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ECOLOGICAL AND BEHAVIORAL STUDIES ON THE THREATENED OREGON SILVERSPOT BUTTERFLY AT ITS ROCK CREEK, CASCADE HEAD, MT. HEBO, AND CLATSOP PLAINS POPULATIONS IN OREGON

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ABSTRACT

Field and laboratory studies were conducted during 1986 and 1987 on the Oregon Silverspot butterfly, *Speyeria zerene hippolyta*, which is recognized as a federally-listed, threatened species in accordance with the Endangered Species Act of 1973. Field studies were undertaken at four coastal Oregon localities where the butterfly is known to occur. These studies focused on the behavior of adult butterflies and the importance of the forest fringe areas in their ecology. During this study, 10,416 adults were observed a total of 14,939 times. A behavioral repertoire, including eight primary and 20 secondary behaviors, was compiled from field observations. Results were used to determine: 1) which habitats and vegetation types of each study site were occupied by butterflies at different times during the day; 2) which areas were favored by butterflies under varying weather and shelter conditions; 3) the frequency of various behaviors and possible associations with particular habitats, topographic features, and plant species; and 4) diel activity patterns.

In addition, the vegetational composition and structure of selected forest fringe and meadow areas was characterized by measuring the cover-abundance of several herbaceous plants known to be important to the butterfly. Also, the basal diameters and heights of selected trees in forest fringe areas were measured. The point-centered quarter method was used to randomly select trees in the forest fringe areas to characterize the timber stand structure. Results are used to describe the vegetation composition, spatial configuration, physical and biological conditions of fringe areas preferred by OSB. These results are also used to describe the physical and biological characteristics of prime breeding and larval developmental areas.

The developmental time in degree-days of the immature stages of the butterfly, including its egg, larval, and pupal stages, was estimated. Livestock, from field-collected females, were exposed to constant temperature regimes of 8 to 24 ^{o}C to calculate the degree days required for development and the threshold developmental temperature.

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I. INTRODUCTION

The Oregon Silverspot, *Speyeria zerene hippolyta* (Edwards) (Lepidoptera: Nymphalidae), is a butterfly that is endemic to the coastal zone of southern Washington, plus northern and central Oregon, where it lives in meadows and forests. It is one of 15 subspecies recognized in association with the Zerene Silverspot (or fritillary), which ranges widely throughout the cordilleran region of western North America.

Historically, the Oregon Silverspot butterfly (OSB) was known from 17 localities, ranging from Grays Harbor, Washington, to Rock Creek near Florence, Oregon. However, widespread loss and alteration of its coastal meadow habitat led to the butterfly's nomination in the late 1970's for endangered species status. In 1980, the OSB was recognized by the U.S. Fish & Wildlife Service as a threatened species, pursuant to the provisions of the Endangered Species Act of 1973. At the time of its listing, viable OSB colonies were known only from two Oregon localities: a) the Big Creek-Rock Creek area in Lane County, and b) Mt. Hebo in Tillamook County. Subsequent searches located a viable colony on Cascade Head in Lincoln County, and rediscovered a weaker colony in the Clatsop Plains area near Gearhart, Clatsop County.

Like other federally-listed endangered butterflies, the OSB has declined due to the activities of man, who has destroyed many of its natural habitats. However, in contrast to other endangered butterflies that often now inhabit highly disturbed remnants of habitat (see Arnold 1983), natural ecological successional processes have converted significant sectors of remaining meadow habitat for the OSB to brushland and forest. For example, McCorkle et al. in 1980 identified about 20% of the Rock Creek area as fair to optimal habitat for the silverspot population there. However, by 1983 their resurvey of the same area indicated that conditions had deteriorated dramatically, with only 2% of the total area being fair to optimal habitat for the butterfly. Thus, even though major portions of remaining OSB habitat are protected from further large-scale loss of habitat, conservation of this butterfly will depend on management of the vegetation in these remaining habitat areas to benefit the OSB.

Substantial portions of the Rock Creek, Cascade Head, Mt. Hebo, and Clatsop Plains sites are owned by government agencies (U.S. Forest Service and military) and The Nature Conservancy. Representatives from these organizations, plus the U.S. Fish & Wildlife Service, and private individuals interested in the OSB, have formed a group to oversee recovery of the butterfly, as outlined in the Oregon Silverspot Butterfly Recovery Plan (U.S. Fish & Wildlife Service 1982) and Oregon Silverspot Butterfly Forest Implementation Plan (U.S. Forest Service 1984). These documents describe several conservation measures and research activities needed to successfully manage and maintain the OSB at its four remaining colonies in Oregon.

To properly implement vegetation management programs to benefit the OSB, a thorough understanding of the butterfly's behavior and utilization of its various habitats is required. Previous studies on the OSB have concentrated on determining the butterfly's geographic range (McCorkle et al. 1980; Hammond 1980), status surveys (Hammond and McCorkle 1982 and 1985), basic biology and life history (McCorkle et al. 1980; Hammond 1980), estimating its population numbers (McCorkle et al. 1980), plus autecological studies of the butterfly's larval foodplant, *Viola adunca* (Hammond and McCorkle 1984; Hammond 1986 and 1987).

This report describes activities of a contracted research study for the U.S. Fish & Wildlife Service (USFWS contract #14-16-0009-85-029) conducted during the 1986 and 1987 OSB flight seasons. Primary purposes of this study were to determine: 1) the role and importance of forest fringe areas in the ecology of this butterfly; and 2) larval developmental biology. These activities were undertaken to satisfy objectives outlined in the OSB's Recovery Plan (U.S. Fish & Wildlife Service 1982), in particular Tasks #121 (role of forest edge to butterfly's various life stages) and #122 (autecology and limiting factors of butterfly). Results from a combination of field and laboratory investigations are presented.

Field observations of OSB adults during both flight seasons are used to construct an ethogram, which describes the adult behavioral repertoire of this butterfly. Observed behaviors are correlated with habitat and vegetation types. Biological and physical features of the meadow and forest habitats utilized by OSB are characterized. Herbaceous vegetation is characterized by estimating the frequency and cover-abundance of 15 plants, including the OSB's larval and adult foodplants, plus other plants indicative of the butterfly's habitat. In forested areas, tree stand structure is characterized by measurements of basal diameters and heights of resident trees. Results are used to describe the physical and biological features of habitats used for breeding activities and larval development. Laboratory studies are employed to estimated development time, in degree days, for immature stages of the butterfly. Recommendations on management and enhancement of forest fringe areas are suggested to benefit the threatened butterfly.

II. MATERIALS AND METHODS

A. Study Sites

Field studies were conducted at four Oregon localities (Figure 1) that support the threatened OSB:

1) Rock Creek (T16S, R12W, Sections 10 & 15) in Lane County;
2) Mt. Hebo (T4S, R9W) in Tillamook County;
3) Cascade Head (T6S, R11W) in Tillamook County; and
4) Clatsop Plains (T6N, R10W) in Clatsop County.

Field studies occurred on 32 days in August and September 1986, and 31 days in June, July, August, and September 1987. During 1986 I spent 13 days at Rock Creek, seven days at Mt. Hebo, seven days at Cascade Head, and five days at Clatsop Plains, while in 1987 field time included 16 days at Rock Creek, six days at Mt. Hebo, six days at Cascade Head, and three days at Clatsop Plains. Eight students (all with bachelors' degrees and six with master's degrees) from the University of California's University Research Expedition Program (UREP), assisted me with field studies on 12 days in August 1987. Due to the low numbers of OSB observed at Clatsop Plains during 1986 field studies, it was agreed, prior to the OSB's 1987 flight season, that no vegetation studies would be undertaken there (J. Michaels, U.S. Fish & Wildlife Service, pers. comm.).

B. Definition of Terminology

During the course of reviewing the literature and conducting this study, it became apparent that the term "forest fringe" was not well defined and was interpreted differently by various individuals. Therefore, it is appropriate to establish a definition for this term.

The phrase "forest fringe" suggests an area at the interface, edge, or border between grassland meadows and forested areas used as habitat by the OSB. However, these forest fringes assume various forms, and this is where there may be some confusion in applying the terminology. Forest fringes may occur deep in the dense forest where there are small, natural, grassy pockets or interior meadows surrounded by dense forest, such as are found at Rock Creek. Similarly, forest fringes occur at the perimeter of clearcut areas, where the clearcut is surrounded by dense forest, as at Rock Creek. Forest fringes also occur at the border between dense forest and coastal grassland habitats, as is found in the hilltop meadows at Cascade Head. Some people might prefer to refer to this latter fringe situation as "forest edges" rather than forest fringes. During this study, all four types of forest fringe habitats, grassy forest pockets, interior meadows, clearcuts, and forest edges, were sampled to determine utilization by OSB.

C. Butterfly Studies

<u>1. Adult Behavioral Studies.</u>
At each locality, observations were conducted along transects or observers worked in an assigned habitat area, as described by Morlan (1987) for Cascade Head, Hammond and McCorkle (1985) for the Clatsop Plains, Hammond (1980) for Mt. Hebo, and McCorkle et al. (1980) for Rock Creek. Open meadows, forest fringes, clearcuts, open pockets supporting meadow habitat within the forest, and brushland habitats were sampled. Individual OSB adults were observed as long as visual contact could be maintained. Binoculars were used as necessary to assist with observations. Walkie-talkies were briefly used to coordinate tracking of individual butterflies by different observers working in

the same area or on opposing sides of forest fringes. Information on each butterfly's behavior, plant associations, and duration of each behavioral activity were recorded using either a voice-activated, microcassette, tape recorder or specially-prepared data forms for manually recording the information associated with each observation. Observers carried hand-held instruments to periodically record temperature and wind speed in their assigned areas.

The following types of information were recorded for each butterfly observation:
1) sex;
2) wing wear condition (fresh, slightly worn, or battered);
3) behavior (nectaring, perching, basking, courting, mating, ovipositing, flying, male-male interaction, dead, etc.);
4) plant association, if any, for observed behavior;
5) vegetation type where behavior was observed, including:
   a) grassland meadow (salt spray meadow, open grassland, grassy balds, fern-grass meadows, old dune meadow, wet meadow, interior meadows, etc.);
   b) brushland (*Pteridium-Rubus*, fern, or salal);
   c) forest fringe or edge (mixed conifer, conifer-alder, alder, or pine);
   d) forest pocket;
   e) clear cut;
6) study site (Rock Creek, Mt. Hebo, Cascade Head, or Clatsop Plains);
7) subsite:
   a) Mt. Hebo: areas #1-#8 (see Hammond 1980)
   b) Rock Creek: areas #1-#14 (see McCorkle et al. 1980)
   c) Cascade Head: slopes or hilltops (see Morlan 1987)
   d) Clatsop Plains: Del Rey Beach area, Camp Rilea, Pacific Power & Light, or Cullaby Lake;
8) date;
9) time of day;
10) temperature;
11) cloud cover (sunny, partly cloudy, foggy, overcast, or rain);
12) wind speed:
   a) none, i.e., calm
   b) intermittent or slight breeze, less than 8 km/hr (i.e., <5 mph)
   c) moderate breeze, 8-16 km/hr (i.e., 5-10 mph)
   d) strong or gusty breeze, greater than 16 km/hr (i.e., >10 mph)
13) observer's initials;
14) topography (steep slope, gradual slope, hilltop, valley, flat or gently rolling);
15) duration of observed activity (in seconds);
16) exposure (exposed, sheltered, or partial shelter); and
17) miscellaneous notes.

All data were entered into a COMPAQ, portable microcomputer. The commercially-available database programs, DBASE II^{tm} and DBASE III PLUS^{tm} from Ashton-Tate, were used for data management and some analyses. The above-noted 17 categories of information were entered for each butterfly observation. Every butterfly that was observed during this study has at least one record in the database. If the same butterfly was observed exhibiting different types of behavior, then the number of records in the database for that individual equals the number of different behaviors that were observed. Similarly, if one individual nectared on three different species of flower or on five different specimens of the same kind of flower, each occurrence was entered as a separate record in the database.

Using the information that accrued from these observations, a variety of analyses were performed to determine:
1) which subsites of a study site were occupied by OSB adults at

different times during the day;

2) which subsites were occupied under varying weather and shelter conditions;

3) frequency of various behaviors, and possible associations with particular subsites, topographic features, vegetation types, forest fringes, degree of shelter, or particular plant species;

4) diel activity patterns; and

5) sexual and wing wear class differences among individuals exhibiting various behavioral activities.

Also, the information was used to compile an ethogram, i.e., a catalog of all behavioral patterns exhibited by OSB adults. Both longitudinal (i.e., continuous trailing of a particular individual) and cross-sectional (i.e., observations of many individuals) field observations of OSB adults were used to compile the ethogram.

2. Larval Rearing Studies.

In 1986, three females at Rock Creek were netted using a standard butterfly net to obtain eggs for the larval rearing studies. They were immediately transferred to containers as described by McCorkle et al. (1980) for oviposition. Methods used for inducing oviposition also followed McCorkle et al. (1980). Although my permit from the Portland Regional Office of the U.S. Fish & Wildlife Service allowed me to collect as many as 15 adult females for oviposition, population numbers of the Rock Creek population during 1986 seemed lower than in previous years, thus I was reluctant to collect more than the three females.

Newly laid eggs were placed in growth chambers equipped with thermostats for temperature control (accurate to $\pm$ 1^{0} C). VITA-LITE Fluorescent lamps provided 16 hours of daily light and 8 hours of daily darkness (16:8 LD), and constant 75% relative humidity.

Fertile eggs were divided into five batches to estimate developmental times under different temperature regimes, a standard entomological procedure for estimating degree-days. Temperatures utilized were 8^{0}, 12^{0}, 16^{0}, 20^{0}, and 24^{0} C (all $\pm$ 1^{0} C). Larvae from each batch of eggs were reared in the same growth chambers using potted *Viola adunca*, the OSB's natural larval foodplant, for larval forage. Each batch was reared at the above-noted constant temperatures. Data reported include only those individuals that survived to adulthood.

Degree-days for each immature stage were calculated as follows. The observed rate of development (1/# of days for development) was plotted against temperature and linear regression analysis was used to estimate the threshold temperature (x-intercept) for each stage. The equation

$$C = D(T-K)$$

was used to determine thermal constants which express the degree-days required for development of each immature stage. In this equation, C = degree days, D = developmental duration, T = temperature, and K = the threshold temperature for development.

D. Vegetational Composition, Spatial Configuration, and Physical Conditions of Forest Fringe Areas

Sampling was conducted at Rock Creek, Cascade Head, and Mt. Hebo to characterize the vegetation growing at forest fringe subsites within each locality that were heavily utilized by the OSB. Much of the 1986 and a portion of the 1987 OSB flight season was spent determining which forest fringe subsites at each locality were favored by the butterfly during weather conditions that were optimal and suboptimal for butterfly activity in the more exposed meadow areas. As very few OSBs were observed at the Clatsop Plains during 1986, Jim Michaels, Contracting Officer for U.S. Fish & Wildlife Service, and I decided prior to the onset of the OSB's 1987 flight season that 1987 vegetation studies would be limited to Rock Creek, Cascade Head, and Mt. Hebo.

1. Herbaceous Vegetation.

Herbaceous vegetation growing in open meadow and forest fringe areas at Rock Creek, Cascade Head, and Mt. Hebo was characterized using the Domin-Krajina (Krajina 1933) cover-abundance classes (Table 1) for several plant taxa, including the OSB's larval foodplant, actual and potential nectar plants, plus other forbs, grasses, shrubs, and trees characteristic of these areas (Table 2).

Forest fringe areas, which supported OSB activity during suboptimal weather conditions, were selected for vegetation composition and stand structure analysis. Similarly, meadow areas, where OSB adults were active during optimal weather conditions were selected for comparison to the forest fringe areas.

The number of vegetation sampling subsites at each study site are as follows:
a) Cascade Head- six forest fringe and two meadow areas;
b) Mt. Hebo- eight forest fringe and two meadow areas; and
c) Rock Creek- six forest fringe and two meadow areas.

Three meter by three meter (ca. 10 ft. x 10 ft.) quadrats were laid at each vegetation subsite. The number of quadrats at a particular subsite varied, ranging from 40 to 120, depending on the size of the subsite and the diversity of resident plant species.

The cover-abundance of all selected plant taxa was scored for each quadrat within a given subsite. Data were used to calculate: 1) observed frequency of occurrence for each plant taxon within all quadrats of the subsite; 2) mean cover for each plant taxon for only those quadrats in which it was found; and 3) mean cover for each plant taxon throughout all quadrats of the subsite. These relative measures of cover-abundance can be used not only to characterize a particular subsite, but also to compare and contrast vegetative conditions between subsites. Using the commercially-available spreadsheet program, SUPERCALC 4^{tm} manufactured by Computer Associates, I designed a spreadsheet model named VEGCOVER, to execute these calculations for each subsite.

2. Forest Vegetation.

In forest fringe and open pocket areas of Rock Creek, Cascade Head and Mt. Hebo, trees were inventoried and their physical dimensions (height and basal circumference) measured to characterize stand structure. Originally, I had hoped to use existing aerial photography from the U.S. Forest Service to measure tree dimensions for numerous subsites, but consultations with staff at the Hebo Ranger District Office of the U.S. Forest Service and the Remote Sensing Lab in Forestry Department at the University of California, Berkeley, revealed that the available photos were unsuitable for this purpose. Thus field sampling was necessary and the number of subsites examined was reduced due to the amount of time required to collect these data in the field.

Initially, each taxon of spruce, fir, and deciduous trees selected for sampling was identified to species. However, these were later lumped into just two tree groups, conifers and deciduous. As the trees at each subsite were randomly distributed and fairly densely packed, the Point-centered quarter method Cottam and Curtis (1956) was used to randomly select and sample trees to characterize the forest fringe areas. Cottam and Curtis (1956) evaluated this and three other distance methods for estimating timber density and stand structure. They found it to be the most efficient and reliable sampling method for timber stands whose species are randomly distributed, such as those at Rock Creek, Cascade Head and Mt. Hebo.

