elements in flying insects suggests that some species are excellent nutritional sources while other species are certainly inadequate. No day-flying insects meet published nutritional requirements for calcium for birds or mammals and, of night-flying insects, only plecopterans (stone flies) meet or exceed those requirements. Exclusive ingestion of a readily available, easily captured insect species by pregnant big brown bats, then, should not be expected to meet all nutritional requirements (Keeler and Studier, 1992). Flying insects, then, do not generally fulfill all nutritional requirements for growth and reproduction in birds and mammals. Growing or reproductively active insectivorous birds and mammals should, therefore, be expected to supplement their insect diet with non-insect sources of deficient nutrients, especially calcium, e.g. grit to meet calcium needs in nestling birds (Turner, 1982), utilization of stored skeletal calcium during pregnancy and lactation in bats (Sevick and Studier, 1992), ingestion of certain non-insect arthropods or other invertebrates which are high in calcium (Reichle *et al.*, 1969; Carter and Cragg, 1976) or cocoons of certain lepidopterans (Studier *et al.*, 1991). Insectivorous time-minimizers would, almost surely, be malnourished in respect to some non-caloric nutrients.

Finally, all of the previous discussion of nutritional requirements applies only to birds and mammals

Table 4. Live mass, percentage body water and element levels (as parts per thousand or percent dry mass) in whole and culled (C) individuals of three species (Sp): *Magicicada septemdecim* (Ms), *Crambus laqueatellus* (Cl), and *Phyllophaga rugosa* (Pr) by sex(s)

Sp	S	*N*	Mass (g)	Water (%)	Fe (ppt)	Ca (ppt)	Mg (ppt)	Na (ppt)	K (ppt)	N (%)
Ms	F	15	0.9549 ± 0.0399*	52.32 ± 1.15	0.420 ± 0.025	1.503 ± 0.109	1.520 ± 0.080	0.641 ± 0.039	5.89 ± 0.18	9.22 ± 0.38
MsC	F	10	0.7067 ± 0.0202*	53.67 ± 2.35	0.614 ± 0.091	2.097 ± 0.331	1.874 ± 0.216	0.632 ± 0.060	5.84 ± 0.36	9.46 ± 0.75
Ms	M	15	0.6947 ± 0.0201	62.98 ± 1.18	0.692 ± 0.063	1.188 ± 0.056	1.950 ± 0.077	1.028 ± 0.050	8.35 ± 0.62	12.20 ± 0.59
MsC	M	10	0.5590 ± 0.0204	63.46 ± 0.89	0.723 ± 0.050	1.051 ± 0.033	2.006 ± 0.056	0.739 ± 0.073	8.54 ± 0.40	12.61 ± 0.58
Cl	U	15	0.0958 ± 0.0042	58.69 ± 0.97	0.061 ± 0.016*	0.267 ± 0.019*	1.119 ± 0.058	0.015 ± 0.009*	7.08 ± 0.21	15.99 ± 0.76
ClC	U	4	0.0900 ± 0.0186	59.53 ± 3.24	0.521 ± 0.089*	0.504 ± 0.035*	1.201 ± 0.211	0.205 ± 0.041*	7.27 ± 0.80	13.45 ± 0.92
Pr	U	15	0.3034 ± 0.0126	67.27 ± 0.95*	0.168 ± 0.010	0.432 ± 0.073	1.898 ± 0.057*	0.787 ± 0.024*	11.51 ± 0.22*	13.16 ± 0.34
PrC	U	11	0.2854 ± 0.0211	71.79 ± 0.83*	0.206 ± 0.025	0.456 ± 0.060	2.637 ± 0.147	1.348 ± 0.054*	15.06 ± 0.74	14.27 ± 0.58

S = Sex, F = female, M = male, U = unknown, *N* = samples analysed. Pairs marked * are significantly different by independent *t*-tests at $P < 0.05$, after adjustment in accord with the Bonferroni method.

during periods of growth or reproductive activity. Although we have found no data for non-reproductively active adults, their maintenance requirements would certainly be less than those of growing or reproductively active individuals. Insects may well be complete nutritional sources during such non-reproductive periods in adult birds and mammals.

Acknowledgements—These studies were supported in part by a Faculty Development Fund Grant from The University of Michigan–Flint. We thank Ms Caroline Forbush, Mr and Mrs Ron Gregor, Mr and Mrs Dennis Viele Sr and, especially, Mr and Mrs Kenneth Clark for permission to collect on their property. We thank the public officials of Byron, MI and Genesee Co., MI, and the directors of Skyline Camp, Lapeer Co., MI for permission to collect on land under their control. We especially thank Dr T. Poulson for collecting and shipping us the cicadas. Dr S. Szczytko graciously identified the *Perlesta decipiens*. We very gratefully thank Margaret C. Rummel, Vickie M. Yott, Lee J. Yott, Dennis P. Viele Jr, Fern Gregor, Ann Studier, Grant Hogle, Lynne Latra, Joanne DeVoll, Chris Sherman, Kathy Lavoie, John Sherwood, Libbi Mason, Larry Atherton, Cathy Sevick, Mary Ann Cardani, Kevin Cardani, John Fitzgibbons and, especially, John O. Keeler for their aid in both field and lab aspects of this study. We are especially grateful for the understanding and patience shown by Cathy Sevick and Ann Studier. Drs M. Scriber, T. Kunz, K. Lavoie and R. Schenck provided useful comments on this manuscript.

