Distribution and Functional Roles of Rare and Uncommon Moths (Lepidoptera: Noctuidae: Plusiinae) Across a Coniferous Forest Landscape

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ABSTRACT The temporal and spatial distribution and abundance of 15 rare to uncommon species of plusiine moths were compared across a watershed landscape dominated by a coniferous forest located on the western slope of the Cascade Mountains in Oregon. The 5-yr study assessed the species in the context of functional roles related to caterpillar host plants categorized into three guilds: conifer, hardwood tree and shrub, and herbaceous-feeding species. Also, the landscape was considered in the context of five geographic zones based on elevation and habitat type. Species richness and abundance were highest within the herb-feeding guild, seven (47%) species and 74 (47%) individuals. The conifer-feeding guild consisted of four species (27%) and 64 (40%) individuals, whereas the hardwood tree and shrub guild consisted of four species (27%) and 21 (13%) individuals. In combination, zones II, III, and IV, high elevation sites with extensive subalpine meadow habitat, exhibited a species richness of 14 (93%) and 119 (75%) individuals. Six species occurred in only one of the five zones, and three of these species occurred in zone II, a mid to high elevation zone with a total of nine plusiine species. Only 3 of the 15 species occurred in all five zones; each of these species represented one of the three feeding guilds and exhibited their highest abundance in zone III, a high elevation site with extensive subalpine meadow habitat. The presence of subalpine meadows contributed to increasing landscape heterogeneity across the watershed and was the primary factor contributing to the overall species richness among the Plusiinae within the H.J. Andrews Experimental Forest by providing a suitable environment for species in the herb-feeding guild. We suggest that, in a context that may be generalized to other environments and other taxa, the additive effects of rare and uncommon species with special or restricted habitat requirements provide an important contribution to the biodiversity within a local landscape. Furthermore, environments with a relatively high degree of temporal variability, such as meadows and other early successional plant communities, can be a major factor in contributing to the biodiversity within a local landscape.

KEY WORDS biodiversity, forest, Plusiinae, species richness, subalpine meadows

THE DISTRIBUTION AND RELATIVE abundance of species across the landscape are integral components to understanding spatial and temporal patterns in biodiversity. The scale of the spatial dimensions under consideration is important to the assignment of species to a rank of rarity or commonness. For instance, McCoy and Mushinsky (1992) suggested seven categories of rarity based on geographic distribution, habitat specificity, and local population size. Regardless of how the criteria are defined for noting a species as rare or common, the spatial scale and the measures of relative abundance provide the basis for inferring patterns of interest. Extensive studies of various biomes, ecosystems, and communities have shown that independent of the spatial scale ≈80% of the listed species were rare to uncommon with a high percentage of the species being recorded from a single observation (Preston 1948, Kempton 1979). Yet, as noted by Kunin and Gaston (1993), a majority of ecological studies typically address the most common species.

The focus on common species in a majority of ecological studies concerned with investigating patterns in assemblages or communities of species certainly is multifaceted. Nonetheless, two perspectives, in particular, are relevant. One of the underlying factors involved in dismissing rare species from pattern analysis is the need to conduct certain statistical tests and to attain lower levels of variance when comparing biodiversity values across habitats or treatments (Gaston 1994). A second factor is the assumption that rare species, because of their lack of abundance, are of little ecological significance at a functional level such as in the processes of ecosystem dynamics (Kunin and Gaston 1993). An exception to the omission of rare species

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from landscape based biodiversity studies occurs when the species of interest are connected to a conservation concern, such as the taxa listed as threatened or endangered.

The incentive to conduct our study came from the issues of how rare and uncommon species are distributed across a landscape of relatively small size, how these species can be assessed for their role in ecosystems, and how they contribute to overall biodiversity patterns. Studies relating biodiversity to the landscape are in turn relevant to environmental impact assessments, conservation, and land management planning. Taxa within the Lepidoptera are particularly appropriate for these types of studies because they are relatively well known at a taxonomic level (at least the macrolepidoptera). Also, habits and habitats of moths and butterflies are relatively well documented and species richness at any one site can be relatively high (Butler and Kondo 1991, Hammond and Miller 1998).

Over the past 10 yr, we have been studying Lepidoptera in coniferous forests of the Pacific Northwest at local and regional levels. We have been concerned with various questions focused on species distributions, larval host plants, the taxonomic composition of faunas across landscapes, the effects of land management practices, and the functional role of this diversity in ecosystem foodwebs (Grimble et al. 1992, Hammond and Miller 1998). Also, studies on nontarget effects of *Bacillus thuringiensis kurstaki* Berliner on native assemblages of Lepidoptera (Miller 1990a, 1990b, 1999) were integrated with projects concerning larval host plant relationships (Miller 1995) and associations between the larval life stage and the adult (Miller and Hammond 2000). Furthermore, studies on Lepidoptera were part of an effort to conduct an inventory of arthropods within the watershed of the H. J. Andrews Experimental Forest (HJA), which is located on the west slope of the Cascade Mountains in Oregon (Parsons et al. 1991). In particular, the projects concerning larval host plant studies and the HJA inventory stimulated an interest in the distribution and abundance of macromoths, including an interest in the rare species, across the entire watershed of the HJA forest.