Briefly, my sampling protocol for the Point-centered quarter method can be described as follows. A strip, usually 10 m by 100 m was laid. Sampling points were designated at 5 m intervals. At each sampling point, four quarters are established by the intersection of two lines; one line is the compass direction of the sampling line, while the second is a perpendicular to the sampling line. In each quarter, the distance from the sampling point to the midpoint of the nearest tree is measured. The four distances for all sampling points along a strip are averaged and when squared equals the mean area covered by each tree group. The number of trees sampled at each subsite varied, but ranged from a minimum of 50 to a maximum of 100, with most subsites in the 70-80 range. Data are used to calculate: 1) density for each tree group; 2) dominance of each tree group; and 3) frequency of each tree group. I designed a spreadsheet model, named TREEDENSITY, using SUPERCALC 4^{tm} to execute these calculations for each subsite.

Height of each selected tree within a subsite was measured using either a clinometer or relascope. A spreadsheet model, TREEHEIGHT, was designed to perform the calculations necessary to determine actual tree height from clinometer readings taken on level, ascending, and descending topographic conditions.

Basal circumference of each sampled tree was measured using a metal tape measure. This measurement was converted to basal diameter using a spreadsheet model named TREEDIA. Although diameter at breast height (DBH) is frequently used by foresters to measure tree diameter, several studies suggest that basal circumference correlates better with other growth characteristics for many trees than does DBH (Mueller-Dombois and Ellenberg 1974). For this reason, and the fact that several of the trees sampled on Mt. Hebo and Cascade Head were *shorter* than breast height (1.5 meters or approximately 4.5 feet), I decided to use basal circumference measurements of tree trunks to estimate basal diameter.

Stand structure was characterized by grouping both the range of basal diameters and tree heights into classes. Results are presented as tables showing the percentage of all coniferous or deciduous trees sampled at a particular subsite that occur in each basal diameter or height class.

3. Spatial Configuration and Physical Conditions of Forest Fringe Areas.

The spatial configuration and physical conditions of each forest fringe area were examined using existing aerial photography borrowed from the U.S. Forest Service, topographic maps from the U.S. Geological Survey, and field surveys. Several physical, spatial, and biological factors were evaluated. Physical conditions, such as aspect, slope, and elevation were noted. Spatial factors included configuration of trees in the fringe area, proximity to nearby meadows, tree density and height, acreage, and degree of shelter afforded by the fringe. Biological factors evaluated included abundance of OSB larval and adult foodplants, plus OSB larval and adult usage of the area.

Aspect was determined in the field using a compass. Slope and elevation were measured in the field using a clinometer and altimeter respectively, and confirmed by examining the appropriate topographic map. Spatial factors were determined by field observations, aerial photography, and measurements of forest stand structure as identified in the methods section titled "Forest Vegetation". Similarly, biological factors were determined by field observations and measurements of cover-abundance of herbaceous vegetation, as described in the methods section titled "Herbaceous Vegetation".

III. RESULTS AND DISCUSSION

A. Adult Behavioral Studies.

1. Butterfly Observations.

At the time each butterfly was first noted, it was assigned a unique observation number in the data records. These observations are hereafter referred to as "first-time" or "initial" observations. Many OSBs were observed for several minutes duration, during which time they exhibited different behaviors (ex., patrolling followed by basking or nectaring) or repeated a particular behavior (ex., nectaring) but in association with different plants or in different vegetation types (ex., patrolling). These repeat observations of the same individual are referred to as "subsequent" or "follow-up" observations.

Table 3 summarizes the number of OSB observations at each study site during this two-year field study. The total number of first-time OSB observations in 1986 was 2,917, with 1,110 follow-up observations, for a grand total of 4,027 observations. During 1987 there were 7,499 initial observations and 3,413 subsequent observations for a grand total of 10,912 observations. As butterflies were not marked to distinguish one individual from another, it is difficult to estimate how many individuals were observed more than once during this study, particularly from day-to-day. Although the increase in butterfly numbers between 1986 and 1987 at all four study sites may reflect an actual increase in OSB population sizes, several more observers assisted with field studies during the 1987 flight season, which undoubtedly increased the number of butterfly observations.

Table 4 provides a breakdown of the total number of OSB observations (initial + subsequent) at each subsite of the four study sites for 1986 and 1987. At Cascade Head, the OSB population appears to be primarily restricted to the hilltop and upper flanks of Cascade Head. The greatest number of butterflies were observed in three sheltered areas, Senecio Slope (SEN), plus the steep slopes referred to as SS-E and SS-W (Figure 2). SEN derives its shelter from the forest fringe, while SS-E and SS-W lie on the leeward side of a steep hill. Although butterflies frequently used the open meadow areas, their activity in these areas was clearly restricted due to the coastal weather conditions. Zika (pers. comm.) reported finding a few OSB adults in the Secret Meadows (LT-E on Figure 2), especially early in the OSB's flight season. During 1986 and particularly during 1987, I visited these and other meadows around the southern perimeter at the base of Cascade Head, but did not observe any OSB's there. Similarly, no OSBs were observed during 1986 visits to the Penacle, thus this subsite was not sampled during 1987 studies. Three males were observed on separate occasions along the Forest Service (FSR) road about 1.7 km east of the parking area for the Cascade Head trail.

During 1986, all OSB observations at the Clatsop Plains occurred in the Del Rey Beach area, specifically in the meadow north of the golf course (Figure 3). No butterflies were seen at Camp Rilea, the Pacific Power & Light (PP&L) corridor, or Cullaby Lake. However, it is possible that I did not spend enough time in these latter three areas to find the OSB, as during the 1987 OSB flight season, adults were noted at three of the four sites, but were still absent at Camp Rilea.

Butterfly numbers on top of Mt. Hebo were greatest in the eastern portions of the mountain, particularly the forest fringe Area #6 and the meadows of Area #7 (Figure 4). Favored nectar plants, *Solidago* and *Senecio* were also most abundant in these areas.

At Rock Creek, most OSB observations occurred in sheltered or partially sheltered areas. For example, the largest number of males and females were observed in a sheltered meadow adjacent to Big Creek (Area #5 in Figure 5), approximately 1 km east of Highway 101 along the Forest Service Road. Similarly, more butterflies were observed in forest fringe areas #1, #2&3, #7, and #8, adjacent to Highway 101 than in the open salt spray meadows. However, butterfly activity in the meadows was limited because of the frequently poor weather conditions (i.e., fog, cool temperatures, orstrong winds), that restricted butterfly activity. On days when weather conditions were good, OSBs were observed in the meadows.

2. Behavioral Repertoire.

During my field studies, the OSB exhibited a repertoire of eight primary and 20 secondary behaviors, as depicted in the ethogram (Table 5). All eight primary behaviors and 19 of the 20 secondary behavioral activities were observed in the field. The eight primary behaviors included: 1) perching, 2) basking (i.e., thermoregulating), 3) foraging (primarily nectar intake), 4) excretion, 5) locomotion (primarily. flying), 6) oviposition, 7) various interactions between individuals, and 8) mating. Although one secondary activity, foreleg drumming by ovipositing females, was not directly observed, it is assumed to occur in OSB as this behavior is known to occur in related species of *Speyeria* (Arnold 1981).

Primary behavioral activities can be divided into two groups, solitary and inter-individual behaviors. Solitary behaviors include activities that are completed by a single individual without the intervention of other adult OSBs. *Perching*, *basking*, *foraging*, *locomotion*, *excretion*, and *oviposition* are examples of solitary behaviors. Inter-individual behaviors describe the mutual interactions and responses of at least two OSB adults and include *interaction flights* and *mating*. The remainder of this section briefly describes the main features of each behavior. Table 6 provides a breakdown of the observed primary behaviors by sex and study site.

In the absence of sunlight, most butterflies cannot maintain a body temperature high enough to permit normal activity, due to their poikilothermic (i.e., "cold-blooded") physiology. Butterflies convert the radiant energy of sunlight into heat by *basking*. Basking is a thermoregulatory behavior designed to help the butterfly warm up to perform other activities. Three primary types of basking have been observed in several butterfly species, including: body, dorsal, and lateral (Douglas 1986). OSB adults were observed basking dorsally, in which the wings are held open like an airplane and the dorsal wing surfaces collect the sunlight like solar panels, and laterally, in which the wings are closed and held tightly above the body and the butterfly tilts sideways, thus presenting only its ventral wing surfaces to the sun. Dorsal basking by OSB generally occurred on the ground or low-lying vegetation, while lateral basking was more commonly observed while adults were on flowers or perched on other vegetation. It is generally believed that the dorsal basking position is more effective for rapid heat gain. Also, in this position the butterfly's thorax and darkly colored wing bases are able to heat up more rapidly. In addition to directly capturing solar radiation, the outspread wings of a dorsally-basking butterfly provides an insulating layer of air beneath the wings that helps to protect the butterfly from cooling breezes (Douglas 1986 and Kingsolver 1985).

Shivering and *wing pumping* occur in association with dorsal basking but were rarely observed. Shivering was noted particularly early in the morning when butterflies were first attempting to warm up. In this activity, which has also referred to as "muscular thermogenesis", opposing pairs of muscles in the thorax contract and relax synchronously rather than in their usual alternating manner, which causes the wings to vibrate. In other butterflies, this intense muscular activity raises the thoracic temperature by 8 to 11 ^{o}C (15 to 20 ^{o}F) within a few minutes (Douglas 1986). Wing pumping, in which the wings would be opened and closed a few times in succession, was generally observed during the terminal stages of dorsal basking and often immediately preceeded take-off for flight activities. Wing pumping was also occasionally noted while adults nectared, however I am not certain if in this situation the activity is a thermoregulatory behavior while nectaring or perhaps is related to foraging. While feeding, wing pumping may help the butterfly withdraw nectar from a flower.

Once a butterfly is warmed up sufficiently, it can undertake other behaviors important in its daily routine. *Locomotion* can be accomplished by *walking* along the ground or vegetation, or more typically by *flying.* OSB males exhibit a flight behavior known as *patrolling*, i.e., males fly, almost incessantly, just above the grass tops. Periodically, they dip down closer to ground level in their search for females. Female flights tend to be more random and not as regimented. *Fluttering* was observed more frequently in females than males and generally involved hovering above a flower with rapid wing movements, similar to but not as graceful as a hummingbird.

Predator avoidance was observed a few times in response to foraging swallows. Patrolling or flying OSBs would immediately cease flight and drop to the ground.

Perching is a frequent, but intermittent activity between flights and probably serves a number of purposes such as resting, cleaning, predator avoidance, etc. It was often seen as a precursor to basking or after nectaring. During routine perching, the adult butterfly stands upright usually on the dorsal surface of vegetation with its wings folded over its body. In contrast to basking, the butterfly's wings are *not* oriented to receive sunlight. When *roosting*, the adult OSB is usually clinging up-side-down to the ventral surface of a leaf or branch with its wings closed and folded over its body. Perching occurs during the daytime hours when the butterfly is able to warm up and be active. The elapsed time of perching is generally brief, lasting no more than a few minutes. In contrast, roosting is initiated late in the day when temperatures drop or winds increase to a level that normal activity cannot continue and lasts until temperatures warm up the next day for butterfly activity to resume.

Foraging included intake of *nectar* and *water* through the proboscis (i.e., coiled, soda straw-like tongue of a butterfly). Nectar was imbibed from a number of flowers, while water was obtained from moist ground. *Excretion* was observed only once, by a female after sucking water from moist ground. Undoubtedly it occurs more frequently, but is undetected.

Oviposition includes five subcategories of behavior including *foreleg drumming*, *abdominal probing*, *walking*, *egg laying*, and *egg-laying flight.* Although not directly observed with the OSB, foreleg drumming is an activity employed by other *Speyeria* taxa (Arnold 1981) to discriminate their violet foodplants from surrounding vegetation. The reduced forelegs rapidly tap and scrape withered violet foliage or stems, presumably to release a chemical cue that tells the butterfly that the plant is a violet. Once a suitable oviposition site has been located, females probe the vegetation with their curled abdomen in search of a proper place to lay each egg. Females frequently walked over the vegetation for several centimeters after a series of abdominal probes or egg laying before stopping at a new location to probe the vegetation. Once a suitable microsite was found, eggs were generally laid singly. However, as many as six eggs, each laid singly, were found on one violet leaf in the field.

Interactive flights involved two or more adult OSBs or at least one OSB and another butterfly or insect. Males often made *investigative flights* in pursuit of other butterflies or insects that cross their paths while patrolling or which flew by them while nectaring, perching, or basking. Usually these encounters lasted no more than a few seconds. Similarly, OSB males would investigate other OSB males, presumably to determine if the encountered male was a receptive female. After the initial encounter, males would often *chase* one another for a few seconds before splitting apart to renew their respective patrolling. *Swarming flights* generally consisted of one female and two or more males vying for the female. Investigative flights and chases were generally parallel to the ground while swarming flights were perpendicular.

Mating behavior can be divided into *courtship* and *copulatory* activities. Once a male locates a receptive female, a *pre-nuptial flight* ensues in which both individuals ascend 20-30 meters above the ground while frantically flapping their wings. If receptive, the female rapidly descends and is closely pursued by the male. There may even be a brief zig-zag flight across the grass tops. Then both individuals alight on the ground or low vegetation. Rapid wing fluttering and nudging of the female by the male ensues during this pre-copulatory stage that lasts no more than a few minutes. Eventually, the terminal segments of the male and female abdomens become joined, an activity known as *copulation*. Generally, the copulating pair will remain motionless among the grasses or low-growing vegetation for the duration of copulation. If disturbed, one member of the pair will fly, usually the female, as the male remains *in copulo*. These *copulatory flights* are brief and the pair usually travels only as far as necessary to evade the disturbance.

3. Daily Activity Pattern.

A generalized daily activity (i.e., diel) pattern for OSB adults can be described as follows. OSB activity was greatest during the warmest portion of the day, usually between 1100 to 1600 PDT. Active adults were usually not observed before 0900 or after 1700 PDT, particular in exposed meadow areas due to cooler temperatures and stronger coastal winds. At these early morning or late afternoon times, the primary activities observed were basking, perching, or roosting. The earliest time at which normal flight was observed was 0913 on Cascade Head, while the latest time was 1906 on top of Mt. Hebo. Males appear to become active somewhat earlier in the day, on the average, than females.

Once adults were able to fly, various activities soon followed, including patrolling by males, oviposition by females, plus nectaring, courtship and mating, by both sexes. These activities were generally more prevalent in the late morning and early afternoon hours before the coastal breezes picked up. If the breezes intensified, butterfly activity in the exposed meadows gradually decreased, but activity would often continue in sheltered areas such as the forest fringe or on the leeward side of hills. As the temperature declined, butterflies tended to perch and bask more frequently and eventually sought a roosting site to spend the night. Table 6 details the observed primary behaviors for male and female OSBs at each of the four study sites.

4. Basking.

Basking occurred throughout the day, particularly at times when cloud cover or winds increased, resulting in a drop in the ambient air temperature. A greater proportion of adults observed basking did so in the early morning hours immediately prior to becoming active. Once sufficiently warmed up, adults could then begin other daily activities such as patrolling, foraging, courting, mating, etc. The darker colors of the OSB's wings, especially the heavy black concentrated near the thorax and along the wing veins, probably expedite warm up by the OSB.

5. Patrolling.

Patrolling is a flight activity by males designed to assist them in locating potential mates. Patrolling was observed daily as long as weather conditions permitted adults to be active. However, it was more prevalent in the mid-morning and early afternoon hours, before the coastal winds picked up or the fog rolled in. Patrolling was noted in both exposed and sheltered areas, but was more frequently seen in open meadows.

6. Nectaring.

Nectaring was the primary foraging activity observed, but one male and one female at Rock Creek were also observed drinking water from a mud puddle. After her drink of water, the female excreted a large drop of liquid excrement. OSB adults were noted nectaring at nine composites or asters, including *Senecio jacobaea*, *Solidago canadensis*, *Anaphalis margaritacea*, *Hypochaeris radicata*, *Chrysanthemum* sp., *Aster chilensis*, *Achillea millefolium*, *Cirsium vulgare*, and *C. edule*. The two thistles, *Cirsium vulgare* and *C. edule* could not always be distinguished reliably in the field, thus observations for these species were lumped in Table 7. Two additional plants, *Hypericum perforatum* (Hypericaceae) and *Mimulus guttatus* (Scrophulariaceae) were also visited for nectar. In the case of the *Mimulus* I am not certain that the OSB was able to reach any nectar with its proboscis.

Nectaring was observed throughout the day once adults had warmed up sufficiently to fly, but was most frequently observed during the period from 1100 to 1500. Although not measured during this study, this period may correspond to the time of maximum nectar production and flow in the nectar plants favored by OSB.

The duration of nectaring by an adult on a single flower ranged from a few seconds to several minutes. While nectaring, adults frequently visited several flowers within a few-minute span. During this sequence, the usual tendency was to visit the same type of flower rather than to visit flowers of different species. One female was followed at Cascade Head while she visited 19 different *Senecio* flowers. The longest nectaring duration on a single flower was nearly 25 minutes by a male on *Senecio* at Cascade Head.

Table 7 provides of breakdown of nectar plant utilization for male and female OSBs at all four study sites. At three of the four study sites, *Senecio* and *Solidago* were the primary plants visited for nectar. However, at Rock Creek, there were more visits to thistles than the *Senecio* and *Solidago* combined.

Four of the 12 nectar plants, *Chrysanthemum*, *Aster*, *Hypericum*, and *Mimulus* were not observed growing at Cascade Head in areas frequented by the the OSB or did not flower in significant numbers. Of the remaining eight nectar plants, both males and females preferred the introduced *Senecio* and native *Solidago* by a substantial margin over other available nectar plants. The *Senecio* was particularly abundant in several large patches, especially in the Senecio Slope (SEN) subsite (Figure 2). Its abundance here, along with shelter afforded by the forest fringe, may explain why so many OSBs were observed here. *Solidago* was fairly widely distributed, but tended to occur in forest fringe areas and on the steep, south-facing slopes, SS-E and SS-W.

