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Exploring Mitigation Options to Reduce Vehicle-Caused Mortality for the Oregon Silverspot Butterfly, *Speyeria Zerene Hippolyta*, Along Highway 101 at the Siuslaw National Forest

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1.0 Introduction

Roads and the vehicles traveling on them and allow human society to stay connected for social, work, and trade needs (Forman and Sperling 2003). Approximately 3.9 million miles of road exist within the U.S. and an estimated 200 million vehicles traveling 2.7 trillion miles per year use those roads (National Atlas 2008). One percent of total land within the U.S. is covered by public road corridors but a greater area is estimated to be directly affected ecologically (15-20% of U.S. land) (Forman and Alexander 1998). One impact roads have on the natural environment is direct mortality of individual animals that attempt to cross roads. Cars collide with large animals over 1 million times each year in the U.S. and with smaller animals much more often (Conover et al. 1995). Other indirect pressures roads inflict on wildlife and their habitats include: alteration of landscape spatial pattern, direct loss of habitat, degradation of habitat quality, habitat fragmentation and barrier effects, increased human exploitation, population fragmentation and isolation, disruption of social structures, and reduced access to vital habitats (Jackson 2000).

Roads can affect behavioral patterns of animals (e.g., movements). Wildlife cross roads to access resources (Singer and Doherty 1985; Ries and Debinski 2001*)*, avoid predators (May and Norton 1996 as cited in Shine et al. 2004), and locate mates (Shine et al. 2004*)*. Roadside verges serve as habitat for a wide range of species, including butterflies (Ries and Debinski 2001; May and Norton 1996; Munguira and Thomas 1992; Free et al. 1975), and at times even support higher densities than adjoining landscapes (Adams and Geis 1983). Roads and their verges may offer microhabitats, such as shelter from the wind, that may attract or keep individuals in the road corridor longer than expected. For example, roads may be warmer, warm up earlier in the day, or remain warm for extended periods of time; poikiltherms are attracted to these locations for basking (Ashley and Robinson 1996; Shine et al. 2004).

Road mortality could particularly impact butterfly populations and would likely impose a greater impact if the population is already small and diminishing. Because a population is already at risk of extirpation based on stochasticity, roads can present an additional stressor on an already stressed system. Impacts can be expected when: fecundity is low (which is not typical for invertebrates), breeding occurs after interactions with the road, and especially when mortality from other sources is near or greater than the birth rate. Fragmentation of a population can also pose a problem because it divides populations into smaller ones, which are expected to have lower genetic diversity than those in uninterrupted habitats. Genetic diversity decline is caused by restricted gene flow, genetic drift, and increased inbreeding and is known to decrease the long-term persistence of populations in the wild (Frankham et al. 2002; Saccheri et al. 1998). Also, positive relationships between species diversity and allelic diversity support the importance of preserving biodiversity (Cleary et al. 2006).

Most wildlife-related road ecology research has been performed on mega-fauna; few efforts have been devoted to invertebrate species. Although road effects on invertebrates can be numerous, research on this topic is relatively rare. To increase the probability of safe passage, vehicle speed would likely have to be reduced further for slow moving organisms, especially ones unable to process vehicles trajectories, than faster moving ones. Also, invertebrates often possess a low processing ability that may interfere with sufficient vehicle avoidance (INS 2010). It is difficult to justify listing them as federally threatened or endangered because data are often missing.

Research efforts on the effect of roads on butterflies have been even fewer, although some pioneering studies offer important insight into this topic. For example, Rao and Girish (2007) assessed insect road kills and discovered that butterflies and dragonflies were the major taxa killed by vehicles. They found highest casualties occurred when traffic load on back roads was highest, on Sundays. Ries and Debinski (2001) concluded that higher levels of crossing by and mortality of butterflies occurred along roadsides with native prairie or weeds relative to grassy roadsides. Not all research, however, suggests roads pose a problem to butterflies. Munguira and Thomas (1992) found high butterfly diversity and abundance along roadsides; butterfly abundance was not affected by the amount of midday traffic, and even wide, busy roads did not present a significant barrier to species from open populations. Their bi-weekly surveys, though, suggest that a minimum of 7% of butterflies in open populations were killed from vehicles.