Previously, we reported on a project within the HJA regarding all macrolepidoptera and presented results in the context of host plant-feeding guilds (Hammond and Miller 1998). For this study, we considered a select group of moth species belonging to the subfamily Plusiinae in the family Noctuidae. We chose this particular group for three reasons. First, the species of Plusiinae represent three major host plant guilds: (1) herb feeders, (2) hardwood tree and shrub feeders, and (3) conifer feeders. Second, the subfamily is taxonomically and ecologically well known (Eichlin and Cunningham 1978, Lafontaine and Poole 1991). Third, species within the subfamily are generally uncommon to rare within forested habitats of the Pacific Northwest of North America and within the HJA landscape in particular.

Our objective was to measure plusiine species richness and abundance across the entire watershed to assess relationships involving spatial and temporal patterns relative to elevation and host feeding guilds.

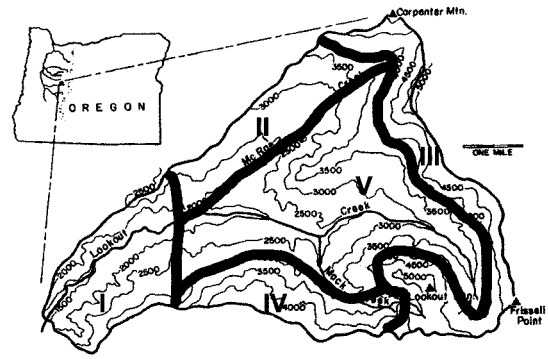

Fig. 1. The location of the H. J. Andrews Experimental Forest [HJA] within the state of Oregon and the five zones within the HJA used for analysis of the distribution of Plusiinae species.

Materials and Methods

Study Site. This study was based on collections of moths within the watershed of the HJA in the Willamette National Forest, Lane County, OR. The HJA is located on the west slope of the Oregon Cascade Mountains, 80 km east of Eugene, and consists of 64,000 ha representing the entire Lookout Creek watershed (Fig. 1). The valley of the watershed starts at an elevation of 425 m on the west end, rising to 1,620 m along a north-south ridge that divides the Lookout Creek drainage from the valley of the Mackenzie River to the east. High elevation ridges ranging from 1,000–1,500 m also mark the boundaries of the HJA to the north and south. Annual precipitation averages 230 cm/yr with most of the rainfall or snow occurring between December and March. The plant communities at the lower elevations, below 1,000 m, are dominated by an overstory of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, and western hemlock, *Tsuga heterophylla* (Raf.) Sarg., with most of the trees creating a canopy 60–80 m high. The understory vegetation at the lower elevations consists of a wide diversity of deciduous hardwood trees and shrubs, including maples (*Acer* spp.), willows (*Salix* spp.), alders (*Alnus* spp.), blueberries (*Vaccinium* spp.), and hazelnut (*Corylus cornuta* Marsh). Steep south-facing slopes occur in various areas throughout the watershed, and the vegetation in these warmer and drier habitats consists of a distinct flora including evergreen hardwood trees and shrubs such as manzanita (*Arctostaphylos* spp.), rhododendron (*Rhododendron macrophyllum* G. Don), and chinquapin (*Castanopsis chrysophylla* Douglas). The plant communities at higher elevations, above 1,000 m, on the eastern ridges support a subalpine forest with a 50–70 m overstory dominated by Pacific silver fir (*Abies amabilis* (Dougl.) Forbes) and noble fir (*Abies procera* Rehder). In addition, extensive subalpine meadows and barren rocky

Table 1. Characteristics of five zones delineated by geographic and floristics features within the H.J. Andrews Experimental Forest (HJA) watershed, Oregon. 1994–1996 and 2000–2001

HJA zone	Aspect	Geographic location	Range in elevation (m)	Habitat type	Species richness
I	mixed	west	low-mid, 500–850	Douglas-fir, riparian	4
II	south	north	mid-high, 800–1200	Douglas-fir, western hemlock	9
III	west	east	high, 1200–1700	true fir, Douglas-fir, subalpine meadows	8
IV	north	south	high, 1000–1500	Douglas-fir, true fir, western hemlock	9
V	mixed	central	mid-high, 600–1100	Douglas-fir, riparian	7

ridgetops occur along the eastern boundary and support a rich diversity of herbs and grasses.

For the purpose of our study, the landscape of the HJA was divided into five zones based on geographical position (Fig. 1), elevation, and the flora (Table 1). Zone I included the low elevation west boundary consisting of the Lookout Creek riparian area and slopes with a mixed orientation in the upland areas dominated by Douglas-fir. Zone II included the north boundary consisting of mid and high elevation slopes with a south facing aspect dominated by Douglas-fir and western hemlock. Zone III included the east boundary dominated by true firs, Douglas-fir, and subalpine meadows at high elevations with a west facing aspect. Zone IV included the south boundary dominated by true firs, Douglas-fir, and western hemlock at high elevations with a north facing aspect. Zone V included the central area of the watershed at mid elevation consisting of the upper portion of the Lookout Creek riparian area and slopes with a mixed orientation in the upland areas dominated by Douglas-fir.