Nectar plants utilized at the Clatsop Plains included *Aster*, *Senecio*, and *Solidago*. Although the total number of visits is relatively small, a slight preference for *Senecio* and *Solidago* is evident. In contrast, OSB visited all nine resident nectar plants at Mt. Hebo. Once again, *Senecio* and *Solidago* were the preferred nectar plants, followed by *Anaphalis* and *Hypochaeris*. Late in the flight season, one male was noted nectaring on *Hypericum*, another introduced plant.

At Rock Creek, introduced thistles accounted for the largest proportion of nectar plant visits. Indeed, the total number of visits to thistles in 1987 exceeded the combined number of visits to *Senecio* and *Solidago* in both 1986 and 1987. Most of the thistles were situated in the sheltered meadow at Area #5, where butterflies could be active longer due to warmer temperatures and minimal breezes due to the shelter afforded by the forest fringe. The *Senecio* also exhibited a rather localized distribution at Rock Creek, with major patches growing along the forest fringe just east of Highway 101. Similarly, the *Anaphalis*, *Hypochaeris*, and *Solidago* were found primarily in association with the forest fringe, whereas the *Aster* and *Achillea* were more abundant in the salt spray meadows. One male was observed trying to obtain nectar from *Mimulus* flowers at the Big Creek meadow (Area #5).

7. Other Flight Activities.

Interactive flight activities such as chasing, investigative flights, and swarming were observed throughout the day, but were generally more common in the late morning or early afternoon. Chasing usually involved two or more males in what appeared to be a playful chase. Chases often followed interactive flights, in which a male would fly after another male presuming that it was a female. During this interaction, there frequently was a very brief ascending flight, similar to the pre-nuptial flight in courtship. However, the males would generally break apart and fly off in their separate directions within a few seconds. When they did not break apart, a chase often ensued. Patrolling males would occasionally investigate other insects, including butterflies, bees, and dragonflies.

At Cascade Head and Clatsop Plains, swallows (presumably barn swallows) were observed trying to catch patrolling males. In each instance, the patrolling male would successfully avoid their predator by immediately closing their wings and dropping to the ground. Once on the ground, they remained motionless for several seconds to a few minutes before resuming their normal activity. Although the predation was unsuccessful in these attempts, I presume that the swallows are successful but that I was unable to observe this in the field.

8. Roosting.

Selection of roosting sites by adult OSBs was observed at Cascade Head (n = 5), Mt. Hebo (n = 12), and Rock Creek (n = 2). Plants used as roosts included primarily herbs and forbs such as several grasses, *Senecio*, thistles, *Pteridium*, *Anaphalis*, and shrubs. One adult at Mt. Hebo selected a small spruce, about 1 meter tall, for its evening roost. At Rock Creek, a male was noted roosting about 1.5 meters above the ground on a spruce that was nearly 15 meters tall. Roosting sites were located in both forest fringe and open meadow areas. At Cascade Head, roosting was observed in subsites SS-E (sheltered meadow), FF-B (forest fringe), UM-B (exposed meadow), and SEN (sheltered meadow/fringe), while at Mt. Hebo roosting was noted in sheltered Areas #2 and #6, plus exposed meadow Areas #7 and #8. Observed rooting sites at Rock Creek included the sheltered meadow Area #5 and the forest fringe Area #8.

9. Courtship and Mating.

On good weather days, mate location, courtship, and mating were observed in exposed meadow areas, where males most frequently patrolled, as well as forest fringe and topographically protected areas. However, on bad weather days, mate location, courtship, and mating activities were largely restricted to sheltered areas such as the forest fringe or topographically protected areas such as the steep south slope (SS-E in Figure 2) of Cascade Head. Males of all wing wear classes attempted to court and mate with females, but most copulating pairs consisted of fresh females and males.

As is the case for many other *Speyeria* populations, females of the OSB appear to mate just once. Two of the three females collected for laboratory oviposition possessed hardened mating plugs. Sims (1984) found mating plugs in females from several California populations of *Speyeria zerene*.

10. Oviposition.

Oviposition was observed between 1000 to 1700, but primarily occurred in the late morning and early afternoon. Subsites that were particularly favored by females included the meadow south of Del Rey Beach Road at the Clatsop Plains, SS-E and FF-B of Cascade Head, Areas #4, #6, and #7 on Mt. Hebo, plus the salt spray meadows of Rock Creek. In addition, eggs were also discovered on violets in the SEN and FF-A subsites of Cascade Head, Areas #4 and #7 of Mt. Hebo, plus the salt spray meadows (Areas #10 and #14) and below Area #7 at Rock Creek.

Females of many *Speyeria* populations exhibit a reproductive diapause, i.e., a delay in ovarian development, even though no delay of spermatogenesis is apparent in males. Although females usually mate shortly after emergence, onset of oviposition can be delayed for several days to a few weeks due to the reproductive diapause condition. Sims (1984) noted that this reproductive diapause is often associated with *Speyeria* populations which inhabit warm, dry weather areas where violets are generally withered and unsuitable for larval forage at the time of adult flight.

During this study I could not establish whether or not OSB possesses a reproductive diapause. Although my permit authorized me to collect as many as 15 OSB females from the Rock Creek population during 1986, I did not feel that the population was robust enough to collect that many females for oviposition. Thus only three females were collected. Only 68 fertile eggs were obtained, all from one female. Dissection of the reproductive system of a second female that did not lay eggs revealed that she had not mated, i.e., there was no spermatophore. A third female laid 184 eggs, but all of these proved to be infertile. No additional females were collected during the 1987 flight season.

Both of the females that laid eggs were of the fresh wing-wear class when collected in late August and early September. Initial ovipositions began within two days after they were transferred to oviposition containers (for oviposition methods refer to McCorkle et al. 1980). McCorkle et al. (1980) report a five-day time lag in onset of oviposition for a female collected in early September. Clearly, additional work will be necessary to elucidate the reproductive diapause condition of OSB. Since substantial violet foliage is present in good condition at the time of adult flight, the average length of reproductive diapause, if any, in OSB may be less than that observed for other *Speyeria* populations.

11. Effects of Weather and Exposure on Behavior.

As noted in the MATERIALS AND METHODS section, all areas where OSB activities were observed were classified according to their degree of exposure and weather conditions. Three exposure classes were used: 1) exposed, i.e., no protection from trees, other vegetation or topographic relief; 2) sheltered, i.e., significant protection due to presence of trees, other vegetation, or topographic relief; and 3) partial shelter, i.e., areas farther removed from the forest fringe, areas where tree cover was sparse or tree height was short, or areas where topographic relief provided some shelter depending upon the prevailing wind direction. Similarly, wind speed and ambient air temperature readings were periodically recorded using hand held instruments on each day that butterfly observations were made.

The lowest observed ambient air temperature for butterfly activity was 12.2 ^{o}C (54 ^{o}F). At this temperature in the early morning, butterflies were observed basking dorsally. Male patrolling flights were observed at 13.8 - 14.4^{o}C (57-58^{o}F) when skies were sunny and wind speed was negligible. If there was any cloud cover or wind, then the ambient air temperature had to be somewhat higher than this apparent threshold temperature for active flight to be observed. Most OSB activities were observed within the temperature range of 14.4 - 23.9^{o}C (58-75^{o}F). Air temperatures above 23.9^{o}C during this study were infrequent. The highest observed temperature was 31.1^{o}C (88^{o}F) at Cascade Head and Mt. Hebo, and 23.3^{o}C (74^{o}F) at Rock Creek.

As afternoon winds and cloud cover increased, sheltered forest fringe areas were often 1-2^{o}C warmer than exposed meadows. During 1987, field assistants with temperature recording equipment were simultaneously stationed in exposed, sheltered, and partially sheltered areas at each study site and regularly measured ambient air temperatures. The most extreme temperature differential witnessed at Cascade Head was 6.7^{o}C, when the temperature was 20^{o}C in the sheltered SS-E while it was only 13.3^{o}C in the exposed meadows, UM-A and UM-B. At Rock Creek the most extreme ambient air temperature differential was 9.5^{o}C, when it was 13.8^{o}C and windy (no OSB activity) in the salt spray meadow, while it was 23.3^{o}C and calm (much OSB activity) in the sheltered meadow in Area #5. On Mt. Hebo, the greatest differential between sheltered and exposed areas was only 4.4^{o}C.

Ideally it would be desirable to measure thoracic temperatures of OSB to correlate body temperature with ambient air temperature and more precisely measure the temperatures at which various behaviors occur. Unfortunately, my permit from the U.S. Fish & Wildlife Service did not allow me to capture butterflies as would be necessary to measure their thoracic temperatures. Perhaps this can be done at a later date.

Seasonal and daily wind patterns clearly affect adult OSB activity by influencing the butterfly's mechanical ability to fly as well as adversely affecting heat loss. Measurements of wind speed during my field studies suggest that summer winds of July and August tend to be stronger than those in late August and September. Weather data presented by Ripley (1983) confirms this assumption. Afternoon winds generally increased in intensity and were frequently accompanied by fog or clouds that resulted in lower ambient air temperatures and reduced solar radiation and light. Rapid temperature drops of 2-3^{o}C were experienced even within a few minutes in exposed meadows at Cascade Head and Rock Creek as wind speed and cloud cover increased. On days when the ambient air temperature was at or near the threshold necessary to support butterfly activity, even brief cooling off periods were sufficient to dramatically reduce butterfly activity.

Strong, gusty winds (greater than 16 km/hr.) curtailed butterfly activity in all but the most sheltered areas. Moderate winds, 8-16 km/hr., dampened butterfly activity in exposed meadows and forest fringe areas, but activity continued, albiet often at a reduced level, in the fringe areas. In a few well protected areas, such as SS-E of Cascade Head at the alder fringe, OSB activity did not appear to be affected. However, in exposed or partially sheltered areas, adults spent a proportionately greater amount of time basking and perching under these windy conditions, in contrast to normal flight activities. Although the amount of actual time available daily for OSB activity was the same in sheltered and exposed areas, realized activity time by OSB in sheltered and partially sheltered areas was greater than in exposed areas. Thus sheltered areas of habitat allow butterfly activity to continue even under less than optimal weather conditions as may frequently be experienced along the Oregon coast during the OSB's flight season.

Clearly, weather conditions that are suboptimal for flight activity may exert a negative effect on adult butterfly survivorship and fecundity. The inability to fly due to suboptimal weather conditions may expose OSB adults to greater risk of mortality due to predation, as has been demonstrated for *Papilio polyxenes* by Lederhouse (1983) and *Euphydryas chalcedona* by Bowers et al. (1984). These studies suggest that butterflies may be most susceptible to predation during times of roosting and basking behaviors, when they are unable to attain the body temperature necessary for flight.

Similarly, suboptimal weather conditions limit the amount of oviposition activity by females, which could influence population dynamics of OSB. Kingsolver (1983a and b) studying *Colias* butterflies, determined that because *Colias* females lay their eggs singly and need to fly between larval foodplants to oviposit, sufficient flight time is need to find foodplants and lay a full complement of eggs (maximum fecundity estimated to be 700-1000 eggs). By comparing field data on available and realized flight times, activity budgets, adult longevity, and maximum oviposition rates, Kingsolver estimated that *Colias* butterflies laid only 20-50% of their full egg load due to weather limited flight time. Like *Colias*, *Speyeria* butterflies, including the OSB, lay their eggs singly and usually fly between patches of foodplants to oviposit. Thus, the frequently foggy and windy weather which limits OSB flight activity, may prevent OSB females from laying their full complement of eggs.

Courtney (1984) summarized field data for realized fecundity of insects. Among lepidoptera, the mean realized fecundity of those species that lay their eggs singly was less than one-third of the maximum for all reported species. Furthermore, Dempster (1983), using key-factor analysis to identify determinants of population fluctuations in temperate lepidoptera, concluded that variation in realized fecundity was the single most determinant factor which influenced population fluctuations. As egg maturation rate is a temperature-dependent process in many insects, clearly the ability of females to thermoregulate could influence this process, particularly in a butterfly such as the OSB which may also experience a reproductive diapause.

Thus sheltered areas such as the forest fringes and leeward slopes of hills enable the OSB to remain somewhat active during periods of suboptimal weather conditions. By remaining active, the butterfly probably improves its chances for survival and increases its fecundity.

12. Effect of Wing Wear on Behavior.

Wing wear, i.e., loss of scales and fraying of the wings, accumulates gradually as butterflies age, thus it can be used as a relative index of age (Arnold 1983). Thus younger butterflies should exhibit less scale loss and wing fraying than older butterflies.

OSB adults of all three wing-wear classes, fresh, slightly worn, and battered, were observed partaking in most activities. The average daily wing wear for females generally lagged slightly behind that for males, as would be expected due to the emergence time lag.

There were a few instances in which fresher butterflies seemed to be favored or at an advantage compared to more worn butterflies. For example, primarily fresh males and females were observed in copulation even though slightly worn and battered males courted females of all wear classes. Battered butterflies, especially males, appeared to bask and nectar for slightly longer periods of time than fresh or slightly worn individuals. This finding suggests that loss of scales and frayed wings may slightly impair the thermoregulatory ability of OSB. The lost scales on males were the black ones nearest the thorax and along the wing veins. Clearly loss of black scales, good for maximum absorption of the sunlight, could affect thermoregulatory ability of OSB males.

13. Correlation of Behaviors and Habitats.

Table 8 depicts the observed frequency of occurrence for all primary behavioral types in each subsite at all four study sites. Data for Cascade Head, Mt. Hebo, and Rock Creek are sufficient to analyze trends. Data for Clatsop Plains are presented, but due to their paucity, analysis of trends is tenuous at this time. The remainder of this section highlights apparent trends and possible correlations between behavioral traits and associated habitats.

Mating behavior includes courtship and copulation. Most courtships and the vast majority of observed matings were in open or sheltered grasslands. At Cascade Head, 32% of all courtships occurred in forest fringe areas while 68% were noted in open meadow or sheltered meadow situations. Similarly, on Mt. Hebo, 78% of observed courtships occurred in open or sheltered meadows, while only 22% were in forest fringe areas. At Rock Creek, 45% of all courtships were witnessed in the salt spray meadows, 18% in sheltered interior meadows such as along Big Creek, and 36% in association with forest fringe areas. Matings in open or sheltered meadows occurred with frequencies ranging from 83% at Cascade Head to 100% at Rock Creek. Only a limited number of matings were observed in forest fringe areas, including 10% of all observed matings at Mt. Hebo and 17% at Cascade Head. Several of the matings in forest fringe areas were noted at times when weather conditions in the open meadows did not favor butterfly activity there.

Like mating and courtship, oviposition activities were largely associated with the open or sheltered meadow areas where violets grow. Nearly 73% of all ovipositions at Cascade Head, 93% at Rock Creek, 98% on Mt. Hebo, and 100% at Clatsop Plains were in association with meadows.

Although frequencies varied from site-to-site, interactive flights at Cascade Head, Mt. Hebo, and Rock Creek were observed more often in open or sheltered meadow areas than along forest fringes. Frequencies for exposed meadows ranged from 29% at Rock Creek to 77% Mt. Hebo, while frequencies for fringe areas ranged from 18% at Rock Creek to 26% at Cascade Head. Frequencies for sheltered meadows ranged from 23% on Mt. Hebo to 53% at Rock Creek.

Thermoregulatory activities, i.e., basking, occurred in both open and sheltered meadows as well as forest fringe areas but frequencies varied between study sites. At Cascade Head, 21% of the basking observations were in forest fringe areas, nearly 35% in open meadows, and 44% in sheltered meadows. All basking individuals at the Clatsop Plains were noted in open grassland. In contrast, on Mt. Hebo 58% of the observations were in open meadows while 42% were along forest fringes. Similarly, at Rock Creek nearly 45% of the basking observations were in the salt spray meadows, while only 8% were in the sheltered, interior meadows, and 47% were in forest fringes.

In contrast to the previously mentioned behaviors, there was no overall correlation of nectaring behavior with habitat types among all four study sites. At Cascade Head, 15% of all nectar observations occurred in open meadows, 79% in sheltered meadows (primarily SEN and SS-E), and only 6% in forest fringe areas. All nectar observations at the Clatsop Plains were in open meadow areas. On Mt. Hebo, 40% of nectar observations were in open meadows, while 60% occurred in fringe areas and sheltered meadows. At Rock Creek, 10% of the observations were in the exposed salt spray meadows, 59% in the interior, sheltered meadows (especially the Big Creek meadow, Area #5), and 31% were associated with forest fringe areas.

Selection of evening roosting sites by OSB adults was observed only 19 times during the two-year field study. At Rock Creek, both roosting observations occurred in sheltered areas, such as the Big Creek meadow and forest fringe (Area #8). Similarly, 60% of the roosting observations at Cascade Head were located in forest fringe or sheltered meadows, while 40% occurred in exposed meadows. Twelve of the 19 total roosting observations were made at Mt. Hebo. In contrast to both Cascade Head and Rock Creek, 67% of the Mt. Hebo roosting sites were on grasses and other herbaceous vegetation in exposed meadows, while 33% were in forest fringe and sheltered meadows. Due to the limited number of observations at Cascade Head and Rock Creek, it is difficult to ascertain whether different behavioral strategies are involved at these coastal sites versus the inland Mt. Hebo study site or whether the number of observations is just inadequate to discern any actual tendencies among all three study sites.

Similarly, common patterns among the study sites for perching behavior are not apparent from the results. Most perching observations at Mt. Hebo occurred in open meadows (82%), at Cascade Head in sheltered meadows (46%), and at Rock Creek in forest fringes (60%). Perching activities were noticed less frequently in fringe areas on Mt. Hebo (18%) and Cascade Head (15%), while at Rock Creek perching was least frequently noted in the exposed salt spray meadows (5%), perhaps because butterflies appear to leave the meadows when weather conditions do not favor their activity there. Perching OSB adults were witnessed in sheltered meadows at Cascade Head (46%) and Rock Creek (34%) with regularity, but were rarely noted on Mt. Hebo (3%).

B. Rearing Studies

Degree-days are often used to estimate the developmental time of immature stages and to predict the seasonal occurrence of pest insects that infest agricultural crops and forests. The concept of "degree-days" is based on the knowledge that the developmental threshold temperature is the air temperature below which an organism shows no real biological development and above which its development progresses. Therefore, to predict the organism's growth, it is the temperatures above this threshold that are important. Some organisms also have upper limiting temperature thresholds beyond which development ceases.

