BUTTERFLIES AND THEIR LARVAL FOODPLANTS AS BIOINDICATORS FOR ECOSYSTEM MONITORING IN THE PACIFIC NORTHWEST

by

Paul C. Hammond

Eastside Ecosystems Management Strategy Project

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INTRODUCTION

Many ecologists such as Ricklefs (1983) have emphasized the Importance of structural complexity and biotic diversity In maintaining the health and stability of natural ecosystems. For example, forests In western North America are not homogeneous tree plantations equivalent to agricultural corn or wheat fields. At the structural level, topographic features of east, west, north, and south slopes provide major environmental gradients of temperature and moisture, Mesic or hydric habitats dissect *the* forest with riparian gallery communities along small streams to large rivers, Interdispersed with natural marshes, bogs, and lakes. Xeric habitats also dissect the forest with open meadows, natural prairie balds, barren rocky ridgetops and cliffs, and rocky talus slopes. Different seral stages In forest succession also contribute to this complexity.

Structural complexity Is directly responsible for supporting biotic diversity. Species diversity at all trophlc levels of an ecosystem's food chain provides ultimate stability and equilibrium to the system. The more 'species that an ecosystem can support through Intricate and Interweaving food webs, the greater its inherent stability. By contrast, simple, linear food chains involving only a few species are very unstable, and typically oscillate between population explosions and crashes that are determined by simple density dependent-Independent processes as discussed by Berryman et al. (1987).

An example of a simple, linear food chain Is a dense, monoculture stand of Douglas fir (Pseudotsuga menziesii), the Douglas-fir tussock moth (Orgyia pseudotsugata) and western spruce budworm (Choristoneura occidentalis), and what few predators and parasitoids specialize on these defoliating herbivores. Campbell (1993) concluded that generalist predators may be most Important in controlling such herbivores outside of epidemic outbreaks. The Important point to consider Is that such generalist predators are *not* generally supported within an ecosystem by a 'single. species of plant (I.e. Douglas fir) as primary producer for the system.

The trophlc levels of all natural ecosystems are ultimately based upon the plants as primary producers, which are eaten by herbivores as primary consumers, which In turn are eaten by predators as second and third order consumers, A high species diversity of plants supports a high diversity of herbivores, which In turn supports similar diversity among generalist predators.

In terrestrial ecosystems, Insects function as planktonic-type organisms, the equivalent of zooplankton In marine systems. Lepidoptera (butterflies and moths) are the primary defoliating herbivores In forest ecosystems, converting plant biomass into animal biomass, and making It available to higher trophic levels In the food chain (Stamp & Casey, 1993).

Lepldoptera are also Important In grassland systems, but share the defoliating role with grasshoppers (Orthoptera) and herbivorous mammals. of the insects, Lepidoptera are primarily active In spring and early summer, while Orthoptera become dominant defoliating herbivores In mid to late summer.

Another Important point Is that most Lepldoptera are highly monophagous, and feed exclusively upon a single type of plant. This is also true of many grasshopper species. Consequently, the more plant species that an ecosystem can support will be reflected by more herbivore and predator species at higher trophic levels.

Small vertebrates such as passerine birds, rodents, shrews, and bats are particularly dependent upon Insects for a dietary protein source when rearing their young In spring and early summer (Welty, 1975). . For example, Graber & Graber (1983) found that migratory passerine birds such as warblers are Largely dependent upon Lepidoptera larvae as a food source, and consume 1.2-1.7 times their own-weight In larvae per day. Likewise, the big-eared bats of the genus Plecotus are known to feed primarily on large adult moths (Whltaker, Maser & Keller, 1977).

These first order predators then become food themselves for second order predators- such as hawks, owls, coyotes, and bobcats. A good example Is the northern spotted owl (Strix occidentalis), which feeds primarily upon the northern-flying squirrel (Glaucomys sabrlnus), which In turn is highly Insectivorous in feeding upon Lepidoptera larvae, beetles, and other Insects (Forsman, Meslow & Wight, 1984; Larrison, 1976).

Considerable progress has recently been achieved towards understanding the rich species diversity at all of these trophlc levels within western coniferous forest ecosystems. Much of this work Is the result of collaboration between the U.S. Forest Service (Pacific Northwest Research Station) and Oregon State University. The H.J. Andrews Experimental Forest (HJA) on the Willamette National Forest has been the site for much of this research. For example, Franklin & Dyrness (1971) listed 475 species of vascular plants on the HJA outside of Introduced conifer plantations, Including 21 species of sporophytes, 16 species of conifers, 58 species of woody angiosperms, and 380 species of herbs and grasses. The Important point Is that 92% of forest plant diversity consists of angiosperms, while only 3% consists of conifers.

Likewise, Parsons et al. (1991) listed 3402 species of arthropods *on* the HJA, Including 492 species of butterflies and moths. Of these defoliating herbivores, 90% feed on angiosperms and only 10% feed on conifers. This Is only logical considering the above plant species diversity.. In other words, It Is the angiosperms that largely support species diversity In forest ecosystem food chains with respect to defoliating herbivores, while conifers are of very little significance. The latter are of more Importance to those portions of the food chain Involved with wood decomposition.

This diversity of defoliating herbivores, that Is supported by the diversity of angiosperms, IS in turn supporting a rich diversity of generalist predators, Including arthropod predators and parasltolds, passerine birds, bats, rodents, and other small mammals. The U.S. Forest Service (1991) found about 100 species of small vertebrates In the Cascade Range that may directly consume lepidopteran larvae, pupae, or adults, or may Indirectly consume Lepidoptera as seoondary predators. These Included 70 species of birds, 20 species of Insectivores and rodents, and 12 species of Insectivorous bats.