Sampling Protocol. Moths were collected at ultraviolet blacklight traps (BioQuip model #2851, 22-watt circle line bulb, powered by a 12-volt battery, and equipped with a killing agent) during the conduct of two related projects involving seasonal and spatial abundance of moths over a period of 5 yr. The first project involved 263 trap sites and occurred over a period of 3 yr when samples were collected between May and October from 1994 to 1996. The second project involved 12 trap sites and occurred over a period of 2 yr when samples were collected between July and September of 2000 and 2001. In both projects, 12 traps were operated during a single night. One trap was located at each of 12 sites, typically placed 1–2 km apart from one another. In the first project, a set of 12 traps was placed along a transect that extended across multiple zones within the watershed. A total of four transects were established to provide representation of each zone of the HJA watershed as equally as possible. A given transect was sampled once a month over the 3-yr period. A small, select set of locations were sampled each time a given transect was visited. However, most of the traps were moved up to 50 m and placed at a site near the previous sample location to represent the general area but also to obtain collections of moths from different microhabitats. In the second study, the traps were positioned in locations along transects involving zones II and IV to provide data for an area otherwise underrepresented by the first project. Thus, the two projects provided data on moths from a combined total of 275 trap sites representing each zone with an equal sampling effort.

Moths were identified and counted according to date and location of collection. The account of each species includes notes from the literature and our knowledge regarding overall biogeography, general distribution and abundance within Oregon, hosts, HJA counts and locations, map of distribution within the HJA, and summary comments on distribution and abundance related to feeding guilds. Each of the species with known host plants was placed into one of three feeding guilds: (1) conifers, (2) hardwood trees and shrubs, and (3) herbaceous vegetation. The species lacking published records for host plants were assigned to a guild based on our information regarding habits and habitat requirements for related species, thereby providing us with a suspected feeding guild association.

Results and Discussion

Overall, the total numbers of macromoths collected were 49,127 individuals represented by 507 species. Among the Plusiinae, a total of 159 individuals were represented by 15 species. Thus, the species of plusiines comprised a very small proportion, 1% of the individuals and 3% of the species, of the total macromoth fauna. The abundance, species richness, and food plant guild associations of the Plusiinae are the topic of our results and discussion.

Species richness in four of the five zones was very similar, ranging from seven to nine species (Table 1). The lowest value for species richness was noted in zone I, with just four species, none of which were unique to zone I. Zone I, in combination with zone V, demonstrated that the low- to mid-elevation habitats, including mixed aspects dominated by Douglas-fir and with the riparian area of upper and lower Lookout Creek, were areas of the forest not favored by the plusiine species. Only one species, *Eosphoropteryx thyatyroides* (Gn.) was limited to low elevation habitats. Zones II, III, and IV in combination contained 14 of the 15 species. Seven of the 14 species were present exclusively in the high-elevation zones, suggesting the higher elevation habitats, including subalpine meadows, were favored by the plusiine species.

The current list of plusiine species provided an array of host plant generalists and specialists belonging to the three feeding guilds. Each of the three host plant guilds consisted of 4–7 species. The herb-feeding guild included three species with documented host plants:

Table 2. Species richness and abundance of Plusiinae according to larval feeding guild among five geographical zones within the H.J. Andrews Experimental Forest watershed, Oregon, 1994–1996 and 2000–2001

Variable	Zone					Total
	I	II	III	IV	V	
Herb feeding guild						
Richness	1	3	4	4	2	7
Abundance	4	13	45	6	6	74
Conifer feeding guild						
Richness	2	4	1	2	3	4
Abundance	10	18	21	2	13	64
Hardwood tree and shrub feeding guild						
Richness	1	2	2	3	2	4
Abundance	1	3	8	4	5	21

Autographa californica (Speyer), *E. thyatyroides*, and *Trichoplusia ni* (Hbn.). Four additional species lack published host plant records but are likely to be herb feeders: *Autographa metallica* (Grt.), *Autographa pseudogamma* (Grt.), *Autographa sansoni* Dod, and *Autographa speciosa* Ottol. The hardwood feeding guild included four species: *Autographa ampla* (Wlk.), *Autographa corusca* (Stkr.), *Syngrapha epigaea* (Grt.), and *Syngrapha orophila* Hampson. The conifer feeding guild included four species: *Syngrapha alias* (Ottol.), *Syngrapha celsa* (Hy. Edw.), *Syngrapha rectangula* (W. Kby.), and *Syngrapha viridisigma* (Grt.). The following accounts of species distribution, abundance, and host plants are presented according to host plant guilds and in order of overall abundance (Tables 2–4).