Degree-days are the amount of heat within these lower and upper developmental thresholds, i.e., the heat that is generating the organisms's growth. Thus, degree-days can be defined as arbitrary values derived from accumulated daily minimum and maximum temperatures that are associated with various biological processes. Specifically, for a given species a developmental minimum temperature is determined. This temperature is calculated by measuring development over a range of temperatures, fitting these growth rates to a line, and then extrapolating to zero.

Efforts to locate current or historical daily weather data, especially maximum and minimum temperature data, for Cascade Head, Mt. Hebo, and Rock Creek to estimate degree days for the field conditions were unsuccessful. I contacted several county, state, and federal agencies in an effort to locate such data, but was repeatedly told by agency representatives that such data for these or geographically nearby sites that might experience similar weather conditions were not available. Such data would be useful to relate the results of laboratory-reared livestock to field conditions. Due to the lack of such field temperature data, it is impossible to use the lab data from this study to extrapolate to field conditions for the purpose of estimating field developmental times of immature stages and predicting the onset and duration of adult flight seasons.

Livestock for estimating degree-day developmental times for OSB came from the Rock Creek population. Although my permit authorized me to collect as many as 15 OSB females from the Rock Creek population during 1986, my field observations suggested that the population level at that time was not robust enough to collect as many as 15 females for laboratory oviposition. Thus only three females were collected. From these females, a total of only 68 fertile eggs was obtained, all from one female. Dissection of the reproductive system of a second female that did not lay eggs revealed that she had not mated, i.e., there was no spermatophore. A third female laid 184 eggs, but all these proved to be infertile.

As noted in the Materials and Methods section, the eggs were divided into five batches and each batch was reared under a constant temperature (+ $1^{o}C$) to adulthood. Two batches of 13 eggs each were reared $8^{o}C$ and $24^{o}C$, while three batches of 14 eggs each were reared at 12, 16, and $20^{o}C$.

Egg hatch was lowest at $8^{o}C$, with only 4 larvae emerging (30.7%). Eleven of 14 eggs hatched at both 12 and $16^{o}C$ (78.5%), 13/14 (92.8%) at $20^{o}C$, and 12/13 (92.3%) hatched at $24^{o}C$. None of the larvae reared at $8^{o}C$ survived to adulthood. Only 2/11 (18.2%) reached adulthood at $12^{o}C$, 9/11 (81.8%) at $16^{o}C$, 11/13 (84.6%) at $20^{o}C$, and 5/12 (41.7%) at $24^{o}C$. Each larva was reared on a potted violet covered by fine netting. Larval developmental time was longest at $12^{o}C$ (x = 97 days) and fastest at $24^{o}C$ (x = 52 days). Pupation times ranged from an average of 11 days at $24^{o}C$ to 26 days at $12^{o}C$.

Developmental times of specimens surviving to adulthood for each constant temperature regime were used to calculate the developmental threshold temperature and degree days for OSB development. Based on these results, the total estimated number of degree-days for OSB development from the egg through the pupal stage is 506.3 degree-days with a development threshold of $10.2^{o}C$.

Before these results are used for any management purposes, I suggest that these laboratory studies be repeated with much larger sample sizes and a greater range of temperature regimes. Also, due to the small sample sizes, I could not examine the effects of different day lengths or variable temperatures, factors known to be important in regulating insect development (Tauber et al. 1986). As only one female laid fertile eggs, I also could not estimate the average number of degree-days *prior* to onset of oviposition. Clearly, this number should be included in the total developmental time, especially if female OSBs possess a reproductive diapause, as is suspected.

I should also note that the degree-day and threshold temperature estimates may *not* be accurate because the OSB larvae did not readily break their first instar diapause and begin feeding when held at constant temperature and day length, as is necessary to accurately estimate developmental times and degree-days. Thus the constant temperature regime was broken for a four-week period during which all larvae were chilled to 2^{o} C under 16:8 LD. Chilling is a commonly used entomological practice to break the diapause of insects (Tauber et al. 1986) and I have previously used chilling to break the larval diapause when rearing *Speyeria*. Upon returning to the constant temperature regime, OSB larvae began feeding and developed normally. However, this interruption of the constant temperature regime may have skewed the estimates of developmental times and degree-days.

Lack of accurate daily minimum and maximum temperature data from the four study sites makes it impossible to correlate these or future laboratory results with field conditions. For this reason, it would be useful to set out small weather stations along with recording devices to collect site-specific weather data. It would also be useful to set out more than one weather station per study site to measure the temperature differentials that undoubtedly exist on north-facing versus south-facing slopes, such as at Cascade Head, and differences due to varying degree of exposure. In addition, it would be desirable to record not only the daily maximum and minimum for ambient air temperature, but also similar daily temperatures in the grassy shelters where OSB complete their development. Observations of OSB larvae in the field revealed that temperatures in their shelters were often as much as 3.5^{o} C warmer than the ambient air temperature (see also McCorkle et al. 1980). Thus a good correlation between ambient air temperature and larval shelter temperatures would need to be established before laboratory results could be reliably extrapolated to field conditions.

Because of their dark ground color, OSB larvae are probably able to warm up to temperatures that are several degrees warmer than the ambient or shelter air temperatures. Thus it would be useful to measure the temperatures of larvae in the field with probes to determine this differential. Black globe temperature readings, which are influenced by both ambient air temperature and radiant heat load, may be useful in this regard and to more accurately correlate adult behavioral activities with ambient air temperatures.

C. Vegetational Composition, Spatial Configuration and Physical Conditions of Forest Fringe Areas

1. Herbaceous Vegetation.

Results of the vegetation cover-abundance estimates for eight sites at Cascade Head, 10 sites at Mt. Hebo, and eight sites at Rock Creek are presented in Tables 9, 10, and 11 respectively. Six forest fringe and two meadows were sampled at Cascade Head, eight forest fringes and two meadows were sampled at Mt. Hebo, plus five forest fringes and three meadows were sampled at Rock Creek.

Various grass species (lumped together for this analysis) exhibited the highest frequency (generally = 100%) in all six fringe and both meadow sites at Cascade Head (Table 9). *Achillea* had the next highest frequency in four of six fringe areas and one meadow site. Primary nectar plants or the larval foodplant, *Viola adunca*, generally were the next most frequently observed plants in fringe situations. The OSB's favored nectar plant, *Senecio*, was usually seen more often than *Solidago*. However, violet was the second most frequently observed plant in meadow areas.

At Mt. Hebo (Table 10), grasses exhibited the highest frequency of occurrence and highest average cover in both the fringe and meadow sites. The exotic *Hypochaeris*, a nectar plant for OSB, usually ranked second or third in observed frequency, ranging from 55-100%. Violet frequency and cover was generally among the leaders in the meadows but ranked near the bottom in fringe areas. Among favored nectar plants, *Solidago* was observed more often than *Senecio* and ranked in the mid-range of all plant frequencies compared to *Senecio* which was generally at the low end of the frequency range.

At Rock Creek (Table 11), grasses displayed the highest frequency (100%) and average cover at all subsites. *Achillea* exhibited the second highest frequency and cover values in the meadows, and was either second or third highest in the fringe areas, where its frequency ranged from 36-100%. *Hypochaeris* generally had a high ranking frequency in the fringe, but was lower in the meadows. It was absent in Area #5 at Big Creek. Violet was also absent at Area #5 as well as Area #4. In contrast, it was common in the salt spray meadows (Areas #6, #9&10, and #11-14), ranging in frequency from 76 to 80% with an cover range of 1.1 to 3.8. In the fringe areas, violet was much rarer, with a frequency range of only 6-15% and an average cover no higher than 1.1.

2. Forest Vegetation.

A variety of trees grow in forest fringe areas at the three study sites. Species encountered included Norway spruce (*Picea abies*), sitka spruce (*P. sitchensis*), douglas fir (*Pseudotsuga menziesii*), noble fir (*Abies procera*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*) among the conifers, while red alder (*Alnus rubra*) was the primary deciduous tree noted.

An example of Point-centered quarter method is presented in Table 12, using data from the forest fringe stand at SEN of Cascade Head. An example of actual calculations for density, dominance, and frequency are also presented at the bottom of the Table 12. Tree data from all other fringe areas were analyzed using an identical procedure. Results are presented in Table 13.

Stand structure 'for the various subsites at the three study sites can be summarized as follows. Tree density, especially among conifers, was generally greater at Cascade Head and Mt. Hebo than at Rock Creek. Although the density of conifers (primarily spruce) at Cascade Head and Rock Creek was generally less than the density of deciduous trees (primarily red alder), conifers were generally more dominant at both sites. This is probably due to the fact that the few large conifers at both sites had greater basal areas than the deciduous trees, hence the greater dominance values. The absolute frequency of conifers was almost always 100% at Cascade Head and Mt. Hebo. However, at Rock Creek the frequencies of conifers and deciduous trees were inversely related. Areas with high deciduous frequencies had much lower conifer frequencies, while low frequency deciduous areas exhibited much higher conifer frequencies.

Basal diameter and height classes are enumerated in Tables 14 and 15. Trees sampled at Cascade Head and Rock Creek included a mixture of coniferous and deciduous tree species, while only conifers were found in samples at Mt. Hebo. Basal diameters (Table 14) of most conifers at Cascade Head and Mt. Hebo were generally =< 20 cm., while those at Rock Creek were more evenly distributed among the four classes =< 40 cm. Basal diameters of deciduous trees, primarily red alder, at Cascade Head were almost entirely =< 20 cm., while those at Rock Creek were somewhat more evenly distributed among at least three and often four classes, =< 40 cm.

The majority of tree heights (Table 15) of both conifers and deciduous trees at Cascade Head were =< 15 meters, with just a few conifers taller than 15 meters. All sampled conifers on Mt. Hebo were =< 20 meters, with the majority =< 10 meters. In most forest fringe subsites at Rock Creek, the majority of conifers and deciduous trees sampled were =< 20 meters. However, both conifers and deciduous trees in the Big Creek meadow (Area #5) were significantly taller, ranging over 30 meters, than those in other sampled fringe areas.

<u>3. Spatial Configuration and Physical Conditions of Forest Fringe Areas.</u>

Tables 16, 17, and 18 summarize the spatial, physical, biological factors characteristic of forest fringe areas in each of the subsites for Cascade Head, Mt. Hebo, and Rock Creek. Despite examining numerous physical, spatial, and biological features of forest fringe areas, it was difficult to discern general, common patterns among the various factors, both within and between study sites which would facilitate development of management recommendations and implementation of management activities. For example, among the physical factors examined, elevation ranged from slightly above sea level at Rock Creek to about 990 meters (3200 feet) on Mt. Hebo. Generally, elevation among subsites within a particular study site, differed by no more than about 60 meters (200 feet). North-facing, northwest-facing, and east-facing aspects were more common than south- and west-facing aspects, but again no general pattern or stronger correlation with OSB usage emerged. Similarly, slope ranged from relatively flat meadows at Rock Creek to 60% slopes at SS-E on Cascade Head. However, slight slopes were more common than steep slopes among the three study sites. Nonetheless, the steep slopes of Cascade Head were heavily utilized both by adults for all activities as well as larvae.

Among spatial factors, configuration of the trees in the fringe area was important, especially in peripheral, edge-type, forest fringe areas. Trees oriented to create a windbreak from the prevailing westerly and northwesterly winds were most effective in providing shelter on hilltops at Cascade Head and Mt. Hebo. For example, subsite SEN of Cascade Head forms a U-shaped pocket in the peripheral forest fringe, with the mouth of the 'U' opening onto an adjacent meadow. Several U-shaped pockets exist on Mt. Hebo, but in general they appear to be under-utilized compared to SEN. This may be due to the limited number of nectar plants growing in many of the pockets on Mt. Hebo, particularly *Senecio* and *Solidago*, plus an understory of ferns, salal, and *Rubus*, rather than grassland as is found at SEN.

Other peripheral fringe areas are linear in shape, particularly along the roadway on Mt. Hebo and along Highway 101 at Rock Creek. The roadway on Mt. Hebo has in several places provided an opening in what is otherwise dense forest growth and its shoulders support nice stands of nectar plants favored by OSB. Thus these areas not only provide shelter and nourishment for OSB, but also a corridor for dispersal between meadows on the western, northern and eastern portions of the mountaintop. At Rock Creek, the peripheral, edge-type, forest fringe lies parallel to and east of Highway 101. Areas such as #8, which has two parallel, north-south trending stands of trees, with an open space between the stands, provided better shelter and supported activities of more OSBs than exposed areas such as Areas #2&3, where butterfly activity was limited primarily to calm days.

Interior forest fringe sites, such as the inland meadows in Areas #4 and #5 at Rock Creek, provided the greatest shelter for OSB adults, but were of no value to larvae as they lack violets. Nonetheless, these interior meadows provided nice refuges for OSB adults to forage and thermoregulate, but only limited courtship and mating activities were observed here. Adults must traverse to the peripheral fringe and salt spray meadows to mate.

Topographic features are also important for providing shelter for OSB. In some places, the protection offered by topographic relief may be equal to or even greater than that offered by trees that compose the forest fringe. For example, FF-B at Cascade Head would probably not offer much shelter for OSB if the adjacent meadow hillside did not somewhat shield the fringe from the prevailing coastal winds. Fringe areas #1 and #7 at Rock Creek similarly benefit from hillside protection. Even more dramatic is the situation at SS-E and, to a lesser extent at SS-W, on Cascade Head. The leeward portions of these steep, south-facing slopes provide a zone that experiences little wind when exposed upper slopes are buffeted by strong, gusty winds.

In peripheral, edge-type forest fringe areas, taller trees furnish shelter on their leeward sides over a greater distance immediately adjacent to the fringe, than do short trees. This was particularly evident in FF-C of Cascade Head where resident trees were too short along the fringe to provide much protection, thus fewer OSBs were observed here than at other fringe areas when strong winds were prevalent. Similarly, dense stands of trees in the peripheral fringe areas, provided better shelter from prevailing winds than sparse stands. Ambient air temperatures in these sheltered fringe areas were often 1 or 2^{0} C warmer than exposed meadow areas, and occasionally even higher, whereas sparse stands offered little protection from the winds and no noticeable temperature differential compared to exposed meadows.

On Mt. Hebo, peripheral fringe areas that were near or adjacent to open meadows were preferred by OSB. In contrast, at Rock Creek, an interior fringe area, #5, was preferred by OSB to the peripheral fringe areas, perhaps due to the greater shelter afforded by the interior location. The situation at Cascade Head is more difficult to properly assess as all peripheral fringe areas are adjacent to meadows and OSBs were not observed at interior fringe areas, such as LT-E.

The presence of nectar plants, especially preferred ones such as *Senecio*, *Solidago*, or thistles, was important in fringe areas to attract OSB and keep OSB in these areas, as well as provide nutrients and energy. Fringe areas dominated by grasses rather than brush, such as ferns, *Rubus*, or salal, also were favored by OSB. This was particularly noticeable on Mt. Hebo. OSB adults would use fringe areas dominated by ferns, salal, and *Rubus*, but generally did not linger in these areas unless nectar plants were plentiful. Interestingly, some of the best fringe areas either lacked violets (ex., areas #4 and #5 at Rock Creek) or the violets were present at low frequency and cover.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

My observations on the role of forest fringe areas in the ecology and behavior of the OSB, suggest that the fringe functions primarily as sheltered zones where OSB activity can continue when the strong coastal winds blow across the open meadows that the butterflies usually frequent. Observations during windy weather at Rock Creek, Cascade Head, and Mt. Hebo indicated that ambient air temperatures were typically 1-3^{O} C warmer in the more protected fringe areas and occasionally even much warmer. OSB adults were observed basking, perching, nectaring, courting, and mating in fringe areas during windy periods. During non-windy weather, OSB adults were also observed to utilize the forest fringe for these purposes, although a greater percentage of observations were in the open meadows when the weather was favorable. Butterflies at Rock Creek and Cascade Head appear to spend a greater amount of time.active in these sheltered areas than do butterflies at Mt. Hebo, perhaps due to the proximity of the former sites to the immediate coast.

Earlier studies of the OSB have suggested that when adults emerge from their pupae, they disperse into the adjacent forests to mature and avoid the generally windy coastal conditions characteristic of July and August. Despite spending a great deal of time in grassy pockets and clearcuts, only a handful of OSBs were observed in these types of forest fringe zones. Similarly, only a few adults were observed in the forest canopies. My field assistants and I even used walkie-talkies to try and track individual adults in the forest canopy, but the butterflies were always lost before we could follow them for any significant distance.

OSB's were frequently observed to fly into, but above, the forest canopy in fringe areas. Although visual contact was usually lost temporarily, within a few seconds or minutes an adult was frequently observed flying out of the fringe and back into the adjacent open meadow. As individual butterflies were not marked during this study, it is impossible to know whether the butterflies exiting the fringe were the same as those entering. A marking study would be useful to determine this as well as movements of the butterflies between and among habitats throughout their adult lifetimes. We also tried using the walkie-talkies to track OSBs in these areas, with observers stationed on either side of the fringe zone, for example between Areas #7 and #8 on Mt. Hebo, but this proved to be unsuccessful and was abandoned.

Despite these negative results, it is clear that OSB adults must move through, or more likely, above the forest as adults were found at the inland meadows, Areas #4 and #5, of Rock Creek. While it is possible that all adults merely follow the creeks inland to these meadows, undoubtedly some OSBs fly over the forest canopy in other places, but could not be tracked during this study to confirm this behavior.

Forest fringe areas varied widely in their species composition, density, dominance, and frequency of resident trees. The types of tree species present in a favored fringe area varied from subsite to subsite within a particular study site, as well as between study sites. Orientation of the trees, rather than the species of trees seemed to be more important. Butterfly activity was greatest in fringe areas where the trees were oriented to provide a windbreak from prevailing westerly and northwesterly winds. Fringes configured as a U-shape or as a linear opening in the forest were favored by OSB. The presence of nectar plants, but *not* violets, also seemed to be important in fringe areas favored by OSB. Finally, the importance of shelter afforded by topographic relief should not be overlooked.