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APPENDIX 1

Wet mass, sex, month(s) of collection in 1990, percentage body water, dry mass and elemental composition (minerals in parts per thousand dry mass and nitrogen in percent dry mass) for some insects from south-central lower Michigan

Taxon	S	Date	N_1 (*)	WM (g)	%HOH	N_2 (*)	DM (mg)	Fe (ppt)	Ca (ppt)	Mg (ppt)	Na (ppt)	K (ppt)	N (%)
Ephemeroptera													
Baetidae													
Baetis sp1	F	My	15	0.0113	70.42	4	3.6	0.312	0.396	0.371	3.261	7.90	17.08
						(13)	0.2	0.044	0.049	0.103	0.258	0.05	0.62
Baetis sp1	M	My	21	0.0153	70.42	7	4.6	0.123	0.470	0.678	2.627	7.95	13.62
				0.0001	0.37	(21)	0.1	0.024	0.025	0.069	0.116	0.17	0.22
Heptageniidae													
Stenomena integrum	F	Jn	8	0.0089	69.69	6	3.6	0.007	1.108	1.287	3.337	11.77	20.04
				0.0012	3.62	(21)	0.2	0.002	0.030	0.036	0.103	0.86	0.46
S. integrum	M	Jn	8	0.0067	64.91	6	2.6	0.016	1.254	1.166	2.812	12.03	19.98
				0.0003	1.22	(27)	0.3	0.011	0.274	0.099	0.090	0.51	0.75
S. interpunctatum	F	My–Jn	17	0.0183	67.80	9	6.4	0.372	0.920	1.152	3.788	8.85	18.67
				0.0015	0.57	(19)	0.3	0.091	0.080	0.111	0.261	0.48	0.84
S. luteum	F					4	3.0	0.002	1.375	1.269	3.167	13.20	20.08
						(16)	0.2	0.001	0.052	0.023	0.127	0.64	0.52
S. pulchellum	F	Jn, Au	10	0.0099	62.12	3	3.7	0.132	0.903	1.903	3.278	12.78	20.85
				0.0012	2.34	(9)	0.7	0.039	0.278	0.324	0.247	0.56	1.24
S. pulchellum	M	Au	12	0.0072	62.49	6	2.7	0.222	0.383	0.875	2.606	12.54	19.31
				0.0002	1.24	(24)	0.1	0.027	0.028	0.025	0.056	0.25	0.71
S. tripunctatum	F	Jn	16	0.0103	63.27	6	3.8	0.003	1.097	1.401	3.070	13.32	20.91
				0.0009	1.63	(18)	0.2	0.001	0.036	0.028	0.074	0.69	0.74
Ephemerellidae													
Emphemerella deficiens	F	Jl	1	0.0027	58.78	4	1.0	0.314	0.572	0.982	3.180	14.85	23.07
			(11)			(44)	0.0	0.015	0.025	0.007	0.142	0.46	1.17
Ephemeridae													
Ephemera simulans	F	Jn–Jl	24	0.0220	71.00	11	6.4	1.219	1.022	1.477	2.838	8.28	20.76
				0.0009	0.49	(22)	0.3	0.040	0.046	0.167	0.119	0.30	0.71
E. simulans	M	Jn–Jl	12	0.0156	62.94	3	5.4	1.421	1.083	2.316	2.912	7.41	20.57
				0.0010	2.46	(6)	0.0	0.070	0.098	0.162	0.132	0.65	0.77
Hexagenia rigida	F	Jn	11	0.0992	62.67	9	45.2	0.034	1.275	1.509	2.390	9.97	16.87
				0.0159	1.59	(9)	5.9	0.028	0.070	0.125	0.097	0.49	0.81
H. limbata	F	Jn, Au	22	0.1170	69.09	22	37.5	0.254	1.095	1.349	2.226	10.17	15.44
				0.0088	0.91		3.7	0.042	0.043	0.107	0.159	0.52	0.61
H. limbata	M	Jn–Au	14	0.0893	70.97	13	25.9	0.422	1.538	0.990	1.421	7.76	14.46
				0.0080	1.35	13	1.1	0.118	0.073	0.017	0.202	0.45	0.73
Odonata													
Corduliidae													
Tetragoneuria sp	F	My–Jn	3	0.1989	67.63	3	65.7	0.289	0.775	1.165	2.846	9.81	16.84
				0.0216	1.40		9.4	0.182	0.074	0.040	0.282	0.30	0.85

Libellulidae													
Libellula luctuosa	F	Jn–Jl	3	0.2188	72.07	4	65.9	0.364	0.959	1.760	2.341	12.22	18.82
				0.015	1.77		7.6	0.216	0.099	0.328	0.790	2.92	1.25
L. pulchella	F	Jn	5	0.3806	69.88	4	125.0	0.004	1.001	1.264	3.095	10.52	16.59
				0.0340	2.10		21.4	0.002	0.058	0.067	0.404	0.47	0.60
Pantala flavescens	F	Jn–Au	16	0.0903	72.43	15	21.9	0.034	0.930	1.081	3.765	11.28	17.38
				0.0080	0.91		2.0	0.019	0.051	0.034	0.246	0.25	0.49
P. flavescens	M	Jn–Jl	10	0.0848	73.02	9	22.8	0.078	0.906	1.146	3.497	11.15	16.44
				0.0035	0.67		1.3	0.050	0.044	0.041	0.238	0.38	0.64
Sympetrum semicinctum	M	Jl–Au	13	0.1291	66.37	12	43.4	0.368	0.848	4.682	0.944	7.32	19.60
				0.0030	0.26		1.2	0.111	0.028	0.622	0.048	0.11	0.25
Coenagrionidae													
Argia sp	F	Jn	8	0.0390	75.30	7	11.2	0.001	0.640	1.247	3.294	12.71	20.67
				0.0007	0.38		1.0	0.001	0.021	0.020	0.527	0.25	0.81
Enallagma sp1	F	My–Jn	23	0.0250	72.12	13	7.8	0.613	0.819	1.166	3.966	10.86	19.69
				0.0011	0.88	(22)	0.6	0.065	0.076	0.035	0.214	0.22	0.41
Enallagma sp1	M	My–Jn	15	0.0197	71.71	5	5.1	0.454	0.617	1.104	4.018	11.28	19.99
				0.0014	1.21	(12)	0.2	0.124	0.101	0.036	0.233	0.32	0.96
Enallagma sp2	F					13	11.4	1.020	0.935	1.577	2.076	7.87	18.79
							0.3	0.029	0.023	0.132	0.080	0.09	0.25
Enallagma sp2	M	Jn	21	0.0190	67.08	9	6.4	0.932	0.933	1.243	3.189	7.62	18.57
				0.0005	0.58	(11)	0.2	0.074	0.71	0.067	0.119	0.11	0.41
Enallagma sp3	F	Jn	25	0.0278	67.41	5	7.8	0.958	0.897	1.455	3.879	8.89	19.50
				0.0012	0.82		1.4		0.098	0.260	0.287	0.340	0.72
Plecoptera													
Perlidae													
Phasganophora spp	F	Jn	5	0.0806	66.98	4	33.5	0.490	9.711	2.394	2.491	6.10	15.53
				0.0156	1.77		4.5	0.109	2.796	0.623	0.185	0.15	1.56
Phasganophora spp	M	Jn	4	0.0929	66.75	4	32.8	1.252	9.509	2.060	2.863	6.96	19.35
				0.0233	2.08		9.3	0.373	3.529	0.494	0.623	0.82	2.44
Perlesta decipiens	F	Jl	13	0.0168	67.98	12	5.1	0.495	16.487	2.756	1.406	6.86	15.22
			(25)	0.0003	0.68	(36)	0.1	0.095	0.450	0.149	0.039	0.12	0.18
P. decipiens	M	Jl	16	0.0068	67.55	12	2.1	0.665	3.740	1.811	1.657	7.69	18.93
			(70)	0.0001	0.65	(72)	0.0	0.266	0.101	0.344	0.115	0.46	0.34
Perlinella ephyra	U	Jn	3	0.1491	64.10	3	53.5	0.001	27.467	4.232	2.773	8.83	16.80
				0.0032	0.51		0.4	0.001	0.404	0.113	0.052	0.42	0.03
Orthoptera													
Acrididae													
Arphia sulphurea	M	My–Jn	3	0.2345	69.23	3	71.1	0.802	0.653	1.224	0.345	8.29	16.77
				0.0219	1.89		4.4	0.040	0.072	0.054	0.088	0.64	0.50
Dissosteira carolina	F	Jl–Se	7	0.9060	69.76	7	277.9	0.015	2.430	1.254	0.525	10.11	15.96
				0.0718	1.06		29.6	0.006	0.522	0.091	0.118	1.06	1.74