Conifer-Feeding Guild. The conifer-feeding guild consisted of four species on the HJA (Table 2). Three of the four species are generalist feeders on Pinaceae, with only *S. alias* relatively host-restricted, feeding on needles of *Picea.* None of the three generalist conifer-feeding species appear to be host-plant limited regarding distribution or abundance. However, many of the individual species and the conifer-feeding guild as a whole exhibited geographically distinct distributions across the HJA landscape. Overall, the highest species richness among the conifer-feeding guild occurred in zone II, where four species contributed 11% of the total plusiine abundance. In contrast, although 13% of the total moth abundance occurred among conifer-feeders in zone III, these values were represented by only one species, *S. celsa.*

Two of the species, *S. celsa* and *S. rectangula*, respectively, were ranked second and third in overall abundance. Also, *S. celsa* was widely distributed over the entire watershed, one of the four species to occur in each of the five zones. Although *S. celsa* was widespread it was most abundant in the subalpine forests of true firs on high ridgetops along the east edge of the HJA. In contrast, *S. rectangula*, was absent from high elevations on the east side of the watershed, occurring in the low and middle elevations on the west side of the HJA.

The uncommon species, *S. viridisigma*, was limited in its distribution to the north side of the HJA. The fourth member of the conifer-feeding guild, *S. alias*, was rare and was represented by a single specimen. Among the conifer-feeding guild, *S. alias* is perhaps the only species limited by host resources within the HJA based on the observations that spruces are uncommon within the watershed whereas nearby extensive spruce forests occur at higher elevations outside the HJA boundaries.

Syngrapha alias is widely distributed across the northern regions of North America, extending southward in the Rocky Mountains to New Mexico and along the West Coast to northern California (LaFontaine and Poole 1991). Caterpillars feed on needles of conifers and appear to be host plant specialists on spruces (*Picea* spp.). In Oregon, *S. alias* appears to be limited to spruce forests, both Sitka spruce forests along the coast and Engelmann spruce forests in the Cascade Mountains and Blue Mountains. The collection of a single specimen (Table 3) on the northern ridge in zone II (Table 4) is consistent with statewide

Table 3. Feeding guild, overall abundance, rank, date and site collection data, flight period, and abundance at peak flight for the species of Plusiinae collected in blacklight traps within the H.J. Andrews Experimental Forest watershed, Oregon, 1994–1996 and 2000–2001

Species	Feeding guild[a]	*N*, rank	No. dates	No. sites	Flight period	Abundance at peak flight
Autographa ampla	hardwood	3, 8	3	3	6 Jul–2 Aug	1
Autographa californica	herb	48, 1	22	35	5 Apr–25 Sep	5
Autographa corusca	hardwood	12, 5	10	13	18 Jul–30 Aug	1
Autographa metallica	(herb)	1, 10	1	1	3 Aug	1
Autographa pseudogamma	(herb)	1, 10	1	1	6 Aug	1
Autographa sansoni	(herb)	8, 6	4	5	6 Jul–18 Jul	3
Autographa speciosa	(herb)	13, 4	6	10	25 Jul–30 Aug	2
Eosphoropteryx thyatyroides	herb	2, 9	2	2	6 Aug–11 Sep	1
Syngrapha alias	conifer	1, 10	1	1	11 Sep	1
Syngrapha celsa	conifer	31, 2	10	21	6 Jul–13 Sep	4
Syngrapha epigaea	hardwood	1, 10	1	1	2 Sep	1
Syngrapha orophila	hardwood	5, 7	4	5	6 Jul–2 Aug	1
Syngrapha rectangula	conifer	26, 3	12	20	22 Jul–12 Sep	3
Syngrapha viridisigma	conifer	6, 6	3	4	31 Jul–26 Aug	2
Trichoplusia ni	herb	1, 10	1	1	13 Sep	1

[a] Parentheses denote that no host plant species are recorded but the species of plusiine was assigned to the respective feeding guild based on suspected host relationships.

Table 4. Individual abundance of species of Plusiinae collected in blacklight traps among five zones within the H.J. Andrews Experimental Forest watershed, Oregon, 1994–1996 and 2000–2001

Species	N	Zone					No. zones
		I	II	III	IV	V	
Autographa ampla	3	0	0	0	2	1	2
Autographa californica	48	4	10	29	1	4	5
Autographa corusca	12	1	2	4	1	4	5
Autographa metallica	1	0	0	0	1	0	1
Autographa pseudogamma	1	0	0	1	0	0	1
Autographa sansoni	8	0	0	5	3	0	2
Autographa speciosa	13	0	2	10	1	0	3
Eosphoropteryx thyatyroides	2	0	0	0	0	2	1
Syngrapha alias	1	0	1	0	0	0	1
Syngrapha celsa	31	2	4	21	1	3	5
Syngrapha epigaea	1	0	1	0	0	0	1
Syngrapha orophila	5	0	0	4	1	0	2
Syngrapha rectangula	26	8	10	0	1	7	4
Syngrapha viridisigma	6	0	3	0	0	3	2
Trichoplusia ni	1	0	1	0	0	0	1
Total no. individuals	159	15	34	74	12	24	x
Species richness	x	4	9	7	9	7	x

records indicating rarity but not conclusive that the species is a resident within the HJA. Based on the observation that Engelmann spruce is nearly absent from the watershed and is common at higher elevations in the Cascade Range north and east of the HJA, it is likely that the single *S. alias* record represents a stray.