Prime breeding areas for adults are primarily the open and sheltered grassland meadows that support the OSB's larval foodplant, *Viola adunca*. Males actively patrol in these areas in their search for mates. The vast majority of successful courtships and copulating pairs were also observed in the open and sheltered meadows. Sheltered forest fringe areas, particularly edges, supported these activities when the exposed meadows were too cold or windy for butterfly activity. Oviposition was largely restricted to the open meadows, but was observed in a few forest fringe areas where the adjacent understory supported'violets.

Grassy meadows, with abundant growth of *Viola adunca* were the best areas for larval growth and development. These meadows consist of various grasses and wildflowers, where the amount of thatch buildup is minimal so as to not choke out the violet. Field observations indicated that some larvae foraged in fringe areas that also supported the violet. However, many fringe areas either lacked violets or the violets occurred at very low density, thus their value for development of OSB larvae is at best minimal. Inland meadows, such as the Big Creek (Area #5) and Rock Creek (Area #4) meadows apparently lack violets and thus are of no value to OSB larvae, despite affording shelter for adults.

One of the more interesting results of this study is the observation that three of the OSB's favored nectar plants, *Senecio jacobaea*, *Cirsium vulgare*, and *Hypochaeris radicata*, are introduced species. Furthermore, the abundance of *Senecio* and OSB population numbers seems to be positively correlated. I suggest that eradication efforts towards *Senecio jacobaea* in known OSB localities be minimized until the importance of this and other exotic nectar plants for maintenance of OSB is better understood. A comparative study of the chemical constituents of each OSB nectar plant would help to determine if the concentrations of sugars or amino acids are greater in *S. jacobaea* than other visited nectar plants. Similarly, the floral morphology of the exotics and native plants should be compared to determine if the morphology of the exotics facilitates nectar collection by OSB adults. The exotics may also produce more nectar than the natives. Furthermore, seasonal and daily nectar flow patterns should be examined. For example, *Aster chilensis*, mentioned by McCorkle et al. (1980) as a primary nectar plant, was rarely used during this study, probably because it does not bloom until late in the OSB's flight season.

Nectar fulfills energy, water, and nutrient requirements of adult butterflies. Also, the nectar of many flowers is rich in amino acids and other nutrients important for egg production by female butterflies. Butterflies that are rather short-lived as adults probably obtain much of their nutrient requirements from larval reserves and may utilize nectar primarily for water and energy. Females may obtain some additional nutrition, especially important for egg production, from the breakdown of male spermatophores (Boggs and Gilbert 1979). Butterflies whose adults are longer lived, such as the OSB, may have to rely more heavily on nectar to supplement their nutritional requirements, in order to live longer and produce eggs. Some butterflies (e.g., *Colias*) discriminate among potential nectar sources and preferentially visit flowers that produce nectars rich in water, monosaccharides, and nitrogen-rich amino acids (Watt et al. 1974). Amino acids from pollen contribute to adult longevity and oogenesis in *Heliconius* (Gilbert 1975; Dunlap-Pianka et al. 1977; Boggs et al. 1981). Availability of sugars in the adult diet markedly enhances female longevity and number of egg clusters in *Euphydryas editha* (Murphy et al. 1983). Thus not only the abundance of suitable nectar plants, but also their chemical constituency can be very important for maintaining certain butterfly populations.

In other species of *Speyeria*, notably *S. aphrodite*, *S. cybele* (Arnold, unpublished observations), and *S. callippe* (Arnold 1981), I have noted that adults of certain populations often preferred to nectar at flowers of introduced plants rather than natives, or that the frequency of nectar visits to introduced species was substantial. Preliminary analysis of these situations suggested several possible reasons for these observations, including: 1) floral morphology of the introduced species facilitated nectar collection by adult silverspots; 2) flowers of introduced species were richer in sugars; or 3) flowers of introduced species were richer in amino acids or other chemical constituents.

Clearly, these factors could influence adult longevity, egg production, and population numbers of silverspots, such as OSB. Furthermore, as a resident of a windy and often cool environment where flight activity may be limited, adult silverspots that obtain readily available nectar from *Senecio* and other exotics may experience a selective advantage over adults that only visit native plants for nectar. Murphy et al (1983) found that in *Euphydryas editha bayensis*, the primary role of nectar was to aid longterm population survival by increasing population size in good years, which in turn buffered the butterfly's population from extinction in bad years. Thus the decline in population numbers of OSB at Rock Creek and Clatsop Plains during 1986 may have been due, in part, to reduced numbers of the nectar plant, *Senecio jacobaea*. At the Clatsop Plains, Hammond and McCorkle (1985) also noted that some OSB areas were nearly devoid of *Aster chilensis* and *Solidago canadensis*. For these reasons, I suggest that efforts to eradicate *Senecio jacobaea* from localities known to support OSB should be minimized until importance of this introduced plant for maintenance of OSB is more thoroughly investigated and understood.

B. Recommendations

The prime objective of the OSB's Recovery Plan (U.S. Fish & Wildlife Service 1982) is "to increase the numbers of individuals, populations, and amount of suitable habitat to permit removal of this insect from the list of Threatened and Endangered species". In addition, the OSB's Forest Implementation Plan (U.S. Forest Service 1984) outlines several specific recommendations regarding vegetation and forest management at Rock Creek and Mt. Hebo. Several management activities have already been implemented at Cascade Head, Rock Creek, and Mt. Hebo to improve habitat conditions for the butterfly. The results of this study substantiate the need for these actions and are used to make a few supplemental management recommendations.

1) Previous vegetation management efforts have focused largely on the reversing the conversion of grassland to brushland, which does not favor growth and reproduction of *Viola adunca*, the OSB's larval foodplant. At this time the importance of three introduced plants, which are heavily utilized by OSB adults as nectar sources, needs to be determined. One of these plants, *Senecio jacobaea*, is currently the target of a large-scale eradication program, yet OSBs substantially prefer this plant for nectar compared to natives. Eradication efforts towards the *Senecio* and other exotic nectar plants should be minimized until the importance of these exotics to the maintenance of OSB populations is better understood.

2) If the use of degree-days for predicting the onset and duration of adult flight seasons and larval developmental times is still considered important to the recovery of the OSB, then I recommend that the initial studies reported herein be repeated with larger sample sizes, plus a greater range of constant temperature regimes, as well as differential photoperiods. Also, it will be necessary to obtain, at a minimum, daily minimum and maximum temperature readings from each study site to enable extrapolation of laboratory results to field conditions. Such daily temperature data will need to be collected for a minimum of one year, however data from several years would be preferable to account for annual and seasonal variations that likely occur at each site. Ideally, such data should also be collected from more than one subsite within a particular site, to measure microclimatic variations, for example temperature differences that probably exist between north-facing and south-facing slopes. This information would help to better understand not only the developmental biology of the immature stages, but

also help to explain the protracted period of adult emergence.

3) As noted earlier, management activities have been implemented to reduce the conversion of grassland to brushland. These activities should continue, and if possible, be accelerated. Similarly, several areas that previously supported good fringe habitat (i.e., forest and adjacent meadow plants), have been overgrown by brush (fern, salal, and *Rubus*), plus trees (primarily spruce and alder). Brush and trees in these areas should be removed to create more U-shaped and linear openings in the fringe. Grassland plants, particularly OSB nectar plants, should be reestablished as understory plants.

4) Interior meadow areas at Rock Creek, especially Area #5 along Big Creek, were heavily utilized by OSB adults when weather conditions in the salt spray meadows were unsuitable for adult activity. Just like the violets, continued maintenance of these areas may be essential for sustaining the OSB population at Rock Creek. Only two inland meadows exist at this time, but most of the butterfly activity occurred in just one meadow. For this reason, I recommend that additional areas along Big Creek and Rock Creek be converted to interior meadow habitat to provide shelter and nectar for OSB.

5) In order to more accurately refine the correlation between ambient air temperature or black globe temperature and OSB body temperature, it would be helpful if capture of some OSB adults was allowed to measure their thoracic temperatures. This activity would allow more precise estimates of temperatures associated with various OSB behaviors than could be estimated during this study as butterflies were not captured.

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Table 1. Domin-Krajina cover classes.

Cover Class	Definition
10	100% cover, i.e., complete cover
9	75% > cover < 100%
8	50% > cover <= 75%
7	33% > cover <= 50%
6	25% > cover <= 33%
5	10% > cover <= 25%
4	5% > cover <= 25%
3	1% > cover <= 5%
2	< 1% cover, but scattered
1	< 1% cover, but solitary

Table 2. Plant taxa selected for vegetation cover-abundance studies. Asterisk (*) denotes exotic plant species. Three-letter abbreviations for each plant are used in other tables.

Scientific Name	Common Name	Abbreviation
Abies procera	Noble Fir	CON
Achillea millefolium	Yarrow	ACH
Alnus rubra	Red Alder	DEC
Anaphalis margaritacea	Pearly Everlasting	ANN
Aster chilensis	California Aster	AST
Chrysanthemum sp.	Daisy	---
Cirsium edule	Native Thistle	THI
* Cirsium vulgare	Bull Thistle	THI
Fragaria chiloensis	Strawberry	STR
Gaultheria shallon	Salal	SAL
* Hypochaeris radicata	False Dandelion	HYP
Picea sp.	Spruce	CON
Pseudotsuga menziesii	Douglas Fir	CON
Pteridium aquilinum	Bracken Fern	FRN
Rubus sp.	Blackberry	FRN
* Senecio jacobaea	Tansy Ragwort	SEN
Solidago canadensis	Goldenrod	SOL
Thuja plicata	Western Red Cedar	CON
Tsuga heterophylla	Western Hemlock	CON
Vaccinium sp.	Blueberry	SAL
Viola adunca	Common Blue Violet	VIO
various grass species	Grasses	GRA
bare ground, standing water, or exposed rock	Ground, water, or rock	GND

Table 3. Number of male and female observations, including initial and subsequent observations at four OSB study sites during 1986 and 1987.

Site	Year	Initial Observations	Subsequent Observations	Total Observations
Cascade Head	1986	1429	543	1972
Cascade Head	1987	3641	1761	5402
Totals		5070	2304	7374
Clatsop Plains	1986	2	6	8
Clatsop Plains	1987	54	57	111
Totals		56	63	119
Mt. Hebo	1986	1399	426	1825
Mt. Hebo	1987	3184	1290	4474
Totals		4583	1716	6299
Rock Creek	1986	87	135	222
Rock Creek	1987	620	305	925
Totals		707	440	1147

Table 4. Total number of combined initial and subsequent OSB observations in each subsite at four study sites during 1986 and 1987 flight seasons. (ns = not sampled).

CASCADE HEAD

Subsite	1986 Males	1986 Females	1987 Males	1987 Females
FF-A	43	57	374	107
FF-B	35	36	106	148
FF-C	10	4	21	16
FS Road	0	0	5	0
LT-E	0	0	0	0
LT-W	3	1	41	4
Penacle	0	0	ns	ns
Senecio Slope	202	378	865	695
SS-E	234	292	1071	539
SS-W	82	167	123	199
UM-A	89	70	192	112
UM-B	151	77	474	144
UM-C	38	3	145	21
Totals	887	1085	3417	1985

Table 4 (continued)

CLATSOP PLAINS

Subsite	1986 Males	1986 Females	1987 Males	1987 Females
Del Rey	0	8	47	24
Camp Rilea	0	0	0	0
PP&L	0	0	13	7
Cullaby Lake	0	0	15	5
Totals	0	8	75	36

MT. HEBO

Subsite	1986 Males	1986 Females	1987 Males	1987 Females
Area 1	64	34	195	49
Area 2	81	36	337	97
Area 3	161	40	250	62
Area 4	128	57	292	164
Area 5	82	59	179	77
Area 6	267	159	781	287
Area 7	370	187	1053	352
Area 8	53	47	231	68
Totals	1206	619	3318	1156

ROCK CREEK

Subsite	1986 Males	1986 Females	1987 Males	1987 Females
Area 1	7	5	34	17
Areas 2 & 3	13	6	47	11
Area 4	6	0	11	1
Area 5	82	16	209	84
Area 6	1	0	6	2
Area 7	19	4	105	40
Area 8	24	7	90	41
Areas 9 & 10	7	6	36	56
Areas 11-14	6	13	64	71
Forest pockets	0	0	0	0
Clear cuts	0	0	0	0
Totals	165	57	602	323

Table 5. Ethogram of adult OSB behaviors. Legend: - means behavior not was observed, + means behavior was observed.

Behavior	Males	Females
Solitary Activities		
A. Perching		
Brief Perching	+	+
Roosting	+	+
B. Basking		
Lateral Basking	+	+
Dorsal Basking	+	+
Shivering	+	+
Wing Pumping	+	+
C. Foraging		
Nectar Intake	+	+
Water Intake	+	+
D. Excretion	-	+
E. Locomotion		
Walking	+	+
Flying		
Patrolling	+	-
Fluttering	-	+
Non-patrolling flight	-	+
Predator Avoidance	+	+
F. Oviposition		
Abdominal Probing	-	+
Foreleg Drumming	-	-
Walking	-	+
Egg Laying	-	+
Egg-Laying Flight	-	+
Inter-Individual Activities		
G. Interactive Flights		
Chasing	+	+
Investigative Flights	+	-
Swarming	+	+
H. Mating		
Courtship	+	+
Pre-Nuptial Flight	+	+
Pre-Copulation	+	+
Copulation	+	+
Motionless	+	+
Copulatory Flight	+	+

Table 6. Summary of all (initial + subsequent) behavioral observations of OSB adults at four study sites during 1986 and 1987.

CASCADE HEAD

	1986		1987	
Behavior	Males	Females	Males	Females
Nectaring	275	396	1166	1290
Perching	73	47	54	73
Basking	83	66	460	344
Courting	72	72	27	27
Mating	29	29	7	7
Ovipositing	0	37	0	18
Flying	413	309	1467	270
Interaction	49	22	168	24
Totals	994	978	3349	2053

CLATSOP PLAINS

	1986		1987	
Behavior	Males	Females	Males	Females
Nectaring	0	4	21	24
Perching	0	0	1	4
Basking	0	0	9	8
Courting	0	0	0	0
Mating	0	0	0	0
Ovipositing	0	2	0	3
Flying	0	2	30	4
Interaction	0	0	6	1
Totals	0	8	67	44

Table 6 (continued)

MT. HEBO

Behavior	1986 Males	1986 Females	1987 Males	1987 Females
Nectaring	368	147	819	518
Perching	75	27	203	239
Basking	91	55	425	209
Courting	58	58	76	76
Mating	11	11	20	20
Ovipositing	0	37	0	26
Flying	582	221	1114	542
Interaction	56	28	135	52
Totals	1241	584	2792	1682

ROCK CREEK

Behavior	1986 Males	1986 Females	1987 Males	1987 Females
Nectaring	30	26	168	173
Perching	12	6	48	32
Basking	25	8	74	63
Courting	2	2	9	9
Mating	1	1	4	4
Ovipositing	0	4	0	23
Flying	67	9	215	37
Interaction	21	8	49	17
Totals	158	64	567	358

Table 7. Frequency of adult OSB visits (initial + subsequent) to nectar plants at four study sites. na = not available.

CASCADE HEAD

Plant	1986 Males	1986 Females	1987 Males	1987 Females
Achillea	0	0	31	26
Anaphalis	69	127	748	99
Aster	na	na	na	na
Chrysanthemum	na	na	na	na
Hypericum	na	na	na	na
Hypochaeris	16	23	55	45
Mimulus	na	na	na	na
Senecio	104	141	601	708
Solidago	76	94	380	387
Thistles	10	11	21	25
Totals	275	396	1166	1290

CLATSOP PLAINS

Plant	1986 Males	1986 Females	1987 Males	1987 Females
Achillea	0	0	0	0
Anaphalis	0	0	0	0
Aster	0	0	4	5
Chrysanthemum	na	na	na	na
Hypericum	na	na	na	na
Hypochaeris	0	0	0	0
Mimulus	na	na	na	na
Senecio	0	0	11	9
Solidago	0	4	6	10
Thistles	0	0	0	0
Totals	0	4	21	24

Table 7 (continued)

MT. HEBO

Plant	1986 Males	1986 Females	1987 Males	1987 Females
Achillea	17	0	39	11
Anaphalis	78	29	131	85
Aster	na	na	na	na
Chrysanthemum	2	5	6	16
Hypericum	0	0	1	0
Hypochaeris	35	39	79	105
Mimulus	na	na	na	na
Senecio	85	36	237	134
Solidago	124	34	286	145
Thistles	27	4	40	22
Totals	368	147	819	518

ROCK CREEK

Plant	1986 Males	1986 Females	1987 Males	1987 Females
Achillea	2	1	8	7
Anaphalis	3	1	7	5
Aster	2	1	6	5
Chrysanthemum	na	na	na	na
Hypericum	na	na	na	na
Hypochaeris	3	1	23	18
Mimulus	0	0	1	0
Senecio	6	10	31	34
Solidago	6	7	20	31
Thistles	8	5	72	73
Totals	30	26	168	173

Table 8. Observed behavioral types broken down by occurrence in each subsite of the four study sites. For this analysis, data for males and females from both 1986 and 1987 flight seasons have been combined for each subsite and for most behavioral types.

