Biodiversity and Rarity Of *Phyllophaga* (Coleoptera: Scarabaeidae) in a Temperate Hardwood Forest

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ABSTRACT *Phyllophaga* (Coleoptera: Scarabaeidae) species were collected with a blacklight trap during 1992–1994 at a single site in a relict hardwood forest in central Iowa. There were 1,580 specimens collected, representing 13 species which ranked in proportional abundance from 43.67 to 0.06%. Simpson's diversity index (D) for species taken in this study was $D = 2.87$ compared with $D = 4.17$ for species taken across Iowa in historical data. The disparity in the indices is attributed to the limited ecological habitat sampled compared with available habitats in Iowa. *Phyllophaga balia* (Say) was the most abundant species (43.67%) in the current study, whereas in the historical data it was an uncommon species (0.02%). Another species, *Phyllophaga spreta* (Horn), believed to be a truly rare species throughout the midwestern states, was taken in modest numbers (0.95%). This is the first report of this species in Iowa since it's original description in 1887. Three species from the current study and 8 species derived from historical data are considered to be ecologically rare. It is suggested that the presence of *P. spreta* may be attributed to the habitat quality at the site.

KEY WORDS *Phyllophaga*, biodiversity, rare species, temperate forest

Phyllophaga IS A large genus that occurs throughout North and South America. Luginbill and Painter (1953) recognized 152 species north of Mexico. Adults are primarily nocturnal leaf feeders on woody vegetation (Travis 1934, Andre 1937), are highly polyphagous on a wide range of plants (20–50 species) (Ratcliffe 1991), and most species are strong fliers and highly attracted to electric lights (Ratcliffe 1991). The life cycle from egg through adult requires 2–3 yr in the midwestern United States (Travis 1934, Luginbill and Painter 1953). Several species can be economically damaging to crops and landscape vegetation; because of this commercial and esthetic importance, comprehensive faunal surveys have been conducted in several midwestern states.

Iowa is a state where 2 major ecosystems merge—the eastern hardwood forest and the tallgrass prairie. The *Phyllophaga* in this region of ecological convergence received a significant amount of attention during the early 1900s. Jaques (1926, 1927, 1928), Travis (1934), and Andre (1937) conducted extensive surveys across Iowa and collectively suggested that 33 species probably occurred in the state. Before, and especially after these early faunal surveys, much of the original natural flora and fauna of Iowa was gradually but significantly altered. Eastern hardwood forest covered 12–20% of Iowa when pioneers first settled the region in the mid- to late 1800s, but only 4–6% remain in forest today (Thomson and Hertel 1981, Leatherberry et al. 1992, van der Linden and Farrar 1993, and Dinsmore 1994.) A majority of Iowa's remaining forest is fragmented into smaller woodlots with the floral composition and structure significantly altered by livestock grazing and/or commercial logging (Norris 1995). Some of the forest and nearly all of the tallgrass prairie has been converted to agricultural production and 69.4% of Iowa's land is now in cultivation for crops (Iowa Farm Bureau Federation 1991). One result of this natural ecosystem loss or alteration was the extirpation of 29 species of vertebrates that no longer naturally occur within the state (Dinsmore 1994). The impact of this environmental change on the invertebrate fauna of the state is unknown for most insect taxa.

We sampled *Phyllophaga* in a hardwood forest in central Iowa because the genus is a well known and diverse taxon in the midwestern United States. We believe *Phyllophaga* could be used as an invertebrate index of biodiversity and a benchmark for monitoring influences in future habitat alterations. The 3 objectives of our study were as follows: (1) to characterize the biodiversity of *Phyllophaga* in a relict hardwood forest; (2) to contrast the biodiversity at this site to a statewide survey conducted nearly 60 yr ago; and (3) to determine if any *Phyllophaga* spp. in this forest might be classified as ecologically rare.