Forests in the Blue Mountains of eastern Oregon show similar biodiversity. Grimble, Beckwith & Hammond (1992) conducted a comprehensive survey of the Lepldoptera fauna on the Umatilla and Wallowa-Whitman National Forests, and found 438 species of butterflies and moths, nearly as many as on the HJA. Moreover, 90% of these species feed on angiosperms and only 10% use conifers as a food source, again as on the HJA. Of the angiosperm foodplants, about 50% of Lepidoptera feed on hardwood shrubs and trees, and 50% use herbs and grasses.

Less Is known about Lepidoptera diversity In western rangelands, but 302 species of butterflies and moths have been recorded from the semi-desert rangelands of southeastern Oregon in Harney County.

EFFECTS OF LAND MANAGEMENT PRACTICES ON ECOSYSTEM BIODIVERSITY

As discussed above, complex biodiversity within Intricate food webs confers stability and equilibrium to the overall ecosystem, and this diversity Is based upon angiosperm plants: not conifers. By contrast, monoculture conifer forests that largely exclude angiosperms are lacking In such diversity, and are particularly vulnerable to epidemic explosions of defoliating Insects as a consequence. Much the same Is true of prairies and rangelands that have lost most of their plant diversity through overgrazing by domestic livestock: With the loss of plant and herbivore diversity, the diversity of generalist predators that normally control potential Insect pests is also lost.

Livestock overgrazing has been Identified as a primary factor behind the loss of plant diversity (herbs and grasses) In both forest and rangeland systems. For example, Hammond & McCorkle (1983) found a rich diversity of plants and butterflies on pristine bunchgrass prairie, while adjacent grazed rangeland separated by a fence had almost no plants or butterflies. The fritillary butterflies of the genus Speyeria and their larval foodplants of the genus Viola are particularly sensitive bioindicators of such disturbance, and often become extinct *In* heavily overgrazed areas (Hammond & McCorkle, 1983).

With the elimination of native bunchgrasses and herbaceous plants from rangelands, exotic weeds often invade and replace the natives, Including cheat grass (Bromus tectorum), knapweeds (Centaurea spp.), and leafy spurge (Euphorbla esula). In addition, vast areas of degraded rangelands throughout the western United States have been artificially planted with monoculture stands of exotic crested wheatgrass (Agropyron cristatum) to Improve livestock forage and prevent soil erosion. Unfortunately, most native Insects are unable to feed on exotic plant species, and are not able to survive In *these* degraded grasslands, with the exception of a few Melanoplus grasshopper species that often produce epidemic population explosions In the absence of most predators. Such epidemics have frequently required massive pesticide spray programs for control. However, most insects among the Lepidoptera, Orthoptera, Hymenoptera, and Coleoptera that are so diverse on pristine bunchgrass prairie are conspicuously absent from degraded, overgrazed rangelands overgrown with exotic weeds. BY contrast, Melanoplus grasshoppers are usually scarce or absent from pristine bunchgrass prairie.

Overgrazing by domestic livestock may also be a significant factor behind epidemic explosions of western spruce budworm and Douglas-fir tussock moth In coniferous forests. Campbell & Torgersen (1983) Identified generalist predators such as ants and passerine birds as major consumers of budworms. These predators are largely dependent upon angiosperms and their associated herbivores as a food source when conifer feeders are at low numbers. If livestock eliminate most of the angiosperms (herbs and grasses) from the forest floor, and their defoliating herbivores as a consequence, the generalist predators will also be lost because of a lack of food sources. In turn, with the loss of generalist predators from the ecosystem, conifer feeders such as spruce budworms and tussock moths are free to Increase their populations to epidemic proportions.

Another factor behind the loss of biodiversity In western coniferous forests has been the control of fire during the past 50 years. Periodic ground fires keep the forest'floor open with plenty of light to encourage the growth of angiosperms Including herbs, grasses, and shrubs, which In turn support the herbivores and generalist predators. In the absence of such fires, very dense stands of young fir and pine trees become established and shade out the angiosperms. The forest floor underneath such dense stands retain very few grasses or herbaceous plants. Again, with the loss of general herbivores and predators as a consequence, conifer feeding species are free to expand into epidemics.

There are several management techniques that may be suggested tb address the problems with angiosperm diversity described above, The forest problems caused by elimination of fire could be rectified In two ways. First, controlled ground fires would duplicate the effects of the original, natural fire history In opening up the forest floor for herb-grass growth. Second, selective thinning of over-stocked conifer stands would also help open the forest for more angiosperm growth.

There Is also a simple suggestion to address the destructive Impact of domestic livestock grazing on native grassland plants. Most native herbs and bunchgrasses produce their growth In spring and early summer, and go Into senescence by the middle of July. The plants are primarily vulnerable to livestock grazing during their spring to early summer growth period. If most grazing were delayed until mid-July, livestock would have a much lower destructive Impact upon the native vegetation. While mid to late season forage Is far less nutritious for livestock than the spring forage, delaying grazing until mid-summer does offer a compromise solution for having rich biodiversity In native plant communities together with a domestic livestock grazing program.