Syngrapha viridisigma is widely distributed across the northern regions of North America, extending south through Oregon along the West Coast and through the Rocky Mountains to Arizona (LaFontaine and Poole 1991). Larvae are generalist feeders on needles of conifers with many species of Pinaceae known as hosts. In Oregon, this species is widely distributed in coniferous forests of the Coast Range, Siskiyou, Cascade, and Blue Mountains. However, it is usually rare. The collection of six moths at four trap sites, with a maximum of two individuals in one trap (Table 3) suggested rarity but demonstrated a distribution across two zones (II, and V; Table 4) limited to the north portion of the watershed at elevations of 6l0–900 m (Fig. 2).

Syngrapha rectangula exhibits a disjunct distribution in northeastern North America and in the Pacific Northwest (LaFontaine and Poole 1991). Larvae are generalist feeders on needles of conifers, particularly true firs, *Abies* spp., and Douglas-fir, *Pseudotsuga menziesii.* In Oregon, *S. rectangula* occurs in moist coniferous forests in the northwest corner of the state and may be common in the northern Coast Range. The collection of 26 moths (Table 3) ranked this species as the third most abundant plusiine in the study. Individuals were distributed over four zones (I, II, IV, V; Table 4) in the western portion of the watershed within the western hemlock/Douglas-fir community between 300 and l,220 m (Fig. 2). Given the widespread distribution of this species, it is interesting to note that no individuals were collected in zone III, the zone exhibiting the highest abundance of plusiines. Additionally, moths were absent from most of the higher elevations in the subalpine true fir zone on the east half of the watershed.

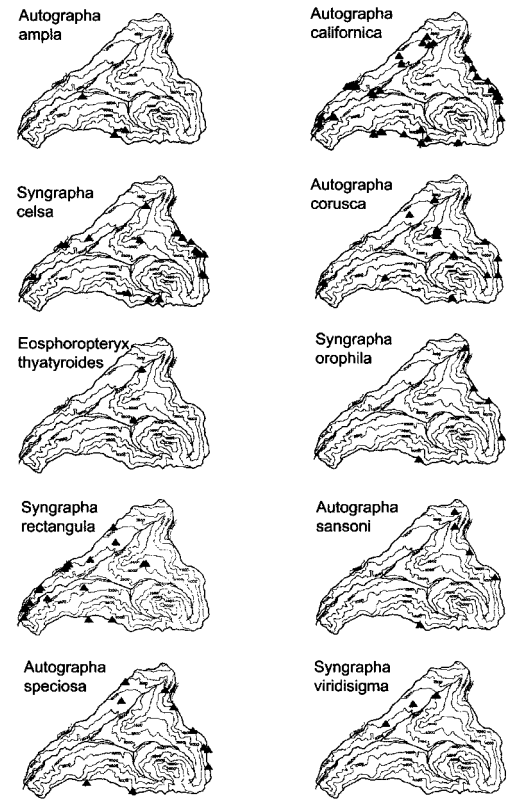

Fig. 2. Maps depicting the distribution of the Plusiinae species present in the H. J. Andrews Experimental Forest during 5 yr (1994–1996, 2000–2001) of sampling.

Syngrapha celsa is limited in distribution to the far western portion of North America extending from southern California and Arizona north to British Columbia (LaFontaine and Poole 1991). Larvae are generalist feeders on the needles of conifers with many species of Pinaceae serving as hosts. This species is common and widely distributed in coniferous forests throughout Oregon, including drier ponderosa pine forests east of the Cascade Mountains. The collection of 31 individuals (Table 3) ranked this species as the second most abundant plusiine in the study, and one of three species represented in all five areas of the watershed (Table 4). A majority of the moths, 68%, were found at high elevations along the eastern ridge in zone III (Fig. 2).

Hardwood-Feeding Guild. Four species were considered as members of the hardwood-feeding guild (Table 2). The highest abundance of hardwood tree- and shrub-feeding species occurred in zone III, which contributed only 5% of the total number of moths collected within the HJA landscape. The highest number of hardwood tree- and shrub-feeding species occurred in zone IV, where three of the four species were present, with *A. ampla* being the most abundant. In contrast, zone I produced only one species, *A.*

corusca. The only host plant generalist among the hardwood feeding guild, *A. ampla*, was generally rare and limited to the south-central portion of the watershed, seemingly not limited by host plant resources. The alder-feeding specialist, *A. corusca*, was the most abundant and widespread moth among the hardwood-feeding species. Alders are common and widespread within the HJA watershed, providing an extensive range of suitable host plant, contributing to *A. corusca* being only one of three species to occur in each of the five zones. However, a hardwood host plant specialist on *Vaccinium*, *S. orophila*, was restricted to the subalpine zone on ridges at an elevation above 1,200 m even though its host plants are widespread throughout the watershed. Similarly, another host plant specialist on *Vaccinium*, *S. epigaea*, was collected only once and would not appear to be limited in abundance and distribution by a lack of suitable host plant resources.