Materials and Methods

Adult *Phyllophaga* were collected at East Reactor Woods, which is located in Ames, IA. This study site is rated as mostly natural forest that has been selectively logged without destroying the structure and

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Table 1. Biodiversity of *Phyllophaga* species collected in East Reactor Woods, Ames, IA (1992–1994), and collected or reported from Iowa (Travis 1934)

East Reactor Woods species	n	Rank abundance	Iowa species	n	Rank abundance
P. balia (Say)	690	1	*P. hirticula* (Knoch)	42,102	1
P. futilis (LeConte)	614	2	*P. implicita* (Horn)	17,208	2
P. crenulata (Frölich)	90	3	*P. fusca* (Frölich)	15,549	3
P. ilicis (Knoch)	84	4	*P. tristis* (F.)	10,732	4
P. anxia (LeConte)	22	5	*P. futilis* (LeConte)	7,416	5
P. tristis (F.)	20	6	*P. rugosa* (Melsheimer)	5,089	6
P. implicita (Horn)	18	7	*P. inversa* (Horn)	906	7
P. spreta (Horn)	15	8	*P. crassissima* (Blanchard)	649	8
P. drakii (Kirby)	10	9	*P. hornii* (Smith)	563	9
P. fusca (Frölich)	9	10	*P. vehemens* (Horn)	434	10
P. marginalis (LeConte)	4	11	*P. anxia* (LeConte)	397	11
P. nitida (LeConte)	3	12	*P. drakii* (Kirby)	340	12
P. inversa (Horn)	1	13	*P. fraterna* Harris	213	13
			P. ilicis (Knoch)	149	14
			P. micans (Knoch)	137	15
			P. crenulata (Frölich)	102	16
			P. marginalis (LeConte)	53	17
			P. prunina (LeConte)	53	18
			P. congrua (LeConte)	44	19
			P. fervida (F.)	28	20
			P. nitida (LeConte)	26	21
			P. balia (Say)	23	22
			P. bipartita (Horn)	17	23
			P. forsteri (Burmeister)	11	24
			P. corrosa (LeConte)	9	25
			P. vilifrons (LeConte)	4	26
			P. barda (Horn)	2	27
			P. lanceolata (Say)	1	28
			P. longitarsa (Say)	1	29
			P. ephilida (Say)	0	30
			P. gracilis (Burmeister)	0	31
			P. quercus (Knoch)	0	32
			P. spreta (Horn)	0	33
Total no. species	1,580			102,258	
D	2.87			4.17	

natural diversity of the woodland community (Norris 1995). East Reactor Woods is ≈15 ha in size, contains some of the highest quality woodlands in Ames, and has the greatest diversity of woodland wildflowers in the county (Norris 1995). The dominant woody vegetation is sugar maple, *Acer saccharum* Marsh.; white oak, *Quercus alba* L.; basswood, *Tilia americana* L.; ironwood, *Ostrya virginiana* (Mill.); and black walnut, *Juglans nigra* L. The topography of the study area is characterized as uplands with gently sloping to very steep, well-drained, loamy soils formed in glacial till (DeWitt 1984).

A 15-watt blacklight trap (O. B. Enterprises, Oregon, WI) was continuously operated for 3 yr (1992–1994) from the 1st week in May until the last week in September directly east of the YMCA lodge (42° 02′ 24″ N, 93° 39′ 25″ W) in East Reactor Woods. Beetles were removed from the trap every 1–3 d and collectively stored in ethyl acetate killing bottles in 7–d increments. Beetles were identified to species, and voucher specimens were deposited in the entomology collections of Iowa State University, Texas A&M University, and each of the authors.

Biodiversity was calculated using Simpson's index:

$$D = \frac{1}{\sum_{i=1}^{S} P_i^2}$$

and determining, for each species, the proportion of individuals that it contributes to the total in the sample (i.e., the proportion is P_i for the ith species and s is the total number of species) (Simpson 1949, Harper and Hawksworth 1995). D was calculated for the species collected at East Reactor Woods and the species reported by Travis (1934).

Ecologically rare species are defined following Gaston's (1994) proportion of species that is equal to the X% with the lowest abundance or smallest range sizes in the assemblage. The 1st quartile of the frequency distribution (i.e., 0–25%) of species abundance (Gaston 1994) is used to define *Phyllophaga* rarity in this study.

Results and Discussion

Thirteen species of *Phyllophaga*, represented by 1,580 specimens, were collected at East Reactor

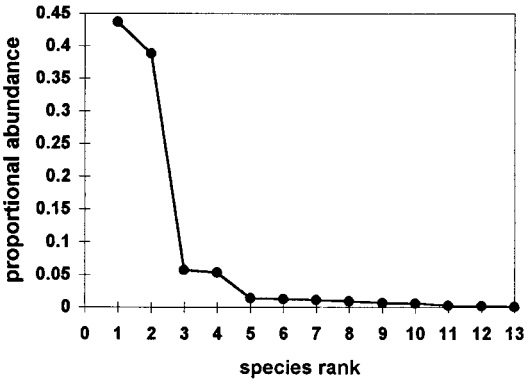

Fig. 1. Proportional abundance of 13 *Phyllophaga* spp. collected at East Reactor Woods, Ames, IA, 1992–1994 (see Table 1 for list of species).