ECOSYSTEM MONITORING PROGRAM

The following monitoring program Is designed to assess ecosystem diversity and complexity In both forest and rangeland communities as a measure of ecosystem health. Plants should be monitored as primary producers for the system. Butterflies were chosen to serve as bioindicators of the defoliating herbivores because they are visually conspicuous and easy to observe in the field.

This monitoring program Is designed to be easy, fast, and economical to apply with a minimum of outside assistance or expertise. Even with a shortage of funds and available personnel, land management agencies will still be able to conduct considerable habitat monitoring with minimal lnvestment'ln time and money. Because this program Is designed for simplicity, it is not Set up for rigorous scientific research, although with proper qualifications, the data could be applied to some research studies. For example, replicated plots for statistical comparisons are not part of this monitoring program because of the labor and time required for such work. Nevertheless, this program will still be able to assess the presence or absence of major foodplant groups and their associated herbivores, and to compare the relative frequency of these organisms through time and among various management areas.

Monitoring can be done for only a single year If the purpose is to simply assess habitat quality within a management area at a single point In time. This might be done as part of a resource mapping project In conjunction with long-term management planning. However, plots and transects should be established on a more permanent basis In order to assess the effects of land management practices through time.

In the future, there will likely be major efforts to restore and renovate badly degraded rangelands and forests by replanting the native bunchgrasses and herbaceous plants that have been lost from the ecosystem. The following monitoring program can also be used to assess the success of such restoration efforts.

A total of 11 major plant-groups and 12 major butterfly groups will be monitored as bioindicators of ecosystem health In this program. Healthy ecosystems usually support representatives of about 8 major plant groups and 10 major butterfly groups. BY contrast, the most degraded environments will have virtually none of these plants and butterflies, and badly degraded habitats will only support 2-4 groups of these organisms (see following section on butterfly-plant groups within habitat types).

BIOINDICATOR MONITORING PROGRAM--PLANTS

As discussed above, the basic foundation of any ecosystem is the plant community as primary producers for the system. without the plants, higher trophic levels such as defoliating herbivores, first order predators', and second order predators can not exist. Most plant diversity consists of angiosperms (herbs, grasses, shrubs). Therefore, a blolndlcator monitoring program needs to monitor the diversity of the plant community. A healthy plant community In either grassland or open forest ecosystems consists of the following dietary food groups for defoliating herbivores in the western United States.

Grasses (Gramineae)

The most Important and widespread native bunchgrasses In the Pacific Northwest are needle-and thread grass (Stipa comata), bluebunch wheatgrass (Agropyron spicatum), Idaho fescue grass (Festuca ldahoensls) , and Sandberg bluegrass (Poa sandbergii). 'Other native grasses are also locally Important In special habitats.

Violets (Violaceae)

There Is usually at least one species of Viola In most western plant communities, Including hydric, mesic, and xeric habitats'. Because violets are delicate plants, they are particularly sensitive bioindicators of ecosystem health as discussed by Hammond & McCorkle (1983).

Mustards (Cruciferae)

Many species of mustards are found In a wide diversity of hydric, meslc, and xerlc plant communities, including Streptanthus, Arabis, Sisymbrium, Dentaria, and Cardamine species.

Buckwheats (Polygonaceae)

A great diversity of buckwheat species (Eriogonum spp.) are found In western plant communities, and are often among the more dominant of the herbaceous plants.

Umbellifers (Umbelliferae)

Members of the carrot family or umbelllfers are another important herbaceous group in most plant communities. The desert parsleys (Lomatium spp.) and close relatives are dominant on dry prairies and in other xerlc habitats. Ligusticum and Angelica species are often Important in meslc, montane communities.

Legumes (Legumlnosae)

The legumes are among the most important herbs in all plant communities because of their nitrogen-fixing capabilities. The lupines (Luplnus spp.) and milk vetches (Astragalus spp.) are the most common and widespread of the legumes. In forest and meslc-meadow habitats, the peas (Lathyrus spp.) and clovers (Trifolium spp.) are also Important.

Scrophs (Scrophulariaceae)

Scrophs or figworts constitute another major group of herbs in most western plant communities. The most common and widespread 'genera are the penstemons (Penstemon spp.) and paintbrushes (Castilleja spp.).

Lilys (Liliaceae)

Lilys are usually herbs of *minor* Importance in most plant communities, but may still be useful as bioindicators. The mariposa lilies (Calochortus spp.) are the most prominent of these herbs.

Composites (Compositae)

The composites are always abundant and Important herbs in nearly all plant communities. of particular Interest are the asters (Aster spp.), fleabanes (Erigeron spp.), native thistles (Cirsium spp.), balsam roots (Balsamorhiza spp.), and mules ears (spp.) ia

Nettles (Urticaceae)

Nettles (Urtica spp.) are common bioindicators of mesic riparian habitats, and support a wide diversity of defoliating herbivores in marshes, bogs, lake edges, and along streams.

Shrubs and Small Trees

Woody angiosperms are the other major class of foodplants for defoliating herbivores. These are found in all plant communities ranging from xerlc desert to hydric riparian habitats. The most important include the sages (Artemlsla spp.), rabbit brush (Chrysothamnus spp.), bitter brush (Purshla tridentata), currents (Ribes spp.), snow brush (Ceanothus spp.), cherries (Prunus spp.), willows (Salix spp.), poplars (Populus spp.), alders (Alms spp.), birches (Betula spp.), maples (Acer spp.), mountain mahogany (Cercocarpus spp.), and various other members of the rose family (Rosaceae) and heath family (Ericaceae) Including the huckleberries (Vaccinium spp.) and manzanitas (Arctostaphylos spp.).