continued

APPENDIX 1—*continued*

Taxon	S	Date	N_1 (*)	WM (g)	%HOH	N_2 (*)	DM (mg)	Fe (ppt)	Ca (ppt)	Mg (ppt)	Na (ppt)	K (ppt)	N (%)
D. carolina	M	Jl–Se	17	0.4448	69.03	16	138.5	0.261	1.864	1.338	0.248	9.13	14.03
				0.0162	0.76		6.3	0.071	0.171	0.093	0.057	0.42	0.32
Hippiscus rugosa	F	My–Jn	6	1.1465	71.77	5	304.7	0.091	1.623	1.426	0.703	12.67	13.50
				0.1124	0.91		28.9	0.077	0.174	0.132	0.151	0.61	0.49
H. rugosa	M	My–Jn	8	0.6356	70.41	8	190.8	0.104	1.593	1.454	0.341	10.8	15.81
				0.1555	0.75		47.6	0.069	0.594	0.125	0.177	0.35	0.81
H. rugosa	I	My	4	0.2605	74.09	4	66.3	0.532	1.176	1.533	0.697	11.38	15.71
				0.0636	1.03		14.8	0.062	0.277	0.197	0.085	0.32	0.10
Melanoplus spp	U	My–Jl	107	0.1237	72.06	82	42.9	0.360	2.185	1.634	0.337	11.98	17.37
				0.0140	0.48	(117)	4.6	0.056	0.094	0.054	0.057	0.20	0.25
M. bivittatus	F	Jl	9	0.8966	69.87	9	277.7	0.002	2.470	1.390	0.056	11.33	15.25
				0.0734	1.16		34.4	0.001	0.235	0.063	0.040	0.39	0.68
M. bivittatus	M	Jn–Au	18	0.4230	71.93	18	126.0	0.025	1.799	1.286	0.033	12.13	16.07
				0.0192	0.74		8.1	0.016	0.133	0.060	0.027	0.43	0.42
M. bivittatus	I	Jn	4	0.0866	72.83	5	46.2	0.212	2.292	2.155	0.035	13.75	17.19
				0.0451	0.94		13.0	0.173	0.261	0.221	0.031	1.83	0.61
M. borealis	F	Au	12	0.2586	71.40	12	74.8	0.089	2.167	0.767	0.310	15.10	16.61
				0.0146	0.72		5.6	0.030	0.266	0.123	0.163	0.87	0.74
M. borealis	M	Au	24	0.2410	69.63	23	73.7	0.070	1.216	0.942	0.934	12.98	17.09
				0.0060	0.55		2.9	0.011	0.117	0.076	0.136	0.57	0.47
M. confusus	F	Au	9	0.7327	68.41	9	234.4	0.057	1.314	1.160	1.077	11.25	13.53
				0.1499	1.47		54.3	0.017	0.249	0.070	0.131	0.60	0.61
M. confusus	M	Au	12	0.4912	67.60	9	161.5	0.049	0.927	1.085	0.901	11.12	15.64
				0.0115	0.16		4.7	0.012	0.067	0.063	0.110	0.28	1.45
Tettigoniidae													
Orchelimum vulgare	F	Au	6	0.1305	72.51	6	36.0	0.103	0.786	1.064	0.545	14.53	16.09
				0.0231	0.82		6.8	0.038	0.082	0.030	0.099	0.72	1.22
O. vulgare	M	Au	4	0.1129	70.92	4	33.4	0.161	0.645	0.930	0.565	13.28	22.75
				0.0111	1.70		4.4	0.075	0.079	0.060	0.162	0.30	2.39
Gryllidae													
Gryllus pennsylvanicus	F	Jl–Se	17	0.1384	73.60	16	36.3	0.170	3.312	1.456	2.208	14.99	15.31
				0.0345	0.76	(17)	10.3	0.047	0.362	0.191	0.303	1.29	0.42
G. pennyslvanicus	M	Jl–Au	11	0.0716	76.46	11	16.8	0.090	1.256	1.091	2.552	18.10	16.87
				0.0051	0.65		1.3	0.017	0.152	0.044	0.245	0.81	0.45
Hemiptera													
Nepidae													
Ranatra fusca	U	Au	3	0.0620	72.26	3	17.3	0.649	7.506	2.630	2.259	6.22	17.98
				0.0101	3.75		3.7	0.056	0.727	0.791	0.135	0.30	0.86
Reduviidae													
Arilus cristatus	M	Au	3	0.0327	69.83	4	46.3	0.028	2.759	1.815	1.890	13.94	17.31
				0.0006	1.34		31.5	0.010	0.615	0.262	0.512	0.69	1.47