Table 2. Historical surveys for *Phyllophaga* in the midwestern United States

State	No. species	No. specimens examined	No. *P. spreta* specimens	Reference
Illinois	34	114,493	0	Forbes 1916
Indiana	22	7,912	0	Chandler et al. 1955
Iowa	32	102,258	0	Travis 1934
Iowa	26	42,559	0	Andre 1937
Iowa	23	22,413	0	Jaques 1926, 1927, 1928
Iowa	15	1,580	15	Rice and Riley (current study)
Kansas	44	?	0	Knaus 1897
Missouri	29	>10,000	0	Owens 1950
Nebraska	33	6,623	0	Ratcliffe 1991
Ohio	36	80,866	0	Neiswander 1963
Wisconsin	17	50,000	0	Sanders and Fracker 1916
Wisconsin	19	56,344	18	Chamberlin et al. 1943
Total		485,048		

Woods during the 3-yr study (Table 1). The 2 most common species, *P. balia* (Say) and *P. futilis* (LeConte), dominated the *Phyllophaga* fauna, comprising 43.7 and 38.9%, respectively, of the proportional abundance of the 13 species collected in the light trap (Fig. 1). The proportional abundance of any of the other 11 species did not exceed 6%. *Phyllophaga crenulata* (Frölich) and *P. ilicis* (Knoch) ranked 3rd and 4th, respectively, and were nearly equal in proportional abundance; together they represented 11% of the beetles collected at East Reactor Woods. These 4 species comprised 93.6% of the beetles collected during the 3-yr study. In contrast, Travis (1934) did not find *P. balia* to be common in his Iowa collections; it ranked 22nd at a very low 0.022% in proportional abundance when compared with all Iowa species. He found *P. futilis* to be more common, ranking as the 5th most common species and 7.25% in proportional abundance. Travis (1934) reported *P. hirticula* (Knoch) as the most common species in Iowa but we did not collect it at East Reactor Woods.

The remaining 9 *Phyllophaga* species (*P. anxia* through *P. inversa*, Table 1) collected at East Reactor Woods were much less common, or even rare, and ranked from 1.39 to 0.06% in proportional abundance. Five of these species—*P. anxia* (LeConte), *P. tristis* (F.), *P. implicita* (Horn), *P. drakii* (Kirby), and *P. fusca* (Frölich)—were more abundant in Travis's (1934) statewide survey and represented 16.8–0.3% of his observed fauna.

Calculation of Simpson's biodiversity index suggests that the *Phyllophaga* fauna at East Reactor Woods is rated at $D = 2.87$, which is less than the Iowa statewide biodiversity rating of $D = 4.17$ (Table 1). Twenty species recorded from Iowa by Travis (1934) were not collected at East Reactor Woods.

Using Gaston's (1994) definition of rarity as the 1st quartile of proportional abundance, 3 species at East Reactor Woods could be classified as ecologically rare—*P. inversa* (Horn), *P. marginalis* (LeConte), and *P. nitida* (LeConte) (Table 1). When a broader ecological region is considered, in this instance the state of Iowa, 8 species are ecologically rare—*P. barda* (Horn), *P. bipartita* (Horn), *P. corrosa* (LeConte), *P. forsteri* (Burmeister), *P. lanceolata* (Say), *P. longitarsa* (Say), *P. spreta* (Horn), and *P. vilifrons* (LeConte) (Table 1). Although 3 species, *P. ephilida*, *P. gracilis*, and *P. quercus*, appear in the historical list (Travis 1934), they were not collected and are therefore not considered as rare because their presence and or abundance are unknown in Iowa.

Phyllophaga in the midwestern United States were intensively pursued by several entomologists during this century, resulting in the collection of nearly half a million beetles in 8 states with a significant proportion being collected in Iowa (Table 2). The Iowa records begin with Jaques (1926, 1927, 1928) and his collection of 22,413 beetles. When Travis (1934) published his monograph of Iowa *Phyllophaga*, he had accumulated records of 102,258 adult *Phyllophaga* covering a 10-yr period. Although several species eluded his capture, he suggested that 33 species probably occurred within the state (Table 1). Andre (1937) captured 42,559 beetles representing 26 species in 69 of the 99 Iowa counties during the spring and summer of 1935. Many of the *Phyllophaga* surveys in other states were similarly exhaustive in nature, collecting tens of thousands of beetles (Table 2). Except for Chamberlain et al. (1943) in Wisconsin, 1 species had eluded them all; this was *P. spreta* (Horn).