A monitoring program for the plant community should serve two purposes. First, it should compare the diversity and productivity of the community among different sites with different physical aspects and management histories. Second, monitoring should track the response of vegetation at a specific site through time In order to assess the effectiveness of various management programs.

To accomplish these two objectives, it is suggested that permanent monitoring plots be established within the management areas of interest. These might be 100 foot square plots in which all plants are taxonomically Identified. All individual plants of the larger and rarer species within the 100 foot plot should be counted. For the smaller and more abundant species, smaller 10 foot square subplots may be established within the larger plot as the permanent monitoring unlt. All Individual plants within this 10 foot subplot should be counted (clonal clumps may be counted as single individuals). Shrubs also should be evaluated with respect to height and degree of senescence (amount of dead material within the shrub). Plots will be counted three times ln May, June, and July

Care should be taken in choosing the location-of permanent monitoring plots. If a management area is heterogeneous with both upland and rlparlan habitats, independent plots should be established ln each habitat type requiring monitoring. It Is also suggested. that the plots be located along the butterfly monitoring transects, perhaps at the midpoint of a transect.

This type of data will enable the land manager to assess each management area with respect to the relative diversity and productivity of each of the major foodplant groups. described above (i.e. bunchgrasses, legumes, composites, etc.). The response of grasses., herbs, and shrubs to various management programs can then be evaluated through time.

It should be noted that more sophisticated and detailed methods of plant monitoring are also available to assess the actual percentage of land coverage for each of *the* major foodplant groups, and to measure the actual biomass production for each plant group at the end of the growing season. However, this monitoring is far more time consuming and labor Intensive, and can not generally be applied to large areas for most practical purposes. Nevertheless, such detailed monitoring could be of interest for specific research programs ln certain situations.

BIOINDICATOR MONITORING PROGRAM--BUTTERFLIES

Butterflies have been extensively used as a monitoring tool for ecology and conservation in Britain since 1976. The methods used by the British, as described by Pollard & Yates (1993), are adapted below for the North American monitoring program, with modifications related to the differences- between Britain and North America. Britain-has a relatively small geographical area and a long history of Intensive human activity and disturbance compared to western North America. It also has a rather small and depauperate fauna compared to North America.

As discussed by Grimble, Beckwith & Hammond (1992), around' 400-500 species of defoliating Lepldoptera are found In the Blue Mountains of eastern Oregon, and 90% of these feed upon the larval foodplant groups (angiosperms) described above. Of these species, about 80% are moths and 20% are butterflies. Moths are not good organisms to use in blolndlcator monitoring programs because they only fly at night, and can not be visually monitored along transects through the habitat management areas. They must be collected by black-light traps. 'In addition, moths are very difficult to identify, and must be closely examined by a taxonomic expert.

By contrast, butterflies are easy to visually monitor along transect lines during the day, there are major groups of butterflies that feed on most of the major foodplant groups described above, and these butterfly groups are easily recognized In the field by non-experts. Thus, butterflies can serve as representative blolndlcators for the overall Lepidoptera community of herbivores.

In contrast to the plant monitoring described above, butterfly monitoring actually produces more valuable qualitative data than quantitative data In evaluating ecosystem diversity and productivity. This is because Lepldoptera populations can fluctuate drastically from year to year due to seasonal weather variations, In contrast to the greater permanence of plant populations. For example, an El Nlno drought or a cold, rainy summer will usually result In drastic shifts in Lepldoptera abundance the following year, with some species. *Increasing* and other species decreasing In abundance as a consequence. In addition, a late spring or early summer freeze, which occasionally occurs in montane areas, can greatly reduce Lepldoptera numbers for the remainder of the year. Thus, several Years of monitoring may be needed to assess the health of defoliating herbivore populations within a management area.

Nevertheless, butterflies are very sensitive bioindicators of ecosystem health, and are excluded from communities along with 'their larval foodplants In-response to various management histories of overgrazing by domestic livestock or the exclusion of historical fire patterns. The fritillary butterflies of the genus Speyeria and their larval foodplants (Viola spp.) are a classical example (Hammond & McCorkle, 1983).

The following groups of butterflies should be included ln a monitoring program. Each of these groups are closely correlated with one of the major foodplant groups previously discussed. Pyle (1981) is a useful color illustrated guide to use In the field ldentlflcatlon of these butterflies. Hinchliff (1994) provides a useful summary for butterfly foodplants, habitats, and flight periods In the Pacific Northwest.

Umbellifer-feeding Swallowtails (Paplllonldae)

The anise swallowtail (*Papilio zellcaon*) is the dominant umbellifer feeder throughout western North America. In particularly dry or rocky habitats, the Indra swallowtail (*Papilio indra*) may also be locally Important.

Shrub-feeding Swallowtails (Papilionidae)

Three species of tiger swallowtails feed on hardwood shrubs and trees. These Include western 'tiger swallowtail (*Papilio rutulus*) on Sallcaceae (*Salix*, *Populus*), two-tailed swallowtail (*Papilio multicaudatus*) on Rosaceae (*Prunus*), and pale swallowtail (*Paplllo eurymedon*) on snow brush (*Ceanothus* spp.) and *Prunus*. In addition, Baird's swallowtail (*Paplllo bairdii*) feeds on green sage (*Artemisia dracunculus*). Each of these large butterflies is quite distinctive, and should be individually monitored.