The Oregon Silverspot Butterfly (OSB), *Speyeria zerene hippolyta*, is federally listed as "threatened." It historically inhabited coastal regions of Washington, Oregon, and California (USFWS 2001). OSB populations only remain at five sites, four of which are in Oregon; one remaining population is in California, and none exist in Washington state as they have been extirpated (BFCI 2009; USFWS 2001). The site selected for this study was Rock Creek-Big Creek, adjacent to the Siuslaw National Forest (Figure 1) (Appendix 1). At this site OSB habitat is bisected by Highway 101; butterflies are observed to use both sides of the highway throughout their life cycle (P. Hammond, personal communication, June 12, 2009). It is suspected that vehicles on Highway 101, through collisions and their turbulence, present a substantial threat to OSBs at this site. This suspicion, however, has not yet been quantified and is only minimally evaluated in this paper.

Effective mitigation techniques have rarely been developed and tested for small or flying organisms (but see, e.g., Smith 2009, Bard et al. 2002). Mitigation for one species may not work effectively for others (e.g., Jackson and Griffin 2000). Moreover, due to expense and scale, it is prohibitive to test multiple mitigation options sequentially. Therefore, we explored whether gathering targeted ecological data would help prioritize mitigation options for a threatened species, the Oregon silverspot butterfly (*Speyeria zerene hippolyta*, hereafter, OSB). We studied OSB ecology in order to evaluate the likely success of mitigation options before funding was pursued for implementing or directly testing any of them.

In this research, we considered four potential management options that seemed most likely to be effective based on available information, including barrier installation; earthen berm removal and other actions to reduce the attractiveness of the road relative to the surrounding habitat; environmentally triggered, flashing speed-reduction-sign installation; and vegetation manipulation. Again, because these management scenarios are not yet in play, we could not directly test them. Rather, we gathered data on the behavioral ecology of OSBs and the environmental conditions of the road compared to surrounding habitat to determine which mitigation measures would have the greatest potential for effectiveness. To inform mitigation options we examined six questions about environmental conditions across habitats or microhabitats and how these correlated with OSB presence.