Phyllophaga spreta was described late in the 19th century from 2 males collected in Iowa and Maryland (Horn 1887). Forty-seven years later, Travis (1934) noted in his Iowa monograph that *P. spreta* was still a very rare species known only from the 2 type specimens, one ironically being collected in the very state he had exhaustively surveyed. Likewise, Luginbill and Painter (1953) commented that *P. spreta* was "very rare" without quantifying or qualifying this rarity. They had collection records from 4 states (Alabama, Illinois, Ohio, and Wisconsin) and suggested that the host was black walnut, *J. nigra.* Pike et al. (1977) repeated the *P. spreta* midwestern state records of Luginbill and Painter (1953) and included the single Missouri collection record of Sanderson (1936). With

the Pike et al. (1977) publication, *P. spreta* was now widely documented from 7 states but is still a very uncommon species.

Phyllophaga spreta was the 9th most common species at East Reactor Woods and ranked just under 1% in proportional abundance. At East Reactor Woods, 15 specimens of *P. spreta* were captured during 1993 (n = 2) and 1994 (n = 13).

In the context of earlier midwestern *Phyllophaga* surveys and Luginbill and Painter (1953), *P. spreta* could easily be regarded as rare. Gaston (1994) defines rarity as "the state of having a low abundance and/or a small range size." Low abundance, not small range size, is the defining factor with this ecologically rare species because it has been collected across a wide geographical area from the Great Plains (Iowa) to the Gulf of Mexico (Alabama) and to the eastern Atlantic coast (Maryland). Although, species rarity in *Phyllophaga* has been stated (Luginbill and Painter 1953), it has not been defined. It certainly could be argued that *P. spreta* is a rare species in the midwestern states based upon its absence from literature records, but rarity should be defined within a known parameter. A useful cut-off point suggested by Gaston (1994) is the 1st quartile of the frequency distribution of species abundance. This quartile definition measures the population size of one or several species relative to the density of all species being considered. Using this definition, *P. spreta* is not rare at East Reactor Woods but is rare across the state of Iowa and throughout most of its known geographic range.

The *Phyllophaga* biodiversity at East Reactor Woods was not as great as that observed by Travis (1934) across the state of Iowa. This was not unexpected because East Reactor Woods represents only a small fragment of the ecological habitat available to the genus when compared with the entire state. However, the collection of 2 particular species, *P. balia* and *P. spreta*, at East Reactor Woods seems particularly noteworthy when compared with the collection efforts of earlier entomologists.

Phyllophaga balia was not rare by definition (Gaston 1994) during Travis's (1934) 10-yr survey in Iowa, but it was uncommon. In his collection of >102,000 beetles, he found only 23 specimens of *P. balia.* In contrast, *P. balia* was the most ubiquitous species collected at East Reactor Woods, consisting of 690 specimens, comprising 43.7% of the *Phyllophaga* collection.

Phyllophaga spreta, however, truly is a rare species across most of its geographical range. Gaston (1994) argued that although some scientists would clearly prefer to reserve the term "rare" for use only with respect to species' global populations and entire geographic ranges, most scientists would accept that there will be some species that can be regarded as rare at any given spatial scale. The exception to *P. spreta* rarity, however, is the population at East Reactor Woods where it occurs in sufficient densities to be considered fairly common. The specific ecological reasons for the abundance of both *P. spreta* and *P. balia* are unknown. Vinson and Hawkins (1998) have suggested that invertebrate richness in streams is jointly structured by historical events and by the physical and chemical conditions unique to each location. Likewise, Strand and Merritt (1999) suggested that riverine invertebrate communities were altered by land clearing and livestock grazing. Possibly the preservation of the vegetational quality and absence of floral degradation by livestock at East Reactor Woods (Norris 1995) may be significant contributors to the sustainability of these species' population.

What we observed with *P. balia* and *P. spreta* is that individuals of a species are not uniformly distributed in space; they occur in greater numbers in some places than in others (Gaston 1994). The uniqueness of the *Phyllophaga* biodiversity at East Reactor Woods is the rediscovery of what appears to be a viable population of *P. spreta* in a relict hardwood forest. The question of how uncommon or rare species persist is an important one (Gaston 1994) for additional research.

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References Cited

Andre, F. 1937. Studies on brood A June beetles in Iowa. Iowa State Coll. J. Sci. 11: 267–280.