Syngrapha epigaea is widely distributed across the northern regions of North America, extending southward in the mountains to Oregon and Colorado (LaFontaine and Poole 1991). The species is a host plant specialist on blueberries (*Vaccinium* spp.). In Oregon, moths are uncommon to rare but widely distributed in moist forests of the Coast Range, Cascade Mountains, Siskiyou Mountains, and Blue Mountains. The collection of a single specimen (Table 3) on the northern ridge in zone II (Table 4) is consistent with statewide records indicating rarity and residency within the HJA.

Autographa ampla is widely distributed across both northeastern and western North America in moist forests and riparian habitats (LaFontaine and Poole 1991). Larvae are generalist hardwood feeders with host plants documented for numerous species of shrubs and trees. This species is widely distributed in coniferous forests of western Oregon and the Blue Mountains in northeast Oregon. However, moths are uncommon to rare in most areas except coastal rainforests of northwest Oregon where the species can be locally common. The collection of three moths (Table 3) was limited to two zones, IV and V (Table 4), in the south portion of the watershed at elevations of 610-1,200 m (Fig. 2).

Syngrapha orophila is endemic to higher elevations in the northern Rocky Mountains and Pacific Northwest, extending from western Wyoming and Oregon to British Columbia and Alberta (LaFontaine and Poole 1991). Larvae are host plant specialists, feeding on the foliage of blueberries and huckleberries, *Vaccinium* spp. In Oregon, moths occur at higher elevations in the Siskiyou, Cascade, and Blue Mountains. The collection of five moths (Table 3) involved two zones, four of the specimens came from the eastern ridgeline of zone III (Table 4), indicating that this species was limited to the subalpine zones along the ridges above 1,220 m (Fig. 2).

Autographa corusca is endemic to coastal areas of the Pacific Northwest, extending from northern California to southern Alaska (LaFontaine and Poole 1991). Larvae feed on the foliage of alders (*Alnus* spp.). In Oregon, this species may be common but it is limited to the Cascade Mountains and Coast Range. This species, represented by the collection of 12 moths (Table 3), was one of three species to occur in each of the five zones (Table 4). Moths typically occurred above 760 m in the eastern half of the watershed (Fig. 2).

Herb-Feeding Guild. The three species with known host plants were readily assigned to the herb-feeding guild (Table 2). However, four additional species with no recorded host plants are very likely to belong in this group as well. Overall, the herb-feeding species were present predominately in the subalpine meadows along the eastern ridgetops where the diversity of herbaceous vegetation was high. For instance, the herb-feeding guild within zone III contributed 28% of the overall plusiine abundance within the HJA landscape. In contrast, the herb-feeding guild in zone I contributed only 3% of the total abundance and was represented by only one species, *A. californica.* Although *A. californica* is a well-known generalist herb-feeding species in the Willamette Valley vegetable agroecosystems, it was the most widespread species within the HJA and was also particularly abundant in the subalpine meadows where a wide variety of host plants occurred.

Two of the seven herb-feeding species, *T. ni* and *E. thyatyroides*, were absent from the subalpine meadows. Only one individual of *T. ni*, a generalist herb feeder, was collected within the watershed, which is several kilometers to the east from its typical vegetable agroecosytem habitats in the Willamette Valley. Unlike the other agroecosystem associated species, *A. californica*, *T. ni* was rare with the single individual perhaps originating from a residential garden, many of which occur within a couple of kilometers along the McKenzie River drainage. The other plusiine not present in the subalpine meadows was *E. thyatyroides*, an herb-feeding host plant specialist associated with relatively uncommon but widespread species of Ranunculaceae. Nonetheless, *E. thyatyroides* was a rare moth with a very limited local distribution in riparian habitats at middle elevations.

Autographa metallica is endemic to the Pacific Northwest from the coastal mountain ranges in the west, east to Utah, south to the northern Sierra Nevada of California, and north to southern Alaska (LaFontaine and Poole 1991). Larval host plants are unknown but suspected to be herbaceous. This species is widely distributed in Oregon, known from the Coast Range, Willamette Valley, Cascades Mountains, and Blue Mountains. However, moths are rarely collected and not found in numbers exceeding a few individuals. The collection of a single specimen (Table 3) in the south area of the watershed, zone IV (Table 4), is consistent with statewide records indicating rarity and residency within the HJA.

Autographa pseudogamma is widely distributed across the northern regions of North America, extending southward in the high mountains of western North America to California, AZ, and New Mexico (LaFontaine and Poole 1991). Larval host plants are unknown but suspected to be herbaceous. In Oregon, the spe-

cies is strongly confined to high elevations, known from the Cascade Mountains, Blue Mountains, and Steens Mountains. However, this is a rare species and has never been collected in numbers exceeding a few individuals. The collection of a single specimen (Table 3) along a high elevation ridgeline in zone III (Table 4) is consistent with statewide records indicating rarity and residency within the HJA.