Cascade Head:

	Subsites												
Behavior	FF-A	FF-B	FF-C	FSR	LT-E	LT-W	SEN	SS-E	SS-W	UM-A	UM-B	UM-C	Behavior Totals
Interaction	26	40	2	0	0	2	49	36	38	22	30	18	263
Basking	104	93	2	1	0	8	218	143	87	66	136	35	953
Courting	38	26	0	0	0	0	20	72	6	8	24	4	198
Mating	2	4	0	0	0	0	6	46	4	6	2	2	72
Nectaring	137	31	19	3	0	5	1454	1006	77	89	265	41	3127
Oviposition	1	9	0	0	0	0	5	29	3	0	8	0	55
Perching	22	24	0	0	0	0	27	16	73	48	3	29	242
Roosting	0	1	0	0	0	0	1	1	0	0	2	0	5
Patrol/Fly	251	97	28	1	0	34	349	787	283	224	327	78	2459
Subsite Totals	581	325	51	5	0	49	2189	2136	571	463	797	207	7374

Clatsop Plains:

	Subsites				
Behavior	Del Rey	Camp Rilea	PP&L	Cullaby	Behavior Totals
Interaction	0	0	3	4	7
Basking	9	0	6	2	17
Courting	0	0	0	0	0
Mating	0	0	0	0	0
Nectaring	34	0	8	7	49
Oviposition	5	0	0	0	5
Perching	5	0	0	0	5
Roosting	0	0	0	0	0
Patrol/Fly	26	0	3	7	36
Subsite Totals	79	0	20	20	119

Table 8 (continued)

Mt. Hebo:

Behavior	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	Behavior Totals
	Subsites								
Interaction	14	28	6	22	20	14	109	58	271
Basking	7	135	128	73	4	56	331	46	780
Courting	4	14	18	30	6	16	149	31	268
Mating	0	0	4	8	0	2	36	12	62
Nectaring	163	145	117	129	92	600	502	104	1852
Oviposition	0	0	1	43	0	11	8	0	63
Perching	17	16	24	65	15	24	322	49	532
Roosting	0	1	0	0	0	3	4	4	12
Patrol/Fly	137	212	215	271	160	818	551	95	2459
Subsite Totals	342	551	513	641	297	1544	2012	399	6209

Rock Creek:

Behavior	# 1	#2&3	# 4	# 5	# 6	# 7	# 8	#9&10	#11-14	Behavior Totals
	Subsites									
Interaction	0	0	2	48	0	7	10	8	20	95
Basking	11	14	2	12	1	18	37	24	51	170
Courting	0	2	0	4	0	2	4	4	6	22
Mating	0	0	0	0	0	0	0	4	6	10
Nectaring	27	39	9	224	0	26	31	35	6	397
Oviposition	0	0	0	0	0	2	0	0	25	27
Perching	5	6	0	33	1	16	31	4	0	96
Roosting	0	0	0	1	0	0	1	0	0	2
Patrol/Fly	20	16	5	69	7	97	48	26	40	328
Subsite Totals	63	77	18	39	9	168	162	105	154	1147

Table 9. Domin-Krajina cover-abundance values for 15 plant taxa at eight Cascade Head subsites. Asterisks (*) indicate the plants with the three highest values for mean cover throughout the entire subsite.

CASCADE HEAD: Subsite #1 in Area SS-E (80 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	21	26.3	1.3	0.3
ANN	30	37.5	3.2	1.2
THI	54	67.5	5.2	3.5
SOL	16	20.0	6.4	1.3
ACH	74	92.5	4.1	3.8*
HYP	12	15.0	4.4	0.7
VIO	78	97.5	2.7	2.6
GRA	80	100.0	6.3	6.3*
FRN	59	73.8	5.8	4.3*
SAL	-	-	-	-
STR	26	32.5	2.2	0.7
GND	14	17.5	1.3	0.2
CON	13	16.3	7.0	1.1
AST	-	-	-	-
DEC	20	25.0	8.7	2.2

CASCADE HEAD: Subsite #2 in Area FF-C (78 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	41	52.6	2.4	1.3*
ANN	18	23.1	2.4	0.6
THI	40	51.3	1.7	0.9
SOL	26	33.3	2.7	0.9
ACH	77	98.7	2.9	2.9*
HYP	18	23.1	2.8	0.7
VIO	33	42.3	2.0	0.9
GRA	78	100.0	7.6	7.6*
FRN	16	20.5	2.3	0.5
SAL	-	-	-	-
STR	4	5.1	1.3	0.1
GND	20	25.6	1.0	0.3
CON	16	20.5	6.1	1.3*
AST	-	-	-	-
DEC	13	16.7	5.0	0.8

Table 9 (continued)

CASCADE HEAD: Subsite #3 in Area FF-B (110 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	99	90.0	3.3	3.0*
ANN	14	12.7	2.0	0.3
THI	84	76.4	1.7	1.3
SOL	11	10.0	1.0	0.1
ACH	109	99.1	4.1	4.1*
HYP	13	11.8	2.3	0.3
VIO	103	93.6	2.9	2.7
GRA	110	100.0	5.3	5.3*
FRN	24	21.8	2.6	0.6
SAL	-	-	-	-
STR	-	-	-	-
GND	7	6.4	1.7	0.1
CON	16	14.5	4.0	0.6
AST	-	-	-	-
DEC	9	8.2	5.4	0.4

CASCADE HEAD: Subsite #4 in Area Senecio Slope at base (86 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	18	20.9	1.3	0.3
ANN	29	33.7	1.9	0.6
THI	58	67.4	1.8	1.2
SOL	4	4.7	2.3	0.1
ACH	65	75.6	2.4	1.8*
HYP	69	80.2	2.3	1.9*
VIO	19	22.1	1.2	0.3
GRA	83	96.5	4.8	4.6*
FRN	10	11.6	2.8	0.3
SAL	-	-	-	-
STR	24	27.9	1.9	0.5
GND	45	52.3	1.7	0.9
CON	24	27.9	5.0	1.4
AST	-	-	-	-
DEC	2	2.3	2.0	<0.1

Table 9 (continued)

CASCADE HEAD: Subsite #5 in Area SS-W at base (80 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	14	17.5	1.8	0.3
ANN	26	32.5	2.5	0.8
THI	40	50.0	5.5	2.8*
SOL	28	35.0	4.2	1.5
ACH	69	86.3	3.7	3.2*
HYP	17	21.3	3.2	0.7
VIO	36	45.0	2.0	0.9
GRA	80	100.0	6.8	6.8*
FRN	20	25.0	4.6	1.2
SAL	-	-	-	-
STR	22	27.5	2.4	0.7
GND	16	20.0	1.6	0.3
CON	18	22.5	7.5	1.7
AST	-	-	-	-
DEC	17	21.3	7.5	1.6

CASCADE HEAD: Subsite #6 in Area FF-A (80 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	14	17.5	1.0	0.2
ANN	24	30.0	2.8	0.8
THI	12	15.0	2.3	0.3
SOL	51	63.8	2.7	1.7
ACH	72	90.0	3.8	3.4*
HYP	26	32.5	2.5	0.8
VIO	62	77.5	3.3	2.6*
GRA	80	100.0	7.1	7.1*
FRN	10	12.5	1.8	0.2
SAL	-	-	-	-
STR	8	10.0	1.8	0.2
GND	4	5.0	1.0	<0.1
CON	22	27.5	8.2	2.3
AST	-	-	-	-
DEC	16	20.0	6.4	1.3

Table 9 (continued)

CASCADE HEAD: Subsite #7 in Area UM-B (100 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	30	30.0	6.4	1.6
ANN	3	3.0	4.0	0.1
THI	15	15.0	4.4	0.7
SOL	21	21.0	5.7	1.2
ACH	67	67.0	4.6	3.1*
HYP	3	3.0	4.0	0.1
VIO	71	71.0	3.8	2.7*
GRA	100	100.0	8.4	8.4*
FRN	8	8.0	5.0	0.4
SAL	-	-	-	-
STR	4	4.0	3.5	0.1
GND	4	4.0	5.0	0.2
CON	-	-	-	-
AST	-	-	-	-
DEC	-	-	-	-

CASCADE HEAD: Subsite #8 in Area SS-E (100 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	20	20.0	4.3	0.9
ANN	11	11.0	4.6	0.5
THI	22	22.0	6.8	1.5
SOL	44	44.0	5.2	2.3
ACH	88	88.0	5.8	1.6
HYP	27	27.0	5.2	1.4
VIO	98	98.0	4.6	4.5*
GRA	100	100.0	7.4	7.4*
FRN	76	76.0	7.8	5.9*
SAL	-	-	-	-
STR	36	36.0	3.8	1.4
GND	22	22.0	4.4	1.0
CON	-	-	-	-
AST	-	-	-	-
DEC	-	-	-	-

Table 10. Domin-Krajina cover-abundance values for 15 plant taxa at 10 Mt. Hebo subsites. Asterisks (*) indicate the plants with the three highest values for mean cover throughout the entire subsite.

MT. HEBO: Subsite #1 in Area 6 (80 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	2	2.5	1.0	<0.1
ANN	27	33.8	1.4	0.5
THI	5	6.3	1.0	<0.1
SOL	50	62.5	2.2	1.4
ACH	41	51.3	2.0	1.0
HYP	74	92.5	2.2	2.0
VIO	7	8.8	2.6	2.3
GRA	76	95.0	2.0	1.9
FRN	48	60.0	3.4	2.0
SAL	34	42.5	3.2	1.4
STR	68	85.0	3.2	2.7*
GND	62	77.5	4.1	3.2*
CON	58	72.5	3.9	2.9*
AST	-	-	-	-
DEC	-	-	-	-

MT. HEBO: Subsite #2 in Area 7 (120 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	14	11.7	3.0	0.4
ANN	63	52.5	4.3	2.3
THI	29	24.2	2.4	0.6
SOL	72	60.0	3.8	2.3
ACH	108	90.0	5.2	4.7*
HYP	120	100.0	4.4	4.4*
VIO	116	96.7	3.6	3.5
GRA	120	100.0	5.8	5.8*
FRN	40	33.3	8.7	2.9
SAL	-	-	-	-
STR	102	85.0	4.1	3.5
GND	39	32.5	3.4	1.1
CON	48	40.0	8.8	3.5
AST	-	-	-	-
DEC	-	-	-	-

Table 10 (continued)

MT. HEBO: Subsite #3 in Area 8 (100 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	8	10.0	4.5	0.5
ANN	12	15.0	3.8	0.6
THI	20	25.0	3.6	0.9
SOL	36	45.0	3.9	1.8
ACH	40	50.0	5.8	2.9
HYP	76	95.0	4.0	3.8
VIO	54	67.5	4.7	3.2
GRA	78	97.5	7.4	7.2*
FRN	60	75.0	8.2	6.2*
SAL	23	28.8	7.6	2.2
STR	63	78.8	4.9	3.9*
GND	34	42.5	4.5	1.9
CON	42	52.5	7.4	3.9*
AST	-	-	-	-
DEC	-	-	-	-

MT. HEBO: Subsite #4 in Area 2 (100 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	28	28.0	2.6	0.7
ANN	43	43.0	3.2	1.4
THI	22	22.0	3.0	0.7
SOL	61	61.0	4.3	2.6
ACH	35	35.0	3.2	1.1
HYP	92	92.0	5.5	5.0*
VIO	4	4.0	1.5	<0.1
GRA	96	96.0	5.4	5.2*
FRN	38	38.0	4.2	1.6
SAL	16	16.0	6.8	1.1
STR	52	52.0	4.4	2.3
GND	82	82.0	5.1	4.2*
CON	24	24.0	8.6	2.1
AST	-	-	-	-
DEC	-	-	-	-

Table 10 (continued)

MT. HEBO: Subsite #5 in Area 5 (120 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	30	25.0	3.2	0.8
ANN	26	21.7	4.2	0.9
THI	15	12.5	2.0	0.3
SOL	62	51.7	4.6	2.4
ACH	32	26.7	3.2	0.9
HYP	104	86.7	3.7	3.2
VIO	11	9.2	2.2	0.2
GRA	115	95.8	6.3	6.0*
FRN	56	46.7	3.8	1.8
SAL	20	16.7	4.8	0.8
STR	46	38.3	2.5	1.0
GND	85	70.8	5.4	3.8*
CON	43	35.8	9.1	3.3*
AST	-	-	-	-
DEC	-	-	-	-

MT. HEBO: Subsite #6 in Area 5 (80 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	3	3.8	2.0	<0.1
ANN	21	26.3	5.7	1.5
THI	8	10.0	2.5	0.3
SOL	27	33.8	5.9	2.0
ACH	14	51.3	2.5	0.4
HYP	71	88.8	3.8	3.4*
VIO	32	40.0	1.0	0.4
GRA	78	97.5	4.5	4.4*
FRN	75	93.8	8.6	8.1*
SAL	6	7.5	5.0	0.4
STR	54	67.5	1.3	0.9
GND	13	16.3	4.2	0.7
CON	25	31.3	8.4	2.6
AST	-	-	-	-
DEC	-	-	-	-

Table 10 (continued)

MT. HEBO: Subsite #7 in Area 6 (80 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	2	2.5	1.0	<0.1
ANN	11	13.8	5.4	0.7
THI	4	5.0	1.5	<0.1
SOL	20	25.0	5.5	1.4
ACH	16	20.0	2.8	0.6
HYP	68	85.0	2.3	2.0
VIO	11	13.8	1.0	0.1
GRA	76	95.0	4.8	4.6*
FRN	80	100.0	8.2	8.2*
SAL	3	3.8	5.3	0.2
STR	62	77.5	1.6	1.2
GND	21	26.3	3.0	0.8
CON	24	30.0	8.5	2.6*
AST	-	-	-	-
DEC	-	-	-	-

MT. HEBO: Subsite #8 in Area 6 (80 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	18	22.5	5.4	1.2
ANN	11	13.8	3.2	0.4
THI	14	17.5	3.5	0.6
SOL	22	27.5	4.6	1.3
ACH	16	20.0	2.2	0.4
HYP	44	55.0	3.4	1.9
VIO	6	7.5	1.5	0.1
GRA	72	90.0	3.3	3.0*
FRN	63	78.8	8.4	6.6*
SAL	4	5.0	6.5	0.3
STR	31	38.8	2.4	0.9
GND	18	22.5	2.6	0.6
CON	22	27.5	7.6	2.1*
AST	-	-	-	-
DEC	-	-	-	-

Table 10 (continued)

MT. HEBO: Subsite #9 in Area 7 North Meadow (100 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	6	6.0	4.0	0.2
ANN	7	7.0	4.4	0.3
THI	12	12.0	4.5	0.5
SOL	26	26.0	5.2	1.4
ACH	74	74.0	5.2	3.8*
HYP	88	88.0	4.6	4.0
VIO	64	64.0	3.4	2.2
GRA	100	100.0	7.6	7.6*
FRN	2	2.0	4.5	<0.1
SAL	3	3.0	5.3	0.2
STR	62	62.0	4.6	2.9
GND	83	83.0	4.4	3.7*
CON	-	-	-	-
AST	-	-	-	-
DEC	-	-	-	-

MT. HEBO: Subsite #10 in Area 7 South Meadow (100 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	21	21.0	3.3	0.7
ANN	8	8.0	2.5	0.2
THI	15	15.0	3.0	0.5
SOL	32	32.0	4.6	1.5
ACH	100	100.0	5.8	5.8*
HYP	85	85.0	3.7	3.1
VIO	89	89.0	4.8	4.3*
GRA	100	100.0	8.4	8.4*
FRN	4	4.0	6.5	0.3
SAL	2	2.0	7.0	0.1
STR	55	55.0	4.3	2.4
GND	6	6.0	3.5	0.2
CON	-	-	-	-
AST	-	-	-	-
DEC	-	-	-	-

Table 11. Domin-Krajina cover-abundance values for 15 plant taxa at eight Rock Creek subsites. Asterisks (*) indicate the plants with the three highest values for mean cover throughout the entire subsite.

ROCK CREEK: Subsite #1-Big Creek Meadow in Area 5 (86 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	1	1.2	1.0	0.1
ANN	-	-	-	-
THI	49	56.9	2.8	1.6
SOL	-	-	-	-
ACH	45	52.3	4.2	2.2*
HYP	-	-	-	-
VIO	-	-	-	-
GRA	86	100.0	8.4	8.4*
FRN	2	2.3	1.5	<0.1
SAL	-	-	-	-
STR	-	-	-	-
GND	26	30.2	5.8	1.8*
CON	-	-	-	-
AST	-	-	-	-
DEC	2	2.3	5.5	<0.1

ROCK CREEK: Subsite #2-Hilltop Plateau in Area 8 (40 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	30	75.0	3.0	1.0
ANN	7	17.5	1.8	0.3
THI	4	10.0	2.1	0.2
SOL	11	27.5	3.3	0.9
ACH	13	32.5	2.6	0.8
HYP	26	65.0	2.2	1.4*
VIO	6	15.0	1.5	0.2
GRA	40	100.0	8.6	8.6*
FRN	8	20.0	1.5	0.3
SAL	4	10.0	1.3	0.1
STR	8	20.0	3.5	0.7
GND	12	30.0	3.5	1.1
CON	16	40.0	9.0	3.6*
AST	5	12.5	1.4	0.2
DEC	8	20.0	6.4	1.3

Table 11 (continued)

ROCK CREEK: Subsite #3-Salt Spray Meadow in Area 14 (50 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	0	-	-	-
ANN	2	4.0	3.0	0.1
THI	6	12.0	3.8	0.5
SOL	5	10.0	4.2	0.4
ACH	50	100.0	4.4	4.4*
HYP	42	84.0	3.7	4.4*
VIO	38	76.0	1.5	1.1
GRA	50	100.0	9.4	9.4*
FRN	14	28.0	1.4	0.4
SAL	3	6.0	6.3	0.4
STR	27	54.0	1.7	0.9
GND	13	26.0	1.2	0.3
CON	0	-	-	-
AST	8	16.0	1.3	0.2
DEC	0	-	-	-

ROCK CREEK: Subsite #4-Senecio Hilltop Fringe in Area 7 (50 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	34	68.0	5.6	3.8*
ANN	6	12.0	0.5	4.0*
THI	18	36.0	5.0	1.8
SOL	11	22.0	2.3	1.0
ACH	26	52.0	3.7	1.9
HYP	14	28.0	2.2	1.2
VIO	3	6.0	2.7	0.2
GRA	50	100.0	6.8	6.8*
FRN	4	8.0	4.5	0.4
SAL	5	10.0	7.6	0.8
STR	4	8.0	5.5	0.4
GND	19	38.0	4.1	1.6
CON	12	24.0	8.3	2.0
AST	3	6.0	2.0	0.1
DEC	9	18.0	5.0	0.9

Table 11 (continued)

ROCK CREEK: Subsite #5- Forest Fringe in Area 1 (50 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	6	12.0	4.5	0.5
ANN	3	6.0	4.0	0.2
THI	4	8.0	4.0	0.6
SOL	14	28.0	6.5	1.8
ACH	18	36.0	3.2	1.2
HYP	22	44.0	2.4	1.1
VIO	5	10.0	2.5	0.3
GRA	50	100.0	8.6	8.6*
FRN	16	32.0	5.8	1.9*
SAL	2	4.0	5.0	0.2
STR	8	16.0	4.4	0.7
GND	11	22.0	2.6	0.6
CON	16	32.0	8.4	2.7*
AST	3	6.0	3.0	0.2
DEC	4	8.0	8.0	0.6