Chandler, L., J. G. Taylor, and H. O. Deay. 1955. *Phyllophaga* collected at light traps in Indiana (Scarabaeidae, Coleoptera). Proc. Ind. Acad. Sci. 65: 149–158.

Chamberlain, T. R., C. L. Fluke and J. A. Callenbach. 1943. Species, distribution, flight, and host preferences of June beetles, in Wisconsin. J. Econ. Entomol. 36: 674–680.

DeWitt, T. A. 1984. Soil survey of Story County, Iowa. U.S. Department of Agriculture, Soil Conservation Service, Washington, DC.

Dinsmore, J. J. 1994. A country so full of game: the story of wildlife in Iowa. University of Iowa Press, Iowa City.

Forbes, S. A. 1916. A general survey of the May–beetles (*Phyllophaga*) of Illinois. Univ. Ill. Agric. Exp. Stn. Bull. 186.

Gaston, K. J. 1994. Rarity. Chapman & Hall, London.

Harper, J. L., and D. L. Hawksworth. 1995. Preface, pp. 5–12. *In* D. L. Hawksworth [ed.], Biodiversity—measurement and estimation. Chapman & Hall, London.

Horn, G. H. 1887. Revision of the species of *Lachnosterna* of America north of Mexico. Trans. Am. Entomol. Soc. 14: 250.

Iowa Farm Bureau Federation. 1991. 1991 facts: facts on Iowa agriculture. Des Moines, IA.

Jaques, H. E. 1926. A preliminary survey of May beetles (*Phyllophaga* sp.) in Iowa. Proc. Iowa Acad. Sci. 33: 337–339.

Jaques, H. E. 1927. A further report on the May beetles (*Phyllophaga* sp.) in Iowa. Proc. Iowa Acad. Sci. 34: 314–315.

Jaques, H. E. 1928. The distribution of white grubs in Iowa. Proc. Iowa Acad. Sci. 35: 304–305.

Knaus, W. 1897. The *Lachnosterna* of Kansas. Entomol. News 8: 214–217.

Leatherberry, E. C., S. M. Roussopoulos, and J. S. Spencer, Jr. 1992. An analysis of Iowa's forest resources, 1990. U. S.

Dep. Agric. For. Serv. North Cent. For. Exp. Stn. Resour. Bull. NC–142.

Luginbill, P., and H. R. Painter. 1953. May beetles of the United States and Canada. U. S. Dep. Agric. Tech. Bull. No. 1060.

Neiswander, C. R. 1963. The distribution and abundance of May beetles in Ohio. Ohio Agric. Exp. Stn. Res. Bull. 951.

Norris, W. R. 1995. A natural area inventory of Ames, Iowa. M.S. thesis, Iowa State University, Ames.

Owens, V. H. 1950. The *Phyllophaga* of Missouri. M.S. thesis, University of Missouri, Columbia.

Pike, K. S., R. L. Rivers, and Z B Mayo. 1977. Geographical distribution of the known *Phyllophaga* and *Cyclocephala* species in the North Central States. Neb. Agric. Exp. Stn. Misc. Publ. 34.

Ratcliffe, B. C. 1991. The scarab beetles of Nebraska. Bull. Univ. Nebr. State Mus. 12: 1–333.

Sanders, J. G., and S. B. Fracker. 1916. *Lachnosterna* records in Wisconsin. J. Econ. Entomol. 9: 253–261.

Sanderson, M. W. 1936. *Phyllophaga spreta* (Horn) in Missouri. J. Kans. Entomol. Soc. 9: 30.

Simpson, E. H. 1949. Measurement of diversity. Nature (Lond.) 163: 688.

Strand, M., and R. W. Merritt. 1999. Impacts of livestock grazing activities on stream insect communities and the riverine environment. Am. Entomol. 45: 13–29.

Thomson, G. W., and H. G. Hertel. 1981. The forest resources of Iowa in 1980. Proc. Iowa Acad. Sci. 88: 2–6.

Travis, B. V. 1934. Phyllophaga of Iowa. Iowa St. Coll. J. Sci. 8: 313–363.

van der Linden, P. J., and D. R. Farrar. 1993. Forest and shade trees of Iowa, 2nd ed. Iowa State University Press, Ames.

Vinson, M. R., and C. P. Hawkins. 1998. Biodiversity of stream insects: variation at local, basin, and regional scales. Annu. Rev. Entomol. 43: 271–293.

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