Whites (Pieridae)

The white butterflies consist of 7 species in the genera Pieris, Euchloe, and Anthocharis. These Include P. beckerii, P. sisymbrii, P. occidentalis, P. napi, E. ausonides, E. hyantis, and A. sara. All feed on mustards (Cruciferae) In a variety of meslc to xerlc habitats, and can be monitored as a collective group.

Sulphurs (Pieridae)

The sulphur butterflies consist of 3 species including Colias eurytheme, C. occidentalis, and C. alexandra. They feed on legumes (Leguminosae) in a variety-of meslc to xerlc habitats, and can be monitored as a collective group.

(Bluesenidae)

The blue butterflies consist of 14 species In the genera Lycaena, Everes, Euphilotes, Glaucopsyche, and Plebejus. These include L. heteronea, Ev. comyntas, Ev. amyntula, Eu. battoides, Eu. enoptes, G. piasus, G. lygdamus, P. idas, P. melissa, P. saepiolus, P. lcarloides; P. shasta, P. acmon, and P. lupini. All feed on legumes (Legumlnosae) and buckwheats (Eriogonum-Polygonaceae) ln a variety of meslc to xerlc habitats, and can be monitored as a collective group.

Fritillaries (Nymphalidae)

The fritillary butterflies consist of 8 species ln the genus Speyeria. These include S. cybele, S. coronis, S. zerene, S. callippe, S. egleis, S. atlantis, S. hydaspe, and S. mormonia. All feed on violets (Viola-Vlolaceae) In a variety of hydric to xerlc habitats, and can be monitored as a collective group.

Crescents and Chlosyne Checkerspots (Nymphalldae)

The crescents and Chlosyne checkerspots consist of 6 species in the genera Phyciodes and Chlosyne. These Include C. palla, C. acastus, P. selenis, P. pratensis, P. pallidus, and P. mylitta. All feed on composites (Composltae) in a variety of meslc to xerlc habitats, and can be monitored as a collective group.

Euphydryas Checkerspots (Nymphalldae)'

The Euphydryas checkerspots consist of 3 species Including E. anicia, E. chalcedona, and E. editha. All feed on various scrophs or figworts (Scrophulariaceae), particularly penstemons (Penstemon spp.) and paintbrushes (Castllleja spp.), plus snowberry (Symphoricarpus spp.). They occur in a variety of meslc to xerlc habitats, and can be monitored as a collective group.

Anglewings (Nymphalldae)

Anglewings consist of 4 species in the genus Polygonia, including P. satyrus, P. faunus, P. gracilis, and P. progne. They usually occur in meslc to hydrlc habitats where they feed on woody shrubs and trees of the genera Alnus, Salix, and Ribes, plus stinging nettles (Urtica spp.). However, P. gracilis is also found in more xeric habitats with xeric-adapted species of Ribes. Anglewings can be monitored as a collective group.

Tortoiseshells (Nymphalidae)

Tortoiseshells consist of 4 species in the genus Nymphalis, including N. vaualbum, N. californica, N. antiopa, and N. milberti. They usually occur in mesic to hydric habitats where they feed on woody shrubs and trees of the genera Salix, Populus, and Ceanothus, plus stinging nettles (Urtica spp.). They can be monitored as a collective group, although the mourning cloak (N. antiopa) is individually quite distinctive.

Admirals (Nymphalidae)

Admirals consist of 3 species in the genus Limenitis, including L. archippus, L. weidemeyerii, and L. lorquini. They usually occur in mesic to hydric habitats where they feed on woody shrubs and trees of the genera Salix, Populus, and Prunus. They can be monitored as a collective group, although the viceroy (L. archippus) is individually quite distinctive.

Wood Nymphs (Satyridae)

The wood nymphs consist of 5 species in the genera Erebia, Coenonympha, and Cercyonis. These include E. epipsodea, Co. tullia, Ce. pegala, Ce. sthenele, and Ce. oetus. All feed on grasses

(Gramineae) in a variety of mesic to xeric habitats, and can be monitored as a collective group.

These groups of butterflies represent feeding guilds of defoliating herbivores that specialize on particular groups of foodplants. Monitoring these guilds provides an indication of the success-and productivity of each plant group within-the ecosystem in supporting higher trophic levels of the food chain. Healthy, complex ecosystems have many plant groups that support many herblvor guilds, while highly degraded systems are quite depauperate by contrast.

The method of butterfly monitoring will consist of counting numbers of Individuals within- each of the butterfly groups described above along permanent, linear transects of 500-1000 feet in length. The length and number of transects will depend upon the size of the management areas of concern. Again, as with the plant monitoring, if the management area Is heterogeneous with both upland and riparian habitats, separate transects should be maintained within each habitat type.

If there is a need to *monitor* larger management units, it may be necessary to establish longer permanent transects of 2000-5000 feet. Such long transects will certainly extend over a variety Of habitat types. Thus, the transect should be divided Into 500 foot sections, and a separate count of butterflies should be recorded for each section.

Transects should be monitored three times during the season to count spring, early summer, and late summer flying butterflies. In most areas, monitoring should be done in May, Late June to early July, and late July to early *August.* Higher elevation sites should be surveyed several weeks later.

The field observer should walk the transect at a slow pace, perhaps 100 feet in 5 minutes, so that butterflies resting in vegetation have time to fly up and be counted. The observer should have a notebook listing the major butterfly groups described above, *SO* that each butterfly can be recorded according to its group with a tally mark. All butterflies within the line of vision should be recorded, taking care not to count a given area more than once. If butterflies are particularly abundant with dozens of individuals swarming along the transect, it is helpful to block out visual areas and to count each block in a sequential order.