Rhopalidae													
L. trivittatus	I	Jn	20	0.0249	70.92	20	7.3	0.013	3.742	3.778	0.460	11.96	18.54
			(64)	0.0035	0.72	(64)	1.1	0.003	0.252	0.122	0.044	0.29	0.35
Pentatomidae													
Acrosternum hilare	F	My, Se	3	0.0817	62.42	3	20.8	0.775	1.231	1.830	1.017	7.09	16.52
				0.0168	4.25		2.3	0.075	0.217	0.089	0.136	0.44	1.36
A. hilare	M	Jn–Jl	3	0.0990	57.29	3	52.3	0.237	1.264	1.656	0.000	7.31	15.17
							9.3	0.142	0.259	0.635	0.000	0.24	2.07
Nabidae													
Nabicula subcoloepteratus	F	Jn	5	0.0253	63.38	4	10.7	0.377	2.969	1.941	0.477	9.21	19.42
				0.0034	3.01	(5)	1.5	0.109	0.276	0.113	0.233	0.89	0.82
Homoptera													
Cercopidae													
Philaenus spumarius	U	Jn	6	0.0104	67.20	6	3.4	0.013	4.803	3.331	0.103	16.30	18.24
			(25)	0.0006	0.88	(25)	0.1	0.007	0.212	0.134	0.034	0.88	0.20
P. spumarius	I	Jn	10	0.0055	66.29	10	1.8	0.045	5.110	3.500	0.114	15.34	19.10
			(97)	0.0009	0.71	(97)	0.3	0.009	0.184	0.100	0.050	0.35	0.45
Cicadillidae													
Graphocephala sp	F	Jn	10	0.0216	63.39	10	7.7	0.601	0.996	1.207	0.000	9.36	16.63
				0.0006	0.97	(20)	0.2	0.090	0.025	0.028	0.000	0.42	0.29
Graphocephala sp	M	Jn	10	0.175	68.38	10	5.4	0.618	0.904	1.304	0.000	11.74	19.69
				0.0003	0.72	(22)	0.1	0.169	0.012	0.031	0.000	0.76	0.25
Magicicada cassini	F	Jn	14	0.5942	56.54	14	259.4	0.581	1.652	1.730	0.913	7.04	13.93
				0.0285	1.03		15.0	0.040	0.119	0.091	0.099	0.21	0.86
M. cassini	M	Jn	10	0.4768	63.68	10	168.1	0.724	1.097	1.978	1.260	9.21	15.88
				0.0177	1.21		3.8	0.044	0.039	0.038	0.080	0.26	0.70
Coleoptera													
Carabidae													
Carabus nemoralis	U	My–Jn	6	0.4578	62.03	5	204.3	0.631	0.665	0.845	3.692	6.50	15.72
				0.1162	0.98		37.7	0.031	0.087	0.081	0.218	0.50	0.92
Chlaenius pennsylvanicus	U	Jn–Jl	6	0.0527	60.35	6	2.0	0.100	0.769	1.156	1.425	6.29	15.70
				0.0026	0.58		1.3	0.066	0.051	0.096	0.194	0.40	0.50
C. sericeus	U	Jn	5	0.0482	58.39	5	20.3	0.028	1.280	1.413	1.036	8.03	16.24
				0.0042	0.92		2.3	0.008	0.249	0.079	0.088	0.38	0.57
Cymindis sp	U	Jn, Se	3	0.0313	61.50	3	12.0	0.199	0.829	0.459	1.291	9.25	19.20
				0.0008	1.18		0.2	0.064	0.046	0.289	0.151	1.07	0.52
Pterostichus sp1	U	My–Jl	29	0.0895	64.57	20	41.7	0.050	1.709	1.613	1.906	7.24	15.81
			(30)	0.0096	1.46		3.8	0.014	0.235	0.123	0.202	0.33	0.72
Scarites subterraneous	U	Ap–Jn	9	0.4114	59.87	9	156.8	0.268	0.774	0.993	2.778	6.84	15.72
				0.0253	1.23		3.5	0.082	0.046	0.093	0.270	0.90	0.75
Dytiscidae													
Rhantus sp	U	Jn	11	0.0396	68.71	7	15.8	0.010	2.238	1.568	3.113	8.75	17.40
				0.0039	2.06	(10)	3.0	0.003	0.225	0.133	0.460	0.42	1.06

continued

APPENDIX 1—*continued*

Taxon	S	Date	N_1 (*)	WM (g)	%HOH	N_2 (*)	DM (mg)	Fe (ppt)	Ca (ppt)	Mg (ppt)	Na (ppt)	K (ppt)	N (%)
Agabus sp	U	Jn	9	0.0289	74.73	4	7.3	0.022	1.654	2.036	4.812	10.79	19.97
				0.0016	0.43	(8)	0.3	0.002	0.161	0.108	0.124	0.36	0.48
Dytiscus sp	U	Jn	8	0.1375	72.71	7	40.5	0.008	0.865	1.221	4.187	10.77	20.99
				0.121	2.10		8.1	0.003	0.120	0.036	0.357	1.06	1.37
Scarabaeidae													
Macrodactylus subspinosus	U	Jn	16	0.0407	67.83	14	13.5	0.086	0.994	2.551	0.794	12.40	17.52
				0.0013	0.76	(15)	0.7	0.051	0.031	0.101	0.089	0.62	0.47
Elateridae													
Melanotus communis	U	Jn–Jl	12	0.0608	57.13	12	26.0	0.217	0.579	1.336	0.689	5.59	16.21
				0.0074	1.14		3.2	0.080	0.049	0.164	0.150	0.28	0.64
Lampyridae													
Photinus sp	M	Jn	3	0.0133	67.12	1	4.3	0.462	1.594	1.654	1.385	10.37	20.95
				0.0021	3.40	(3)							
Cantharidae													
Chauliognathus pennsylvania	U	Au	13	0.0535	72.81	13	14.6	0.151	0.934	1.730	2.231	13.31	17.96
				0.0023	0.54		0.7	0.051	0.135	0.098	0.218	0.49	0.59
Coccinellidae													
Adalia bipunctata	U	My–Jn	6	0.0123	59.37	3	5.0	0.572	0.865	1.312	0.617	9.69	17.60
				0.0005	0.71	(6)	0.1	0.201	0.047	0.009	0.295	1.42	0.33
Coccinella septempunctata	U	My, Au	21	0.0446	62.37	19	15.4	0.141	0.706	1.136	0.241	9.16	15.72
				0.0038	1.51		1.1	0.059	0.059	0.076	0.079	0.77	0.73
Chrysomelidae													
Calligrapha sp	U	My	6	0.0426	63.72	6	15.5	0.672	0.653	1.666	0.291	7.28	16.92
				0.0032	0.60		1.2	0.083	0.069	0.103	0.072	0.31	0.85
Hydrophilidae													
Enochrus sp	U	Jn–Jl	14	0.0169	74.18	4	4.3	0.559	0.981	2.679	3.869	7.53	17.43
				0.0006	1.15	(13)	0.3	0.217	0.070	0.117	0.354	0.47	0.39
Hydrophilus sp	U	Jn	3	0.2463	56.30	3	106.3	0.011	0.818	1.321	1.906	5.76	13.62
				0.0215	2.08		3.8	0.003	0.153	0.091	0.206	0.33	0.31
Staphylinidae													
Homaeotarsus sp	U	Jn	3	0.0110	57.78	3	4.2	0.403	0.783	1.068	0.968	6.71	20.89
			(9)	0.0007	1.66	(9)	0.2	0.119	0.031	0.053	0.057	0.77	1.32
Staphylinus sp	U	Jn	5	0.0635	62.59	5	24.1	0.032	1.370	1.433	1.991	8.37	14.14
				0.0057	1.04		3.4	0.007	0.175	0.150	0.077	1.05	0.98
Hymenoptera													
Ichneumonidae													
Ophion sp	F	Ap–Jl	21	0.291	60.77	11	12.1	0.232	0.466	0.743	0.200	6.67	18.31
				0.0015	0.68	(18)	0.8	0.104	0.056	0.044	0.048	0.39	0.49
Ophion sp	M	Ap–Jl	11	0.0311	60.46	9	13.4	0.258	0.688	0.838	0.152	6.51	17.36
				0.0027	0.93	(11)	1.4	0.104	0.045	0.066	0.089	0.42	0.65