Trichoplusia ni is widely distributed throughout the United States and occurs throughout all continental regions of the world. This species is known as the cabbage looper and is considered an agricultural pest in numerous vegetable crops (LaFontaine and Poole 1991) where it often occurs in extremely high numbers. Caterpillars are generalist herb feeders with a recorded host list in excess of 150 species with a strong preference for Brassicaceae. In Oregon, the cabbage looper is widely distributed but generally limited to agricultural habitats, such as cole crops, alfalfa, and peppermint. However, adults may disperse over long distances during the late summer months in the Pacific Northwest. Thus, the collection of a single specimen (Table 3) at a low-middle elevation site in the southwestern area of zone II (Table 4), suggests this species is an agricultural vagrant from the Willamette Valley and not a resident of the watershed

Eosphoropteryx thyatyroides exhibits a disjunct distribution, occurring in eastern North America and in the Pacific Northwest (LaFontaine and Poole 1991). Larvae feed on herbaceous Ranunculaceae such as *Thalictrum* and *Aquilegia.* This species is uncommon in Oregon and found in moist coniferous forests on the west slope of the Cascade Range, in the northern Coast Range, and in the Blue Mountains. The collection of only two individuals (Table 3) in two different traps on two different dates, but both from a riparian area in zone V (Table 4) suggested that this is a rare species limited to a mid elevation, 850 m (Fig. 2), mesic habitat, a pattern of distribution consistent with the distribution and abundance of the known host plants within the HJA.

Autographa sansoni is endemic to the higher mountains of the Pacific Northwest, extending from western Wyoming and Oregon, north to central British Columbia (LaFontaine and Poole 1991). Larval host plants are unknown but suspected to be herbaceous. In Oregon, *A. sansoni* is uncommon and known only from high elevation meadows and ridgetops in the Blue, Cascade, and Siskiyou Mountains. This species also occurs in open areas of the northern Coast Range. The collection of eight individuals (Table 3), five from zone III (Table 4), was limited to subalpine meadows and ridgetops above l,220 m (Fig. 2).

Autographa speciosa was previously considered an extremely rare species. Lafontaine and Poole (l99l) reported that this species was known from only three widely disjunct sites; Vancouver Island, British Columbia, southwest Oregon, and the northern Sierra Nevada of California. In addition to these records we have found this species to be uncommon but widely distributed in undisturbed coniferous forests in western Oregon (J.C.M., unpublished data). In the Cascade Mountains, this species occurs in subalpine meadows and high elevation rocky ridgetops, whereas in the Coast Range it occupies low-elevation old-growth coniferous forest. Larval host plants are unknown but suspected to be herbaceous. The collection of 13 individuals (Table 3) occurred across three zones (II, III, IV; Table 4) but was restricted to high elevation ridges and subalpine meadows above 900 m (Fig. 2).

Autographa californica is widely distributed throughout the western United States (LaFontaine and Poole 1991). This species is known as the alfalfa looper and is considered an agricultural pest in numerous vegetable crops (LaFontaine and Poole 1991) where it often occurs in extremely high numbers. Caterpillars are generalist herb feeders. This species is the most common plusiine in Oregon and in addition to occurring in high abundance in agroecosystems moths may be abundant in natural habitats. The collection of 48 individuals (Table 3) was the highest value for any of the plusiine species. This species was also among the three most widespread species with moths occurring in each of the five zones (Table 4). Moths were particularly abundant, 60% of the total, in subalpine meadows of zone III along the eastern ridge (Fig. 2). Meadow habitat is very suitable for this species because not only does the foliage of herbaceous meadow plants serve as a food resource for the larvae but the flowers of these plants also serve as a nectar source for the adults as was observed during the day.

The phenology of rare and uncommon species is difficult to ascertain. The collection of only one specimen, or a few individuals, within a year suggests the need to sample across many years, but requiring an understanding that between-year climatic patterns can shift flight periods significantly. Nonetheless, a comparison of collection dates, flight periods, and the peak number of individuals collected during one trap-night can be used to develop a profile of seasonal occurrence (Table 3). The most abundant species, *A. californica,* showed the highest number of collection dates, sites, and peak abundance per trap-night as well as the earliest species to fly and the longest flight period. These data suggest that the lack of host plant, spatial, and temporal specialization in *A. californica* may contribute to the relatively high number of moths that were collected. However, a rare vagrant species, *T. ni,* shares many of the traits exhibited by *A. californica,* but the two species exhibited very different spatial and temporal patterns. The species placing second in the number of collection dates was *S. rectangula,* the species ranked third in overall abundance. The species ranked second in overall abundance, *S. celsa,* also ranked second in the number of collection sites, exhibited the second longest flight period and second highest peak abundance per trap-night. The species ceasing to fly at the earliest date was *A. sansoni.* In addition to the singleton species, four other species were collected as single individuals when comparing peak abundance per trap night, data further indicating the rare occurrence of 9 of the 15 species. The phenological profile of the plusiines suggests an extensive

collecting effort must be expended to detect the presence of rare and uncommon species and to develop a reliable list of species during projects with objectives concerning biodiversity.