ROCK CREEK: Subsite #6- Forest Fringe in Areas 2 & 3 (50 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	3	6.0	4.0	0.2
ANN	9	18.0	4.7	0.8
THI	5	10.0	4.6	0.5
SOL	12	24.0	5.5	1.3
ACH	48	96.0	4.9	4.7*
HYP	44	98.0	4.2	3.7*
VIO	3	6.0	3.0	0.2
GRA	50	100.0	7.4	7.4*
FRN	13	26.0	4.3	1.1
SAL	-	-	-	-
STR	18	36.0	4.4	0.2
GND	12	24.0	3.5	0.8
CON	8	16.0	7.9	1.3
AST	6	12.0	3.5	0.4
DEC	12	24.0	9.0	2.2

Table 11 (continued)

ROCK CREEK: Subsite #7- Meadow Along Rock Creek in Area 4 (50 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	12	24.0	4.4	1.1
ANN	2	4.0	3.0	0.1
THI	17	34.0	4.3	1.5
SOL	-	-	-	-
ACH	43	86.0	4.3	3.7*
HYP	4	8.0	3.5	0.3
VIO	-	-	-	-
GRA	50	100.0	7.8	7.8*
FRN	5	10.0	2.0	0.2
SAL	-	-	-	-
STR	-	-	-	-
GND	10	20.0	3.9	0.8
CON	5	10.0	6.4	0.6
AST	-	-	-	-
DEC	16	32.0	8.5	2.7*

ROCK CREEK: Subsite #8- Salt Spray Meadow in Areas 9 & 10 (50 quadrats)

Plant	# Quads	Frequency	$\bar{x}$ Cover in Quads	$\bar{x}$ Cover in Site
SEN	-	-	-	-
ANN	-	-	-	-
THI	6	12.0	4.5	0.5
SOL	3	6.0	5.0	0.3
ACH	48	96.0	5.5	5.3*
HYP	5	10.0	4.8	0.5
VIO	40	80.0	4.8	3.8*
GRA	50	100.0	8.6	8.6*
FRN	12	24.0	3.4	0.8
SAL	-	-	-	-
STR	18	36.0	3.8	1.4
GND	3	6.0	4.0	0.2
CON	-	-	-	-
AST	8	16.0	3.6	0.6
DEC				

Table 12. Stand structure analysis using the point-centered quarter method for subsite Senecio Slope of Cascade Head. There are four quarters for each sampling point. The distance for each tree to the sampling point is measured in meters. Trees are classified as conifers (CON) or deciduous (DEC). Basal diameter is measured in centimeters and tree height is measured in meters and derived from a clinometer calculation. Basal area is calculated using the formula:

$\pi * (0.5 * \text{diameter})^2$.

Sample Pt.	Quarter	Distance	Tree Group	Basal Diameter	Basal Area	Height
1	1	2.8	CON	15.2	181.5	4.5
	2	2.2	CON	9.7	73.9	3.0
	3	0.9	CON	9.8	75.4	3.1
	4	1.6	DEC	3.2	8.0	3.0
2	1	2.4	DEC	12.7	126.7	5.5
	2	0.3	CON	22.9	411.9	7.7
	3	3.1	CON	71.1	3970.4	23.9
	4	1.7	CON	25.4	506.7	7.3
3	1	0.8	CON	10.2	81.7	3.7
	2	2.1	CON	19.4	295.6	6.6
	3	3.5	DEC	45.7	1640.3	7.2
	4	1.4	CON	1.6	2.0	2.7
4	1	0.5	DEC	18.6	271.7	7.6
	2	1.9	CON	24.0	452.4	8.4
	3	4.0	CON	26.8	564.1	8.9
	4	2.6	CON	2.4	4.5	1.4
5	1	1.4	DEC	4.0	12.6	1.3
	2	1.2	CON	2.0	3.1	0.9
	3	0.2	DEC	5.1	20.4	2.6
	4	2.1	CON	2.8	6.2	0.9
6	1	0.4	CON	4.5	15.9	1.9
	2	1.1	CON	4.3	14.5	1.8
	3	2.8	CON	9.8	75.4	4.4
	4	4.2	CON	35.6	995.4	6.5
7	1	2.3	CON	8.9	62.2	3.4
	2	1.7	CON	8.1	51.5	5.0
	3	0.6	CON	4.9	18.9	6.0
	4	1.2	CON	7.9	49.0	6.0
8	1	1.4	CON	20.4	326.9	4.0
	2	0.3	DEC	9.7	73.9	5.8
	3	2.9	CON	8.8	60.8	5.2
	4	3.4	CON	12.9	130.7	3.6
9	1	2.6	CON	29.1	665.1	4.2
	2	0.5	CON	32.0	804.2	7.0
	3	3.4	CON	18.3	263.0	9.3
	4	3.2	CON	15.2	181.5	4.6
10	1	1.4	CON	12.7	126.7	5.2
	2	2.3	CON	15.2	181.5	5.4
	3	2.0	CON	12.8	128.7	4.5
	4	2.8	DEC	10.2	81.7	4.7

Table 12 (continued)

11	1	2.3	CON	15.3	183.9	5.3
	2	1.4	DEC	10.5	86.6	5.2
	3	0.7	CON	30.5	730.6	6.1
	4	4.6	CON	33.0	855.3	8.2
12	1	0.2	CON	15.0	176.7	5.6
	2	3.2	CON	40.6	1294.6	5.3
	3	2.4	CON	2.5	4.9	3.0
	4	2.1	DEC	3.6	10.2	0.6
13	1	2.2	DEC	8.2	52.8	6.1
	2	1.8	CON	60.9	2912.9	8.7
	3	3.4	CON	15.3	183.9	5.7
	4	3.2	DEC	17.8	248.8	7.9
14	1	2.9	CON	86.4	5863.0	8.3
	2	3.6	CON	68.6	3696.1	7.6
	3	0.3	DEC	12.1	115.0	3.7
	4	0.9	CON	7.3	41.9	3.2
15	1	3.2	CON	39.9	1250.4	6.9
	2	2.4	CON	19.9	311.0	5.5
	3	2.8	CON	27.6	598.2	6.0
	4	2.1	DEC	16.4	211.2	7.7

Mean Distance = Sum of individual distances / 60 trees = 2.048 meters

Absolute Density = Area/(mean distance) = 100/(2.048) = 23.8 trees
CON Density = 46/60 * (23.8) = 18.25 trees/ 100 m
DEC Density = 14/60 * (23.8) = 5.55 trees/ 100 m

Absolute Dominance = (absolute density) * (mean basal area)
CON Dominance = 18.25 * (627.9 cm) = 11,459.2
DEC Dominance = 5.55 * (211.4 cm) = 1,173.3

Absolute Frequency = # encounters per tree group/total # sampling points
CON Frequency = 15/15 = 100.0%
DEC Frequency = 12/15 = 80.0%

Table 13. Summary of stand structure analysis results for all study sites and subsites, comparing absolute density, absolute dominance, and absolute frequency.

	Density		Dominance		Frequency	
Subsite	CON	DEC	CON	DEC	CON	DEC
Cascade Head						
1. FF-A	24.6	12.7	17,848.0	1,021.0	100.0	70.0
2. FF-B	14.8	9.2	23,974.4	1,767.1	100.0	40.0
3. FF-C	19.3	11.2	6,538.5	1,551,2	100.0	85.0
4. SEN	18.3	5.6	11,459.2	1,173.3	100.0	80.0
5. SS-E	17.7	21.4	1,453.0	2,277.7	100.0	100.0
6. SS-W	15.2	16.0	2,140.2	1,688.6	90.0	100.0
Mt. Hebo						
1. Area 2	20.7	-	6,774.1	-	100.0	-
2. Area 5a	15.3	-	8,992.8	-	100.0	-
3. Area 5b	17.2	-	17,750.1	-	100.0	-
4. Area 6a	9.6	-	10,799.3	-	100.0	-
5. Area 6b	18.3	-	11,918.4	-	100.0	-
6. Area 6c	12.6	-	11,250.9	-	100.0	-
7. Area 7	14.4	-	17,573.3	-	100.0	-
8. Area 8	13.5	-	11,879.2	-	100.0	-
Rock Creek						
1. Area 1	10.4	1.3	6,126.1	569.4	100.0	20.0
2. Areas 2&3	2.6	14.3	549.8	2,002.8	15.0	100.0
3. Area 4	2.9	7.2	844.3	942.5	25.0	100.0
4. Area 5	2.2	8.8	35,463.1	17,896.5	26.7	100.0
5. Area 7	5.7	3.8	4,398.2	1,178.1	100.0	40.0
6. Area 8	6.5	4.2	4,339.3	2,002.8	80.0	35.0

Table 14. Observed frequencies of basal diameters (measured in centimeters) of sampled conifers and deciduous trees in forest fringe areas at Cascade Head, Mt. Hebo, and Rock Creek.

	BASAL DIAMETER CLASSES											
	Conifers						Deciduous					
Subsite	=<10	=<20	=<30	=<40	=<50	>50	=<10	=<20	=<30	=<40	=<50	>50
Cascade Head												
FF-A	31.3	43.8	10.4	8.3	4.2	----	83.3	16.7	----	----	----	----
FF-B	14.3	59.2	14.3	4.1	2.0	8.2	36.4	63.6	----	----	----	----
FF-C	54.8	38.1	7.1	----	----	----	72.2	27.8	----	----	----	----
SEN	36.9	26.1	15.2	10.9	2.2	8.7	42.9	50.0	----	----	7.1	----
SS-E	76.2	23.8	----	----	----	----	82.1	17.9	----	----	----	----
SS-W	79.1	16.3	4.7	----	----	----	78.8	12.1	9.1	----	----	----
Mt. Hebo												
Area 2	73.3	18.3	8.4	----	----	----	----	----	----	----	----	----
Area 5a	61.7	28.3	10.9	1.7	----	----	----	----	----	----	----	----
Area 5b	38.6	44.3	10.0	4.3	2.9	----	----	----	----	----	----	----
Area 6a	41.7	50.0	8.3	1.7	----	----	----	----	----	----	----	----
Area 6b	65.0	15.0	10.0	----	10.0	----	----	----	----	----	----	----
Area 6c	78.0	14.0	----	----	8.0	----	----	----	----	----	----	----
Area 7	53.8	21.3	23.8	1.1	----	----	----	----	----	----	----	----
Area 8	55.0	40.0	10.0	5.0	----	----	----	----	----	----	----	----
Rock Creek												
Area 1	12.5	36.3	47.5	3.7	----	----	20.0	45.0	35.0	----	----	----
Area 2&3	13.3	40.0	26.7	20.0	----	----	11.0	55.0	29.0	5.0	----	----
Area 4	12.0	32.0	16.0	4.0	----	----	14.0	44.0	33.0	9.0	----	----
Area 5	----	----	28.6	28.6	----	42.8	----	6.7	13.3	33.0	40.0	----
Area 7	9.2	12.3	40.0	33.8	4.6	----	16.9	46.2	30.8	6.1	----	----
Area 8	5.6	13.9	33.3	38.9	8.3	----	7.8	27.5	43.1	21.5	----	----

Table 15. Observed frequencies of heights (measured in meters) of sampled conifers and deciduous trees in forest fringe areas at Cascade Head, Mt. Hebo, and Rock Creek.

	HEIGHT CLASSES													
	Conifers							Deciduous						
Subsite	=< 5	=<10	=<15	=<20	=<25	=<30	> 30	=< 5	=<10	=<15	=<20	=<25	=<30	> 30
Cascade Head														
FF-A	45.8	39.6	10.4	4.2	----	----	----	57.1	28.6	16.7	----	----	----	----
FF-B	36.7	55.1	8.2	----	----	----	----	18.2	72.7	9.1	----	----	----	----
FF-C	52.4	38.1	9.5	----	----	----	----	55.6	44.4	----	----	----	----	----
SEN	43.5	54.3	----	----	2.2	----	----	42.9	57.1	----	----	----	----	----
SS-E	25.0	75.0	----	----	----	----	----	71.4	28.6	----	----	----	----	----
SS-W	50.0	41.2	8.8	----	----	----	----	64.3	25.0	10.7	----	----	----	----
Mt. Hebo														
Area 2	48.4	25.0	18.3	8.3	----	----	----	----	----	----	----	----	----	----
Area 5a	46.7	40.0	10.0	3.3	----	----	----	----	----	----	----	----	----	----
Area 5b	38.6	45.7	11.4	4.3	----	----	----	----	----	----	----	----	----	----
Area 6a	56.7	25.0	15.0	3.3	----	----	----	----	----	----	----	----	----	----
Area 6b	67.5	22.5	10.0	----	----	----	----	----	----	----	----	----	----	----
Area 6c	48.0	40.0	8.0	4.0	----	----	----	----	----	----	----	----	----	----
Area 7	52.4	33.8	10.0	3.8	----	----	----	----	----	----	----	----	----	----
Area 8	30.0	48.3	15.0	6.7	----	----	----	----	----	----	----	----	----	----
Rock Creek														
Area 1	17.5	48.4	28.8	5.0	----	----	----	25.0	65.0	10.0	----	----	----	----
Area 2&3	33.3	40.0	20.0	6.7	----	----	----	16.0	65.0	13.0	6.0	----	----	----
Area 4	----	32.0	32.0	24.0	8.0	4.0	----	9.0	22.0	46.0	23.0	----	----	----
Area 5	----	----	----	33.3	----	33.3	33.3	----	----	5.9	11.8	11.8	52.9	17.6
Area 7	16.9	46.2	30.8	6.1	----	----	----	20.0	71.4	8.6	----	----	----	----
Area 8	16.7	66.7	8.3	8.3	----	----	----	21.6	56.9	13.7	7.8	----	----	----

Table 16. Summary of physical and biological features of forest fringe areas at Cascade Head subsites. For aspect, N = north-facing, NW = northwest-facing, S = south-facing, SW = southwest-facing. Slope is measured in percent and elevation in meters. + = present and - = absent. adj = adjacent, while iso = isolated. ? = unknown or could not determine. na = does not apply.

	SUBSITES								
Feature	SEN	FF-A	FF-B	FF-C	SS-E	SS-W	UM-A	UM-B	UM-C
Physical									
Aspect	NW	NW	N	N&NW	S	S&SW	NW+W	S	S
Slope	10	30	30	16	60	50	10	10	10
Elevation	370	340	370	370	250-370	215-340	340	370	385
Spatial									
Acreage	2	2	1	1	>10	>10	<5	2	<2
Tree density	dense	sparse	dense	dense	na	na	na	na	na
Configuration	U-shape	NE/SW rows	abrupt edge	abrupt edge	na	na	na	na	na
Shelter	++	+	+	+	++	+	--	--	--
Proximity to meadows	adj	adj	adj	adj	adj	adj	na	na	na
Biological									
Violets	+	+	++	+	+++	++	+	+	+
Nectar:									
SEN	+++	+	++	+	+	+	+	+++	+
ANN	+	+	+	+	++	+	+	+	+
THI	+	+	+	+	++	++	+	+	+
SOL	+	+	+	+	++	++	+	+	+
ACH	+	++	++	+	++	++	+	+	+
HYP	+	+	+	+	++	++	+	+	+
AST	-	-	-	-	-	-	-	-	-
OSB adult usage:									
Court/Mate	++	++	++	-	+++	+	+	++	+
Oviposit	+	+	+	-	++	+	-	+	-
Nectar	++++	+++	+	+	++++	+	+	+++	+
Bask	++++	++	++	+	+++	++	++	+++	++
Perch/Roost	++	+	++	-	++	++	++	++	++
OSB larval usage:	+	?	+	?	++	+	+	+	+

Table 17. Summary of physical and biological features of forest fringes located at Mt. Hebo subsites. For aspect, N = north-facing, NW = northwest-facing, S = south-facing, SW = southwest-facing. Slope is measured in percent and elevation in meters. + = present and - = absent. adj = adjacent, while iso = isolated. ? = unknown or could not determine. na = does not apply.

	SUBSITES							
Feature	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8
Physical								
Aspect	E	E&W	E	N&E	N	E&W	E	E&S
Slope	<10	<10	< 5	<10	<10	<10	< 5	< 5
Elevation	930	930	930	930	930	960	960	960
Spatial								
Acreage	1	3	3	5	5	2	3	5
Tree density	dense	dense	sparse	na	sparse	dense/ sparse	dense	dense
Configuration	linear	U-shaped	U-shaped	flat U	linear	linear	pear shaped	oval
Shelter	++	++	++	+/-	+	+	+	+
Proximity to meadows	iso	iso	iso	na	adj	adj	adj	adj
Biological								
Violets	+	+	+/-	++	+	+/-	++	+
Nectar:								
SEN	+	+	+	+	+	++	++	+
ANN	+	++	+	-	+	++	++	+
THI	+	+	+	+	+	+	+	+
SOL	+	+++	++	++	++	++	+++	++
ACH	+	+	+	++	+	+	+++	+++
HYP	++	+++	++	+	++	++	++	+++
AST	-	-	-	-	-	-	-	-
OSB adult usage:								
Court/Mate	+	+	++	++	+	+	+++	++
Oviposit	-	-	+	++	-	+	+	-
Nectar	+	+	+	+	+	+++	+++	+
Bask	+	++	+	++	++	+	+++	++
Perch/Roost	+	+	+	++	+	++	+++	++
OSB larval usage:	-	?	?	+	?	?	+	+

Table 18. Summary of physical and biological features of forest fringe areas at Rock Creek subsites. For aspect, N = north-facing, NW = northwest-facing, S = south-facing, SW = southwest-facing. Slope is measured in percent and elevation in meters. + = present and - = absent. adj = adjacent, while iso = isolated. ? = unknown or could not determine. na = does not apply.