Vespidae													
Polistes fuscatus	U	Ap–Au	24	0.1177	62.13	23	47.5	0.082	0.437	0.793	0.477	11.47	19.56
				0.0069	0.49		2.1	0.017	0.032	0.041	0.074	0.78	0.42
Vespula maculafrons	U	My–Jn	4	0.1685	63.83	4	61.2	1.004	0.541	0.946	0.768	5.59	17.20
				0.0034	0.44		1.3	0.030	0.15	0.021	0.069	0.07	0.44
Sphecidae													
Chlorion aerarium	U	Au	9	0.2384	65.23	9	75.2	0.119	0.761	1.062	1.506	11.12	16.75
				0.0267	0.21		11.1	0.012	0.046	0.019	0.210	0.63	0.75
Sceliphron caementarium	U	Jl–Au	11	0.1901	64.47	11	70.0	0.193	0.652	1.209	1.645	10.64	18.00
				0.0171	0.78		5.4	0.077	0.063	0.118	0.137	0.72	0.53
Apidae													
Apis mellifera	U	My–Au	9	0.0829	68.39	10	27.5	0.375	1.410	1.189	0.614	12.75	14.00
				0.0032	0.38		1.6	0.058	0.153	0.047	0.077	1.35	0.93
Bombus sp	U	My–Jn	10	0.5443	63.40	10	200.6	0.284	0.511	0.834	0.203	7.30	15.41
				0.0335	0.66		15.0	0.069	0.088	0.047	0.055	0.38	0.59
B. fervidus	U	Au	3	0.1345	60.23	3	53.6	0.126	1.245	1.005	0.133	12.52	17.05
				0.0086	0.58		4.2	0.032	0.163	0.057	0.027	0.48	0.84
B. pennsylvanicus	U	Jn, Au	11	0.1679	64.58	11	50.6	0.174	1.033	1.004	0.281	11.61	14.75
				0.0346	0.62		6.6	0.018	0.178	0.059	0.064	0.92	0.98
Andrenidae													
Andrena sp	U	My–Jn	19	0.0491	61.66	14	21.6	0.287	0.819	1.128	0.138	7.77	17.02
				0.0069	0.85	(25)	3.0	0.054	0.057	0.049	0.046	0.45	0.84
Andrena sp	U	My	14	0.0520	58.92	7	19.4	0.484	0.974	1.047	0.196	5.21	12.74
w/pollen				0.0051	1.07	(9)	2.4	0.040	0.066	0.073	0.036	0.14	0.36
Aphidiidae													
Ephedrus incompletus	F	Ap–My	6	0.0070	60.41	3	3.0	0.998	1.129	0.991	0.443	5.29	20.42
				0.0015	4.58	(7)	0.4	0.097	0.104	0.144	0.115	0.32	0.73
Trichoptera													
Phryganeidae													
Banksiola dossuaria	F	Jl	4	0.0782	67.55	4	25.4	0.345	1.644	1.777	0.522	6.67	13.63
				0.0086	0.74		3.0	0.080	0.142	0.458	0.023	0.25	0.48
B. dossuaria	M	Jn–Au	3	0.0467	67.04	3	15.3	0.565	1.200	1.995	0.543	7.16	18.25
				0.0027	2.30		1.0	0.219	0.189	0.691	0.331	0.23	0.74
Hydropsychidae													
Hydropsyche sp1	U	My–Jl	19	0.0121	63.16	12	2.6	0.199	0.990	0.797	2.219	7.01	17.22
			(74)	0.0018	0.62	(65)	0.1	0.016	0.028	0.062	0.060	0.17	0.35
Hydropsyche sp2	F	My–Jn	28	0.0101	64.19	10	3.4	0.793	2.581	1.246	2.120	6.85	17.32
				0.0006	0.83	(40)	0.2	0.100	0.283	0.059	0.231	0.33	0.33
Hydropsyche sp3	F	My	4	0.0194	66.09	5	7.3	0.867	2.060	1.059	2.014	5.70	15.63
				0.0031	1.24	(11)	0.4	0.120	0.131	0.061	0.142	0.18	0.46
Macronema zebratum	F	Jl	7	0.0496	56.83	8	21.5	0.062	1.875	1.121	0.622	4.01	14.39
			11	0.0013	0.37		0.5	0.030	0.203	0.087	0.120	0.23	0.27
M. zebratum	M	Jl		0.0254	70.79	6	7.4	0.143	3.401	1.177	1.096	7.03	17.50
				0.0018	1.27	(12)	0.5	0.073	0.425	0.076	0.058	0.25	0.82