In conclusion, species of Plusiinae are usually uncommon to rare moths in forested ecosystems compared with species in other taxonomic groups that comprise the total moth fauna. Among the taxa of macromoths the two projects, conducted over a 5-yr period, collected a total of 49,127 individuals represented by 507 species, of which 159 individuals represented by 15 species belonged in the Plusiinae. Five of the 15 species within the HJA watershed were represented by the collection of only one individual, a singleton species. At least one of these species, *T. ni*, was considered a vagrant rather than a resident that was rare. Another of the singleton species, *S. alias*, may also be a vagrant, but its general distribution and host plant relationships do not allow us to discount the species as a rare resident. The other three singleton species, *A. metallica*, *A. pseudogamma*, and *S. epigaea*, are very likely rare resident species based on general patterns of distribution and host plant relationships. Ten of the 15 species within the HJA watershed were represented by at least two individuals over the 5-yr span of the study and were considered rare or uncommon residents. The most abundant species, *A. californica*, was represented by the collection of only 48 individuals. We do not consider any of the Plusiinae to be abundant when put in the context of moth abundance for other species of Lepidoptera found within the HJA watershed (Hammond and Miller 1998).

The general landscape of the HJA watershed exhibits high environmental heterogeneity relative to elevation, slope, temperature, moisture, and disturbance. These features also create heterogeneity in the distribution and abundance of the flora upon which the moth fauna is dependent for larval food plants. Likewise, plusiine species exhibited variable patterns of distribution and abundance across the physical and biotic environmental gradients of this watershed. Landscape features that were influential in the distribution and abundance of the moths involved elevation and plant community, in particular the disjunct and patchy distribution of various host plants and the plant communities they are associated with. Plusiine species richness and the abundance of a majority of the species were highest at the higher elevations, most notably in the subalpine meadows.

The relationship between common and rare elements of a biota is quite important, both from a theoretical and a practical perspective of overall biodiversity. In most biotas of any complexity, ≈80% of the species are always rare or uncommon, and only ≈20% of species are common to abundant (Preston l948, Kempton l979). Thus, in considering the theoretical and practical aspects of managing for biodiversity, the ecological characteristics of the rare species are of particular significance.

The measures of species abundance and species richness are relevant to each of the food plant guilds occupied by the Plusiinae on the HJA. Each guild consisted of a more common species with a wide distribution over the watershed, and several less common species with limited distributions. The rarest and most spatially limited species of each guild appeared to have very stringent environmental requirements or limitations. For instance, rare species within each guild were limited to a single area at middle elevations on the HJA, as with *E. thyatyroides* in moist riparian habitats. For *S. viridisigma*, this habitat appeared to be south-facing slopes of warmer or drier aspect, whereas *A. ampla* was limited to north-facing slopes of a cooler, moister aspect. Without this microhabitat diversity on the watershed, these species might not be able to survive as part of the HJA fauna. Likewise, without the subalpine forest and meadow habitats at the highest elevations on the ridgetops, *A. speciosa*, *A. sansoni*, and *S. orophila* could not be a part of this fauna. In the absence of such heterogeneity, perhaps only three or four of the most common species would be able to exist.

Another aspect of rarity is relevant to understanding the importance of landscape heterogeneity. Species such as *S. viridisigma*, *A. ampla*, and *E. thyatyroides* appeared to have a fragmented distribution across the landscape. Small areas of suitable habitat for locally isolated populations exhibit qualities of refugia. Such refugia represent isolated islands of habitat that were likely more widespread in the past, or that experience fluctuations in the expansion and contraction of their range because of temporal weather or biotic stresses. From these refugia, rare species have the potential to expand their distributions over the broader regional landscape during years with particularly favorable weather or biotic conditions, providing interconnecting gene flow with similarly isolated populations in other watersheds. The ability of these species to survive in a regional landscape during years with poor conditions is thus dependent upon such refugia at a local level across a multitude of regional landscapes. As an example, the range in the geographical distributions of the plusiines outside the HJA, and throughout the Pacific Northwest, suggests the species may be spread across a large portion of the landscape but in a noncontiguous manner. The existence of multiple but localized patches of suitable habitat is essential to their persistence.

Consequently, the overall diversity of a given ecosystem or local landscape is based upon rare or uncommon species with special microhabitat requirements. Our current discussion of the Plusiinae represents a small component of the ≈507 species of macromoths that occur in the HJA. The special microhabitat requirements, such as meadows, canopy gaps, and riparian corridors of the uncommon species that indicate heterogeneity exists across the landscape and in turn provides for higher levels of biodiversity. Presumably, similar considerations regarding landscape heterogeneity are relevant to the several hundred additional rare species within this watershed. Thus, by considering empirical evidence from a select group of moths, we conclude that studies on the com-

position of biodiversity should include the uncommon and rare species because their presence suggests that environmental heterogeneity occurs in the ecosystem. In particular, land management practices that produce and sustain a greater degree of environmental heterogeneity will also produce and sustain higher levels of biodiversity.

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