	SUBSITES								
Feature	# 1	#2&3	# 4	# 5	# 6	# 7	# 8	#9&10	#11-14
Physical									
Aspect	NW	W	E	S	W	E	W	W	W
Slope	12	0	0	0	0	10	< 5	0	0
Elevation	60-120	5	75	10	10	120	60	<10	<10
Spatial									
Acreage	2	< 5	< 5	5	2	2	3	3	<10
Tree density	dense	dense	dense	dense	na	dense	dense	na	na
Configuration	edge	edge	inland meadow	inland meadow	na	edge	U with parallel rows	na	na
Shelter	+	-	++	++	-	+	++	-	-
Proximity to meadows	adj	adj	iso	iso	na	adj	adj	na	na
Biological									
Violets	+/-	-	-	-	+	+/-	+/-	++	++
Nectar:									
SEN	+	+	++	+	-	++	+	-	-
ANN	+	+	+	-	+	++	+	-	+
THI	+	+	++	+++	+	+	+	+	+
SOL	++	++	-	-	+	+	+	+	+
ACH	++	+++	++	+++	++	+	+	++	++
HYP	++	+++	+	-	+	+	++	+	++
AST	+	+	-	-	+	+	+	+	+
OSB adult usage:									
Court/Mate	-	+	-	+	-	+	+	++	+++
Oviposit	-	-	-	-	-	+	-	-	+++
Nectar	++	++	+	+++	-	++	++	++	+
Bask	++	++	+	++	+	++	+++	++	+++
Perch/Roost	+	+	-	++	+	+	++	+	-
OSB larval usage:	-	-	-	-	+	-	-	++	++

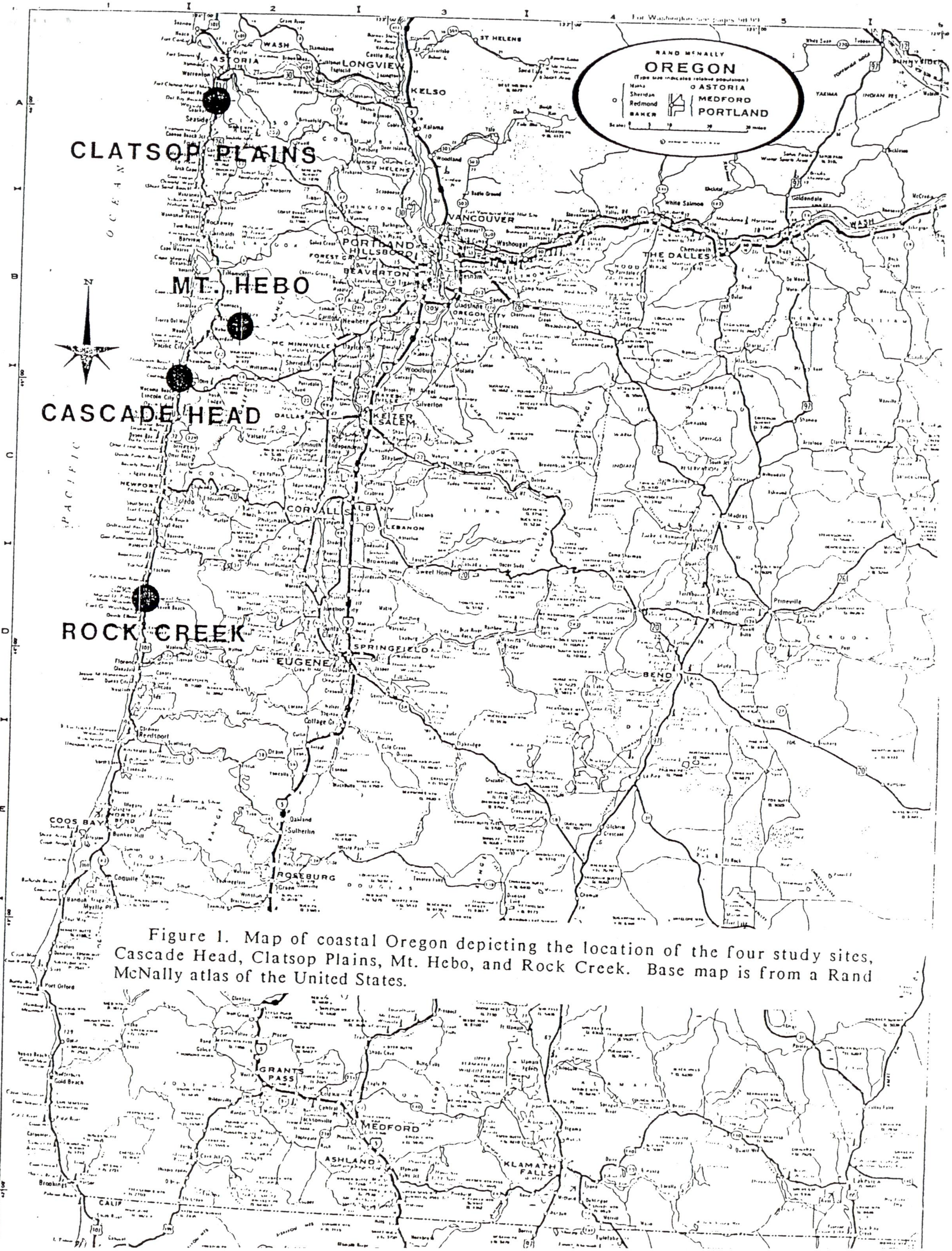

Figure 1. Map of coastal Oregon depicting the location of the four study sites, Cascade Head, Clatsop Plains, Mt. Hebo, and Rock Creek. Base map is from a Rand McNally atlas of the United States.

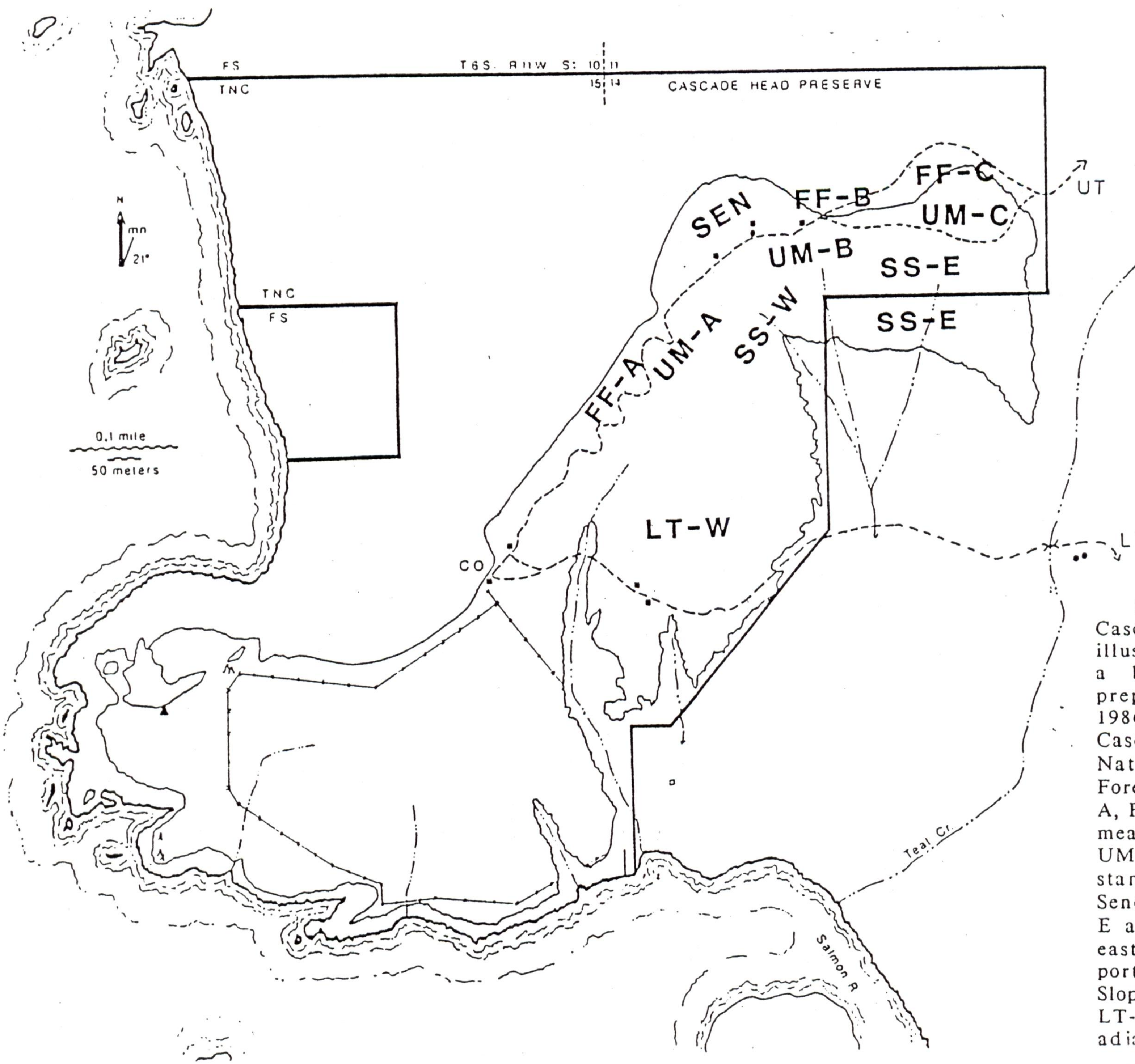

Figure 2. Map of Cascade Head study site illustrating subsites using a base map originally prepared by Peter Zika, 1986 summer intern at Cascade Head for The Nature Conservancy. Forest fringe areas are FF-A, FF-B, and FF-C. Upper meadow areas are UM-A, UM-B, and UM-C. SEN stands for the sheltered Senecio Slope subsite. SS-E and SS-W refer to the eastern and western portions of the steep South Slope. Similarly, LT-E and LT-W refer to areas adjacent to the Lower

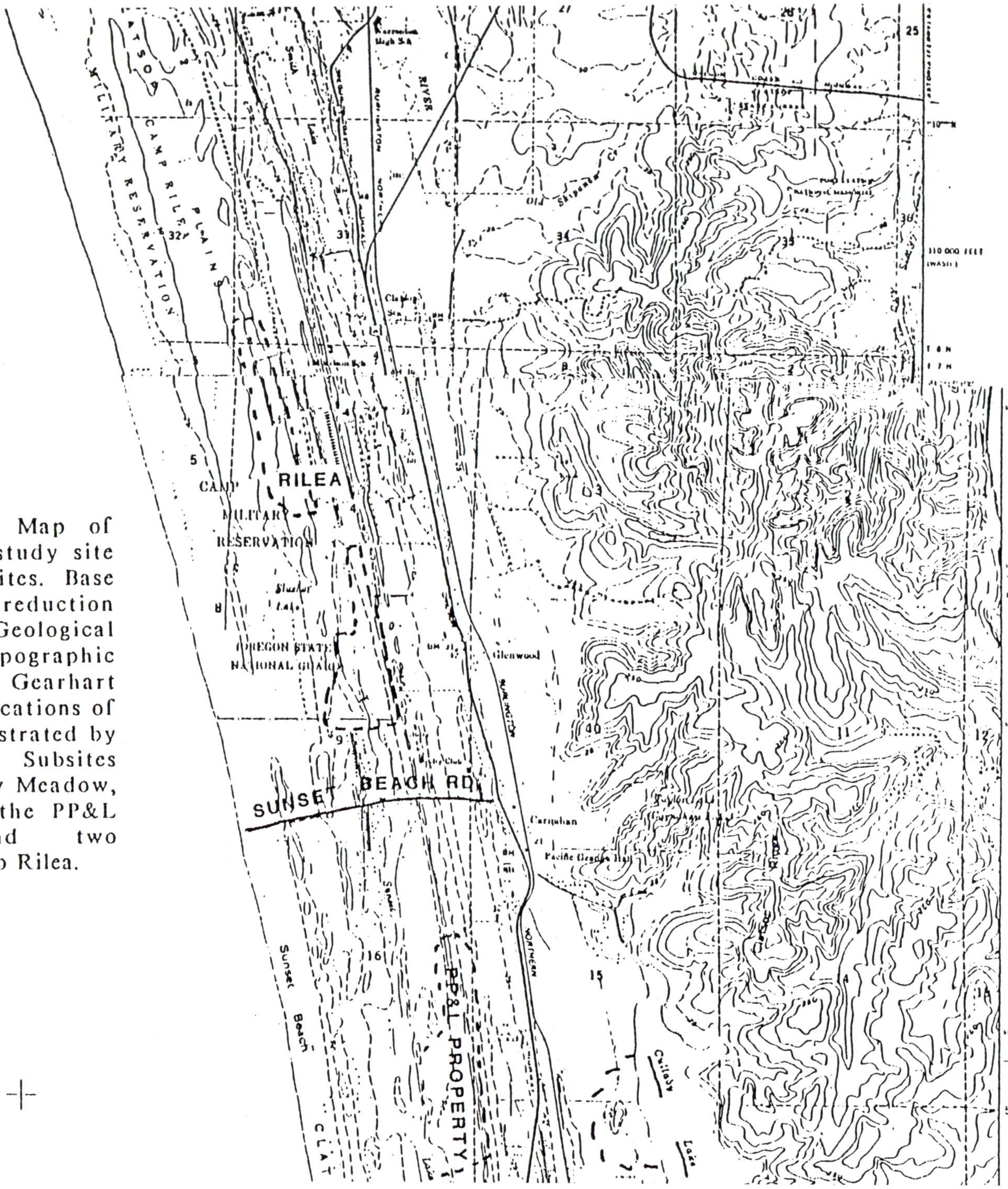

Figure 3. Map of Clatsop Plains study site illustrating subsites. Base map is a xerox reduction of the U.S. Geological Survey's 7.5" topographic map for the Gearhart Quadrangle. Locations of subsites are illustrated by dashed lines. Subsites include Del Rey Meadow, Cullaby Lake, the PP&L property, and two locations at Camp Rilea.

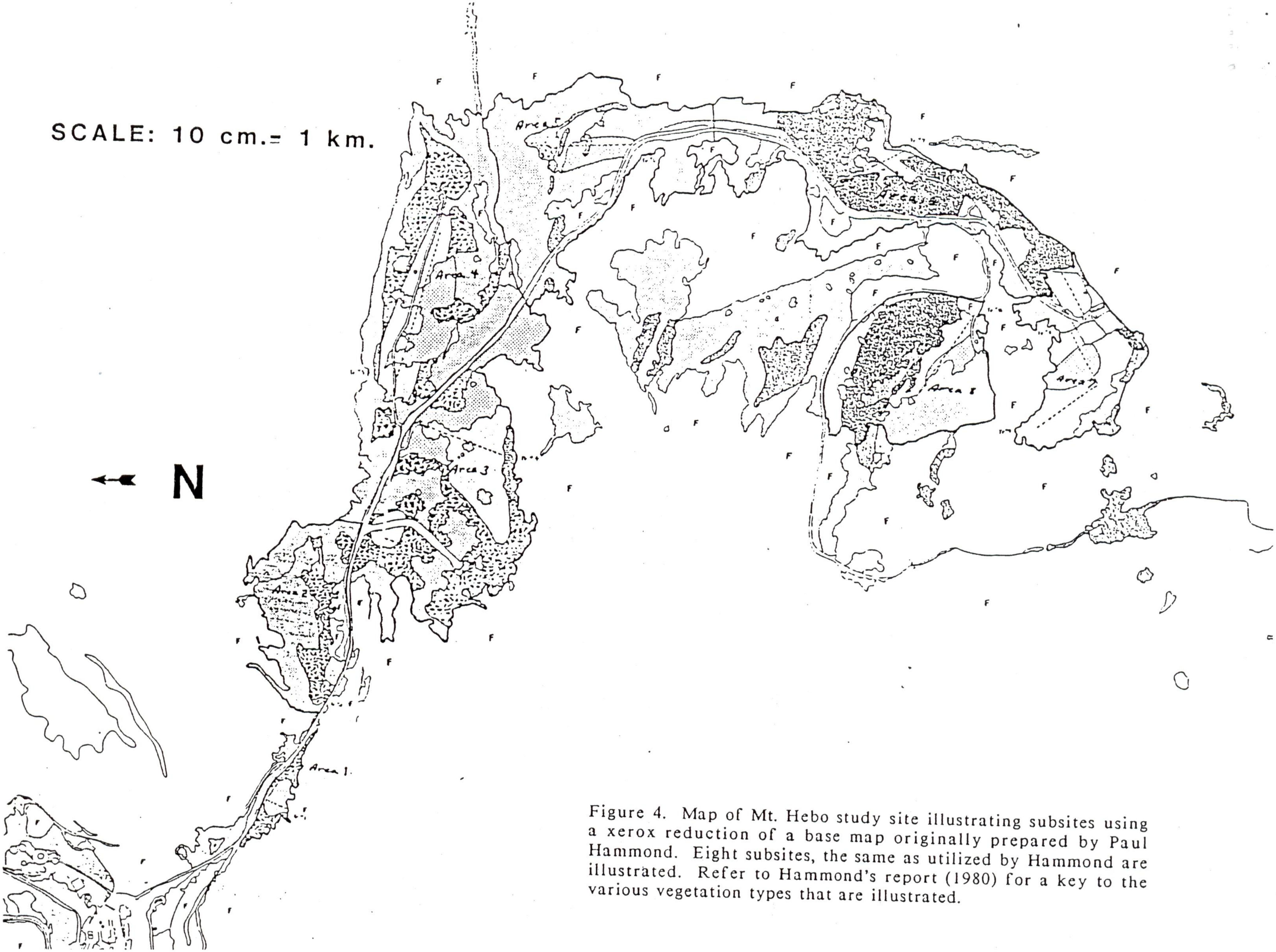

Figure 4. Map of Mt. Hebo study site illustrating subsites using a xerox reduction of a base map originally prepared by Paul Hammond. Eight subsites, the same as utilized by Hammond are illustrated. Refer to Hammond's report (1980) for a key to the various vegetation types that are illustrated.

Figure 5. Map of Rock Creek study site illustrating subsites using a base map originally prepared by David McCorkle et al. as part of their 1980 report. Subsites, numbered 1 through 14, are identical to those used by McCorkle et al. (1980).