continued

APPENDIX 1—*continued*

Taxon	S	Date	N_1 (*)	WM (g)	%HOH	N_2 (*)	DM (mg)	Fe (ppt)	Ca (ppt)	Mg (ppt)	Na (ppt)	K (ppt)	N (%)
Limnephilidae													
Limnephilus consocius	F	Jn–Se	8	0.1014	66.16	8	35.0	0.117	1.982	1.078	0.772	8.28	14.57
				0.0162	0.95		6.3	0.037	0.304	0.230	0.234	1.32	0.56
L. consocius	M	Jn–Se	7	0.0526	68.16	4	25.9	0.106	1.024	1.200	0.409	7.54	19.21
				0.0127	2.47	(5)	8.3	0.040	0.228	0.353	0.195	1.56	1.07
P. radiatus	M	Jl–Au	3	0.1398	65.71	3	48.2	0.197	1.018	1.428	1.243	10.62	17.21
				0.0103	1.41		5.3	0.038	0.206	0.114	0.280	2.42	0.38
Lepidoptera													
Hesperiidae													
Thymelicus lineola	U	Jn	12	0.0328	61.14	8	12.2	0.001	6.155	5.106	0.559	12.32	18.24
				0.0019	0.47	(9)	0.7	0.001	0.475	0.505	0.214	0.85	1.00
Papilionidae													
Pterourus glaucus	U	Jn, Au	6	0.3398	59.57	6	137.4	0.004	2.045	2.727	1.056	10.63	16.29
				0.0612	1.47		24.9	0.001	0.266	0.466	0.364	1.14	1.01
Pieridae													
Artogeia rapae	F	Ap–Jn	12	0.0541	63.60	11	20.1	0.001	0.995	2.385	1.348	12.96	18.21
				0.0044	0.85	(12)	2.0	0.001	0.072	0.200	0.163	0.76	0.68
A. rapae	M	Ap–Jn	13	0.0524	62.33	10	20.4	0.006	1.016	2.609	1.101	12.17	18.30
				0.0022	0.77	(13)	1.2	0.003	0.060	0.189	0.295	1.01	0.94
Colias eurytheme	F	Jn	3	0.0926	63.52	4	34.1	0.005	0.894	2.062	0.097	11.83	17.67
				0.0076	0.73		2.0	0.003	0.170	0.471	0.059	1.62	2.09
C. eurytheme	M	My	3	0.1025	62.50	4	39.9	0.069	0.775	3.518	0.074	15.15	21.41
				0.0042	0.74	(5)	2.6	0.020	0.021	0.544	0.060	0.52	0.65
C. philodice	F	My–Jn	7	0.0630	61.69	4	25.9	0.114	1.176	3.096	0.176	10.63	18.39
				0.0045	0.49	(7)	2.6	0.056	0.191	0.466	0.102	0.84	1.12
C. philodice	M	My–Jn	9	0.0779	62.61	6	30.2	0.085	0.761	3.467	0.104	12.03	17.53
				0.0045	0.72	(10)	2.5	0.038	0.107	0.537	0.065	0.28	1.18
Nymphalidae													
Phycoides tharos	F	My–Jn	3	0.0545	66.92	3	17.6	0.424	1.554	2.937	1.593	9.26	17.21
				0.0054	1.95		1.4	0.185	0.523	0.404	0.305	1.06	0.08
P. tharos	M	My–Jn	9	0.0288	63.05	8	10.8	0.484	3.171	6.790	2.990	10.88	19.49
				0.0007	1.24		0.4	0.137	0.505	0.931	0.474	1.03	0.57
Vanessa atalanta	U	My–Jn	6	0.1843	58.84	6	75.6	0.394	1.429	2.637	1.383	6.52	14.75
				0.0154	1.60		8.0	0.148	0.81	0.297	0.081	0.89	1.03
Satyridae													
Cercyonis pegala	F	Jl	5	0.0848	58.69	14	32.3	0.061	0.962	1.127	0.050	7.67	15.46
				0.0121	1.13		2.0	0.042	0.104	0.083	0.025	0.41	0.92
C. pegala	M	Jl	4	0.0573	62.17	5	22.4	0.007	0.706	0.989	0.041	7.35	15.40
				0.0044	1.78		1.4	0.003	0.110	0.058	0.036	0.36	0.75
Pyralidae													
Ostrinia nubilalis	U	Jn–Se	8	0.0312	60.51	7	14.0	0.362	1.097	1.808	0.204	11.42	13.05
				0.0045	3.39	(9)	1.2	0.159	0.216	0.366	0.100	1.07	0.54