The transect should be walked under warm, sunny conditions in mid-morning between 10:00-12:00. Observations can also be conducted in the afternoon if temperatures are not tbo hot. However, most butterflies seek protective shelter ln shady vegetatic when afternoon- temperatures climb in excess of 90°F. Monitoring should not be done at hot temperatures, which Is advantageous- for the observer's comfort as well.

For data analysis, It is suggested that 500 feet of transect be the standard unlt for comparisons through time and space. Thus, a 1000 foot transect should be divided into two equal-sized section and independent counts be made for each section; Numbers of butterflies within each foodplant guild can then be compared per unit of habitat area, both spatially between- management areas and through time within, a single management area. An index of habitat productivity can then be devised for each foodplant group. A suggested Index would be as follows based upon general experience.

Butterflies/500 ft.	Quality
1	very poor
5	poor
10	fair
20	good
40	very good

The above monitoring program will assess the productivity of each major foodplant group with respect to each guild of defoliating herbivores dependent upon that plant group.' It provides an Indication of ecosystem complexity and Inherent stability, and of how well plant biomass is being processed into animal biomass to sustain higher trophic levels of the food chain.

A total of 8 foodplant groups and their guilds of herbivores will be'monltored ln this program. These are outlined as follows.

Foodplant Group	Butterfly Guild
grasses	wood nymphs
violets	fritillaries
mustards	whites
legumes + buckwheats	sulphurs + blues
scrophs	Euphydryas checkerspots
composites	crescents & Chlosyne checkerspot
umbellifers	swallowtails (zelicaon & indra)
woody shrubs + nettles	swallowtails (bairdii, rutulus, multicaudatus, eurymedon) + anglewings + tortoiseshells + admirals

It should be noted that this monitoring program does not assess species diversity within a particular herbivore guild beyond the general groups of butterflies. For example, legumes and buckwheats can support up to 17 species of sulphur and blue butterflies, and woody shrubs and nettles support up to 15 species of swallowtails, anglewings, tortoiseshells, and admirals. Most butterfly species can not be identified without close examination by a qualified taxonomic expert. The monitoring program described above is designed to examine only the major butterfly groups in general with respect to their major foodplant groups. This approach is very easy and fast, and can be done by any land manager without detailed training in butterfly taxonomy. Most transects can be run in a single hour, so time and labor spent In monitoring is minimal.

Nevertheless, for some management purposes, there may be Interest in assessing the actual herbivore species diversity being supported by the foodplant groups within a specific management area. To do this, samples of all representative groups Of butterflies will need to be collected and sent tb a taxonomic expert for Identification. Butterflies should be captured in a net, killed by pinching the thorax at the wing base while still ln the net, and placed in a paper envelope with wings folded back and flat. The envelope should be marked with the appropriate locality Information (township, range, section, transect number) and date of capture. It should be noted that studies of species diversity are much more time-consuming, labor-intensive, and expensi to perform than the general blolndlcator monitoring previous- discussed.

BUTTERFLY-PLANT GROUPS WITHIN HABITAT TYPES

The GIS classification of vegetation cover types is much too narrow for meaningful discussion of butterfly-foodplant assemblages. For the purpose of using butterflies as bioindicators of ecosystem health, the narrow GIS vegetation cover types are best consolidated together into 9 major habitat types. The butterfly-foodplant assemblage found within each of these major habitat types is described below. Again, it must be emphasized that very few butterflies are found in conifer forests where dense stands of young conifers have shaded out most of the grasses, herbs, and shrubs on the forest floor. Likewise, very few butterflies are found in degraded rangelands where overgrazing by domestic livestock has eliminated most of the native grasses and herbs, and has replaced the natives with weedy, exotic plant species.

1. Montane Meadow-Barren Rock Garden
   (27 butterfly species)

   Grasses - *Cercyonis oetus*, *Erebia epipsodea*

   Violets - *Speyeria mormonia*, *S. atlantis*, *S. egleis*

   Mustards - *Pieris sisymbrii*, *P. occidentalis*, *Euchloe ausonides* *Anthocharis sara*

   Legumes-Buckwheats - *Colias eurytheme*, *Everes amyntula*, *Euphilotes enoptes*, *Lycaena heteronea*, *Glaucopsyche lygdamus*, *Plebejus saepiolus*, *P. icarioides*, *P. idas* *P. shasta*, *P. acmon*

Umbellifers - *Papilio zelicaon*, *P. indra*

Scrophs - *Euphydryas anicia*, *E. chalcedona*, *E. editha*

Composites - *Chlosyne palla*, *Phyciodes pratensis*

Nettles - *Nymphalis milberti*

2. Spruce-Fir-Lodgepole Pine Forest
(22 butterfly species)

Grasses - *Cercyonis oetus*, *Erebia epipsodea*

Violets - *Speyeria hydaspe*

Mustards - *Pieris napi*, *P. occidentalis*, *Anthocharis sara*

Legumes-Buckwheats - *Colias eurytheme*, *C. occidentalis*, *Everes amyntula*, *Glaucopsyche lygdamus*, *Plebejus icarioides*, *P. idas*, *P. acmon*