Sphingidae												
Ceratomia undulosa	U	Jn–Jl	4	1.0216	54.17	3	449.6	0.041	0.768	1.080	0.071	4.63	9.56
				0.0535	2.25		44.5	0.016	0.049	0.067	0.058	0.71	1.29
Arctiidae												
Cisseps fulvicollis	U	Se	9	0.0800	58.01	17	25.0	0.037	1.376	0.745	0.000	12.59	14.30
				0.0034	1.00		1.5	0.004	0.093	0.063	0.000	0.60	0.53
Diacrista virginica	U	My	5	0.1644	59.99	5	63.7	0.039	0.249	0.901	0.091	7.67	14.01
				0.0218	2.83		4.2	0.019	0.013	0.161	0.072	0.97	0.72
Estigeme acrea	M	My–Jn	3	0.2285	61.85	3	88.4	0.013	0.779	1.361	0.000	12.07	14.23
				0.0253	1.86		13.2	0.010	0.174	0.204	0.000	3.17	2.29
Halysidota tesselaris	U	Jn–Jl	19	0.1977	64.86	19	69.6	0.255	1.023	2.693	0.000	8.35	17.22
				0.0073	0.63		2.9	0.061	0.031	0.262	0.000	0.29	0.45
Phragmatobia fuliginosa	U	My, Jl	6	0.0922	61.53	5	33.3	0.008	1.216	0.381	0.066	11.40	18.25
				0.0048	1.34		2.5	0.006	0.239	0.104	0.059	1.26	0.88
Spilosoma virginica	U	My–Jn	6	0.1363	57.55	6	58.2	0.043	0.359	0.858	0.076	7.40	14.35
				0.0051	1.62		4.0	0.017	0.061	0.174	0.042	0.68	1.05
Geometridae												
Eulithis diversilineata	U	Jl–Se	13	0.0299	62.19	9	10.4	0.151	1.388	0.836	0.138	10.58	18.26
				0.0024	1.19		0.4	0.085	0.149	0.316	0.052	0.91	0.59
Eusarca confusaria	U	Jn–Au	6	0.0548	63.46	5	21.9	0.105	1.006	1.544	0.009	6.76	14.75
				0.0073	1.80		3.0	0.086	0.121	0.136	0.008	0.62	0.61
Xanthorhoe ferrugatta	U	My–Jn	5	0.0164	63.74	3	6.5	0.438	1.252	4.056	2.156	10.04	20.68
				0.0011	0.89		0.7	0.185	0.196	0.451	0.517	1.17	1.18
Xanthotype urticaria	U	Jn–Se	7	0.0409	59.33	4	20.3	0.014	1.083	1.326	0.188	9.20	17.86
				0.0132	1.71		6.4	0.012	0.223	0.349	0.114	1.15	1.07
Danaidae												
Danaus plexipus	U	Jn–Au	9	0.2157	64.02	9	77.6	0.313	1.943	2.093	1.491	7.22	17.68
				0.0062	0.62		2.5	0.100	0.182	0.182	0.175	0.35	0.56
Zygaenidae												
Harrisina americana	U	Jn–Au	16	0.0561	64.12	9	21.7	0.013	1.106	2.211	0.014	9.16	16.29
				0.0031	0.75	(10)	2.1	0.008	0.131	0.319	0.007	0.58	0.73
Yponmeutidae												
Yponomeula multipunctella	U	Jn	4	0.0132	62.13	5	5.0	0.001	0.725	0.901	0.022	8.25	16.49
			(13)	0.0004	0.88	(13)	0.4	0.001	0.019	0.065	0.012	0.24	0.88
Ctenuchidae												
Ctenucha virginica	U	Jn–Jl	2	0.1432	62.80	3	49.7	0.150	1.137	0.547	1.013	8.56	13.02
							10.2	0.058	0.286	0.147	0.476	1.42	0.34
Noctuidae												
Abagrotis alternata	U	Jn, Se	3	0.1467	67.81	3	47.5	0.010	0.851	2.231	0.000	9.31	15.01
				0.0202	0.57		7.2	0.004	0.161	0.689	0.000	1.52	1.48
Agrotis gladiaria	U	Se	4	0.1460	63.86	4	52.1	0.037	1.820	1.556	6.093	11.33	14.96
				0.0155	2.71		5.0	0.015	0.310	0.253	0.929	0.88	1.15
Amphipoea americana	U	Jl–Au	19	0.0877	60.88	18	33.9	0.134	1.070	3.236	0.007	8.77	16.18
				0.0036	1.60		1.6	0.042	0.058	0.353	0.005	0.24	0.65

continued

APPENDIX 1—*continued*

Taxon	S	Date	N_1 (*)	WM (g)	%HOH	N_2 (*)	DM (mg)	Fe (ppt)	Ca (ppt)	Mg (ppt)	Na (ppt)	K (ppt)	N (%)
Apamea amputatrix	U	Jl	6	0.2272	58.57	6	95.2	0.052	1.457	3.182	0.009	8.48	15.05
				0.0156	1.11		9.4	0.029	0.134	0.181	0.006	0.73	0.66
Caenurgina sp	U	Ap–My	16	0.0530	65.61	10	23.1	0.061	0.490	2.081	0.105	9.30	17.98
				0.0067	0.92		4.3	0.016	0.045	0.229	0.046	0.33	0.64
C. crassiuscula	U	Jl	12	0.0741	61.43	12	28.6	0.058	0.832	2.477	0.000	7.01	14.24
				0.0022	0.89		1.1	0.020	0.055	0.270	0.000	0.14	0.33
C. erecta	U	Ap, Jl	6	0.0617	64.29	4	22.9	0.033	0.622	2.476	0.087	10.21	16.79
				0.0072	1.13	(6)	3.3	0.026	0.102	0.214	0.049	0.96	1.34
Crymodes devastator	U	Jl–Au	8	0.1576	62.35	8	60.0	0.172	1.524	2.089	5.457	9.65	16.05
				0.0098	1.02		5.0	0.101	0.133	0.160	0.697	0.36	0.87
Feltia jaculifera	U	Jl–Se	19	0.1076	63.63	9	41.2	0.365	0.854	5.298	0.000	7.64	19.89
				0.0054	0.58		3.0	0.120	0.031	0.940	0.000	0.37	0.88
Lacinopolia renigera	U	Jn–Jl	34	0.0707	64.87	20	25.3	0.307	0.938	2.722	0.047	9.16	15.76
				0.0021	0.62		1.5	0.053	0.059	0.147	0.020	0.27	0.41
Lacinopolia lorea	U	Jn–Jl	4	0.0743	67.36	4	24.4	0.223	0.947	3.727	0.000	8.91	16.41
				0.0075	0.58		2.8	0.073	0.071	0.241	0.000	0.36	0.78
Leucania multilinea	U	Jn–Jl	45	0.1317	63.65	25	52.6	0.221	1.287	3.371	0.000	8.83	18.26
				0.0029	0.57		1.9	0.050	0.069	0.329	0.000	0.22	0.44
L. phragmitidicola	U	Jn–Jl	8	0.1446	66.20	8	49.5	0.210	1.439	3.364	0.041	8.31	17.70
				0.0099	1.07		4.3	0.074	0.138	0.609	0.027	0.48	0.56
L. pseudargyria	U	Jl–Se	18	0.2054	65.24	17	74.2	0.158	1.813	1.888	0.000	9.09	17.78
				0.0103	0.81		3.3	0.057	0.095	0.271	0.000	0.30	0.47
Leucania ursala	M	Jn–Jl	6	0.2124	67.41	7	68.3	0.098	1.979	2.537	0.000	9.95	18.31
				0.0056	0.49		1.64	0.044	0.096	0.050	0.000	1.06	0.49
Ogdoconta cinereola	F	Jl	8	0.0896	60.99	8	35.1	0.089	1.694	1.667	2.662	17.25	16.57
				0.0031	0.91		1.9	0.012	0.225	0.123	0.505	1.40	0.90
Panopoda rufimargo	U	Jl	2	0.1558	64.21	3	45.1	0.364	0.713	3.533	0.018	7.04	18.76
							9.0	0.144	0.039	0.597	0.008	1.45	0.57
Pseudaletia unipuncta	U	My–Au	6	0.1493	65.95	5	50.2	0.037	1.075	3.724	0.171	10.31	15.70
				0.0122	2.01		7.0	0.018	0.297	0.644	0.081	1.27	1.36
Schinia sp	U	My	3	0.0664	63.06	4	22.8	0.197	0.565	2.635	0.258	8.30	16.76
				0.0060	2.26		3.0	0.096	0.126	0.225	0.155	0.34	0.85
Simyra henrici	U	My–Jn	3	0.1017	63.92	3	36.5	0.185	0.589	1.449	0.000	7.06	20.86
				0.0016	0.67		1.1	0.097	0.090	0.090	0.000	0.85	0.88
Xestia dolosa	U	Jn–Se	15	1.008	68.48	8	34.2	0.212	0.861	2.837	0.000	8.09	17.34
				0.0064	1.10		2.8	0.054	0.076	0.278	0.000	0.25	1.24
Diptera													
Tipulidae													
Tipulid unknown	F	Se	4	0.0711	72.62	4	19.6	0.077	1.683	0.362	4.047	9.14	14.35
				0.0102	1.84		3.3	0.022	0.304	0.092	0.971	0.45	1.01
Tipula sp1	F	My–Jl	9	0.0315	62.05	5	13.5	0.134	0.855	0.986	1.441	9.67	18.45
				0.0032	0.82		1.4	0.070	0.172	0.067	0.574	1.04	0.92