Umbellifers - *Papilio zelicaon*

Scrophs - *Euphydryas chalcedona*

Composites - *Phyciodes pratensis*

Shrubs - *Papilio eurymedon*, *Polygonia progne*, *P. faunus*, *Nymphalis californica*, *N. vaualbum*, *Limenitis lorquini*

3. Ponderosa Pine Forest
(25 butterfly species)

Grasses - *Cercyonis oetus*, *C. sthenele*, *Coenonympha tullia*

Violets - *Speyeria hydaspe*, *S. zerene*

Mustards - *Pieris occidentalis*, *Anthocharis sara*

Legumes-Buckwheats - *Colias occidentalis*, *C. alexandra*, *Lycaena heteronea*, *Euphilotes battoides*, *Glaucopsyche piasus*, *G. lygdamus*, *Plebejus melissa*, *P. icarioides*, *P. acmon*, *P. lupini*

Umbellifers - *Papilio zelicaon*

Scrophs - *Euphydryas chalcedona*

Composites - *Chlosyne palla*, *Phyciodes pratensis*, *P. mylitta*

Shrubs - *Papilio eurymedon*, *Polygonia gracilis*, *Nymphalis californica*

4. Aspen Forest
(27 butterfly species)

Grasses - *Cercyonis oetus*, *Coenonympha tullia*

Violets - *Speyeria atlantis*, *S. zerene*

Mustards - *Pieris napi*, *P. occidentalis*, *Anthocharis sara*

Legumes-Buckwheats - *Colias occidentalis*, *C. alexandra*, *Glaucopsyche piasus*, *G. lygdamus*, *Plebejus melissa*, *P. icarioides*, *P. acmon*, *Everes amyntula*

Umbellifers - *Papilio zelicaon*

Scrophs - *Euphydryas anicia*, *E. chalcedona*

Composites - *Chlosyne palla*, *Phyciodes pratensis*, *P. mylitta*

Shrubs - *Papilio eurymedon*, *P. rutulus*, *Polygonia gracilis*, *P. faunus*, *Nymphalis antiopa*, *Limenitis weidemeyerii*

5. Native Bunchgrass-Sagebrush-Juniper Steppe
(28 butterfly species)

Grasses - *Cercyonis oetus*, *C. sthenele*, *Coenonympha tullia*

Violets - *Speyeria callippe*, *S. coronis*, *S. zerene*

Mustards - *Pieris beckerii*, *P. sisymbrii*, *P. occidentalis*, *Euchloe ausonides*, *E. hyantis*, *Anthocharis sara*

Legumes-Buckwheats - *Colias alexandra*, *Lycaena heteronea*, *Euphilotes battoides*, *E. enoptes*, *Glaucopsyche piasus*, *G. lygdamus*, *Plebejus melissa*, *P. icarioides*, *P. acmon*

Umbellifers - *Papilio zelicaon*, *P. indra*

Scrophs - Euphydryas anicia

Composites - Chlosyne palla, C. acastus, Phyciodes pallidus, P. mylitta

6. Exotic Grasslands
(7 butterfly species)

Mustards - Pieris beckerii, P. occidentalis, P. rapae (exotic)

Legumes (alfalfa) - Colias eurytheme, C. philodice, Plebejus melissa

Composites - Phyciodes mylitta

7. Canyonland-Dry Shrubland
(32 butterfly species)

Grasses - Cercyonis oetus, C. sthenele, Coenonympha tullia

Violets - Speyeria callippe, S. coronis, S. zerene

Mustards - Pieris sisymbrii, P. occidentalis, Euchloe ausonides Anthocharis sara

Legumes-Buckwheats - Colias alexandra, Lycaena heteronea, Glaucopsyche piasus, G. lygdamus, Euphilotes enoptes, E. battoides, Plebejus icarioides, P. melissa, P. acr

Umbellifers - Papilio zelicaon, P. indra

Scrophs - Euphydryas anicia, E. chalcedona

Composites - Chlosyne palla, C. acastus, Phyciodes pallidus, P. mylitta.

Shrubs - Papilio multicaudatus, P. eurymedon, P. bairdii, Polygonia gracilis, Nymphalis californica

8. Riparian Cottonwood-Willow
(19 butterfly species)

Grasses - Cercyonis pegala

Violets - Speyeria cybele

Mustards - *Pieris napi*, *P. occidentalis*

Legumes - *Everes comyntas*, *E. amyntula*, *Glaucopsyche lygdamus*, *Plebejus melissa*

Umbellifers - *Papilio zelicaon*

Composites - *Phyciodes pratensis*, *P. mylitta*

Nettles - *Polygonia satyrus*

Shrubs - *Papilio rutulus*, *P. multicaudatus*, *Polygonia faunus*, *Nymphalis vaualbum*, *N. antiopa*, *Limenitis archippus*, *L. lorquini*

9. Riparian Meadow-Wet Prairie
(16 butterfly species)

Grasses - *Cercyonis pegala*, *Coenonympha tullia*

Violets - *Speyeria mormonia*

Legumes - *Colias eurytheme*, *Everes comyntas*, *E. amyntula*, *P. meliss*[illegible] *Glaucopsyche lygdamus*, *Plebejus saepiolus*,

Scrophs - *Euphydryas editha*

Composites - *Phyciodes selenis*, *P. pratensis*, *P. mylitta*

Nettles - *Nymphalis milberti*

Mustards - *Pieris napi*, *P. occidentalis*

AREAS OF HIGH SPECIES DIVERSITY FOR BUTTERFLIES IN THE COLUMBIA RIVER BASIN

In general, there is a strong latitudinal gradient in butterfly species richness, with much greater diversity southward In the Columbia River Basin as it borders the Great Basin, and fewer Species northward towards Canada. Second, montane regions have 'the largest number of species due to the elevational gradients and diverse habitat types present In mountains. This ranges from the desert bunchgrass-sagebrush steppe at the foot of the mountains through the various montane life zones and habitat types to the . subalpine tundra and glacial cirques at the top of the mountains. Consequently, the greatest butterfly diversity In the Columbia River Basin Is found In the mountains of southern and central Idaho and Oregon.