Tipula sp1	M	My–Jn	5	0.0310	68.45	5	9.3	0.420	0.671	0.886	1.102	7.82	16.99
				0.0026	1.08	(6)	1.1	0.197	0.096	0.035	0.380	0.53	0.90
Tipula sp3	F	Jn–Se	13	0.0187	67.93	6	6.2	0.093	1.972	0.185	0.975	11.60	17.06
				0.0012	1.25	(12)	0.5	0.013	0.110	0.054	0.104	0.26	0.41
Tipula cunctans	F	My–Se	15	0.0265	60.17	8	11.7	0.773	1.551	1.496	0.933	8.34	18.57
				0.0021	1.63	(9)	1.5	0.354	0.247	0.213	0.261	0.53	1.17
T. cunctans	M	My–Se	8	0.0216	63.33	6	8.5	0.699	2.081	0.953	1.818	9.20	18.23
				0.0035	2.14	(8)	1.2	0.366	0.653	0.244	0.333	0.91	1.10
T. trivittata	F	My–Se	10	0.0435	63.78	6	17.6	0.407	1.290	0.884	2.106	8.53	17.21
				0.0028	1.22		2.2	0.211	0.219	0.143	0.504	1.07	0.91
T. trivittata	M	My	5	0.0204	65.15	5	10.7	1.174	1.353	1.123	1.958	7.99	18.81
				0.0026	2.69		1.4	0.432	0.250	0.265	0.606	0.61	1.13
Culicidae													
Aedes sticticus	M					8	0.9	1.745	1.568	1.525	3.255	7.69	18.27
						(95)	0.1	0.086	0.094	0.102	0.146	0.32	0.29
Aedes vexans	M					3	0.9	0.807	5.254	2.638	2.829	10.01	19.03
						(37)	0.0	0.047	0.111	0.048	0.178	0.08	0.32
Chironomidae													
Chironomous attenuatus	F	Ap	4	0.0035	68.15	7	0.6	0.204	0.871	1.167	3.627	10.28	19.65
			(48)	0.0007	1.51	(122)	0.0	0.034	0.062	0.033	0.100	0.15	0.32
Tanytarsus sp	F	Jn	7	0.0103	67.17	4	3.1	0.473	1.684	1.644	2.570	7.10	18.63
				0.0011	2.04	(15)	0.1	0.321	0.113	0.095	0.095	0.81	0.12
Tabanidae													
Tabanus sulcifrons	M	Jn, Au	5	0.1101	59.09	3	22.5	0.013	3.798	3.305	2.416	8.31	16.62
				0.0249	3.90		3.0	0.000	0.664	0.124	0.205	0.22	1.26
Calliphoridae													
Calliphora vomitoria	F	Jn	3	0.0702	65.40	3	27.5	0.604	0.573	1.989	2.006	6.48	13.68
				0.0049	1.02		3.7	0.081	0.076	0.178	0.166	0.58	1.16
Bibionidae													
Bibio sp	U	My	10	0.0089	67.53	3	2.9	0.185	0.422	1.184	1.203	9.31	20.01
				0.0007	1.50	(10)	0.2	0.008	0.022	0.091	0.358	0.13	0.57
Tachinidae													
Winthermia sp	U	My	5	0.0416	65.75	5	14.5	0.215	1.111	1.307	1.367	8.52	17.90
				0.0022	0.80		1.0	0.026	0.066	0.045	0.156	0.38	0.62
Chaoboridae													
Chaoborus sp	U	My	3	0.0128	67.15	4	2.2	1.906	0.983	1.651	3.003	6.50	18.49
				0.0018	1.68	(27)	0.7	0.052	0.048	0.400	0.240	0.27	0.60
Scatopagidae													
Scatophaga sp	F	My	8	0.0195	69.46	4	6.8	0.158	0.333	1.179	3.243	11.39	18.34
				0.0023	0.72	(8)	1.0	0.011	0.047	0.101	0.435	0.34	0.34
Scatophaga sp	M	My	8	0.0227	66.75	5	7.0	0.187	0.381	0.823	2.476	6.61	17.61
				0.0023	0.64	(9)	0.7	0.031	0.031	0.043	0.238	0.44	0.51

WM = Wet mass, S = sex, M = male, F = female, U = unknown or both, I = immature, Mr = March, Ap = April, My = May, Jn = June, Jy = July, Au = August, Se = September, Oc = October, %HOH = percentage body water, DM = dry mass. WM and %HOH sample size is designated as N_1, sample size for DM and elemental analyses is designated N_2, and (*) = number of individuals tested, if different from number of samples. Values given are arithmetic means with standard errors shown below each mean when $N \geqslant 3$.