Across southern Idaho and Oregon, these include the Alblon Mountains and South Rills of Cassla and Twin Falls Counties, the Owyhee Mountains of Owyhee County, and the Steens and Pueblo Mountains of Harney County. All of these mountain ranges support a strong fauna with Great Basin affinities combined with Rocky Mountain elements. The Wyoming Range, Caribou Range, northern Wasatch Range, Portneuf Range, and Bannock Range of western Wyoming and southeastern Idaho also exhibit high species diversit: although with more strongly Rocky Mountain affinities.

Across central Idaho and Oregon, high diversity is found in the southern portion of the Bitterroot Range and Lemhi Range in Lemhl County, the Lost River Range and Sawtooth Range in Custer County, the Seven Devils Mountains and Imnaha Mountains bordering Hells Canyon, the Wallowa Mountains of Wallowa County, and the Blue and Ochoco Mountains across northeastern and central Oregon.

On the east slope of the Cascades, high diversity is found. near Mt. Adams (Gifford Pinchot NF), the Metolius Basin and Three Creeks Basin near the Three Sisters (Deschutes NF), and in the southern Cascades and Warner Mountains of southern Klamath and Lake Counties bordering California (Winema and Fremont NFs).

In contrast to these southern-mountains, the butterfly fauna of northwestern Montana, northern Idaho, and most of' Washington Is relatively depauperate. This may be partly due to the disruptive effects of Pleistoceneglaciations In these northern mountains. However, unique Arctic-alpine types of butterflies are narrowly endemic to these northern mountains-above timberline. The North Cascades of Washington, Glacier National Park In Montana, the Bltterroot Range In Idaho, and high elevation zones of the Yellowstone-Teton region in Wyoming are the best areas for these Arctic-alpine relicts.

LITERATURE CITED

Berryman, A.A., N.C. Stenseth, & A.S. Isaev. 1987. Natural regulation of herbivorous forest Insect populations. Oecologia 71: 174-184.

Campbell, R.W. 1993. Population dynamics of the major North American-needle-eating budworms. USDA Forest Service, Pacific Northwest Research Station, PNW-RP-463. 222 pp.

Campbell, R.W., & T.R. Torgersen. 1983. Compensatory mortality in defoliator population dynamics. Environ. Ent. 12: 630-632.

Forsman, E.D., E.C. Meslow, & H.M. Wight. 1984. Distribution and biology of the spotted owl In Oregon. Wildlife Monographs 87: 1-64.

Franklin, J.F., & C.T. Dyrness. 1971. A checklist of vascular plants on the H.J. Andrews Experimental Forest, western Oregon. USDA Forest Service, Pacific Northwest Research Station, PNW-138. 37 pp.

Graber, J.W., & R.R. Graber. 1983. Feeding rates of warblers In spring. Condor 85: 139-150.

Grimble, D.G., B.C. Beckwith, & P.C. Hammond. 1992. A survey Of the Lepidoptera fauna from the Blue Mountains of eastern Oregon. J. Res. Lepld. 31: 83-102.

Hammond, P.C., & D.V. McCorkle. 1983. The decline and extinction of <u>Speyeria</u> populations resulting from human environmental disturbances (Nymphalidae: Argynninae). J. Res. Lepid. 22: 217-224.

Hinchliff, J. 1994. The distribution of the butterflies of Oregon. Oregon State University Bookstore, Inc. Corvallis, 0 176 pp.

Larrison, E.J. 1976. Mammals of the Northwest. Seattle Audubon Society, Seattle, Wash. 256 PP.

Pollard, E., & T.J. Yates. [illegible]. Monitoring butterflies for ecology and conservation. Chapman & Hall, London, 274 pp.

Parsons, G.L., G. Cassis, A.R. Moldenke, J.D. Lattin, N.H. Anderson, J.C. Miller, P. Hammond, & T.D. Schowalter. [illegible]. Invertebrates of the H.J. Andrews Experimental Forest, Western Cascade Range, Oregon. V: An annotated list of insects and other arthropods. PNW-GTR-290. USDA Forest Service, Pacific Northwest Research Station. 168 pp.

Pyle, R.M. 1981. The Audubon Society field guide to North American butterflies. Alfred A. Knopf, New York. 916 pp.

Ricklefs, R.E. 1983. The economy of nature. Chlron Press. New York. 510 pp.

Stamp, N.E., & T.M. Casey, eds. 1993. Caterpillars. Chapman & Hall, New York. 587 pp.

U.S. Forest Service, 1991. Wildlife and vegetation of unmanaged Douglas fir forests. PNW-GTR-285. USDA Forest Service, Pacific Northwest Research Station. 533 pp.

Welty, J.C. 1975. The life of birds. W.B. Saunders Co., Philadelphia. 623 pp.

Whitaker, J.O., C. Maser, & L.E. Keller. 1977. Food habits of western Oregon 'bats. Northwest Science 51:46-54.