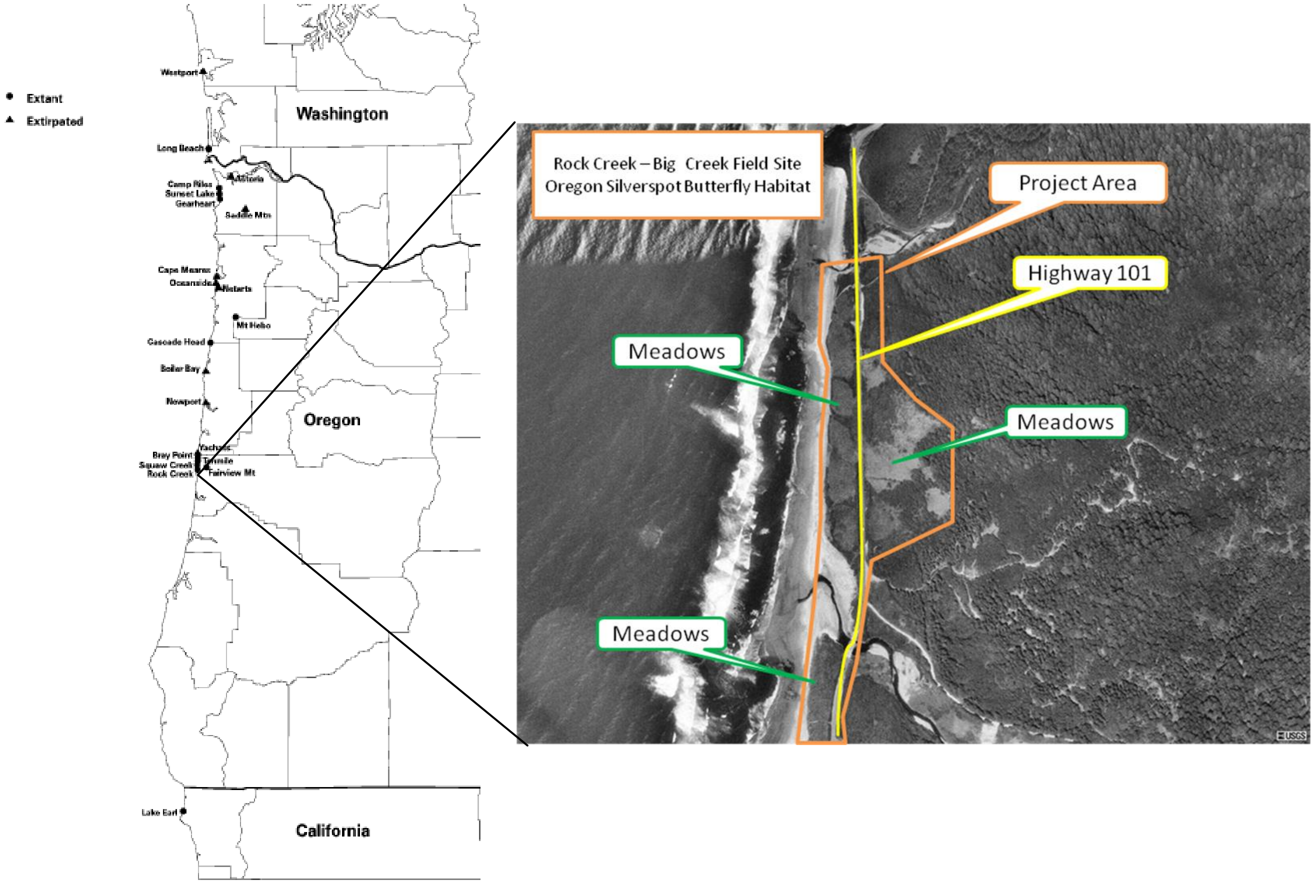


Figure 1: OSB Distribution within Oregon State and Rock Creek – Big Creek Locator Map; this study was conducted at the southernmost site in Oregon, Rock Creek-Big Creek.

2.0 Background

Life History and Habitat Requirements

The OSB transforms through six larval instars and a pupal phase prior to eclosing as an adult (USFWS 2001) (Appendix 2). Adults appear throughout late summer beginning in July and continue to emerge through late September to mate. The first adult OSBs that appear are males and emerge several weeks prior to females (USFWS 2001). Eggs are laid on or near *Viola adunca* plants, and hatch shortly thereafter. The larvae soon enter a winter diapause (dormant state) during which they spend the winter. In the spring, the larvae rouse and begin feeding on violet leaves until the late spring or summer when they pupate. Their pupation time is short (~2 weeks) and adults soon emerge to continue the cycle (McCorkle and Hammond 1988).

The OSB requires one of three types of grasslands to complete its life cycle: coastal salt spray meadows, stabilized dunes, or montane meadows. These grasslands must have both the larval host plant and nectaring plants. Also, OSBs typically use forest fringe areas to roost in the evenings. The primary source of food for OSB larvae is the *Viola adunca* (western blue violet) (USFWS 2001). Food (nectaring) plants for adults include multiple native and non-native species: Canada goldenrod (*Solidago canadensis*), dune goldenrod (*S. spathulata*), California aster (*Aster chilensis*), pearly everlasting (*Anaphalis margaritacea*), dune thistle (*Cirsium edule*), yarrow (*Achillea millefolium*), tansy ragwort (*Senecio jacobaea*), false dandelion (*Hypochaeris radicata*), thistles in the genus *Cirsium*, chaparral broom (*Baccharis pilularis*), smooth hawksbeard (*Crepis capillaris*), and woolly sunflower (*Eriophyllum lanatum*) (USFWS 2001).

Habitat and Population Management History

One of the main factors attributed to the decline of OSBs is the invasion of non-native plant species (mostly grasses) such as: heath grass (*Danthonia decumbens* [*Sieglingia decumbens*]), bent grass (*Agrostis alba*), velvet grass *(Holcus lanatus*), orchard grass (*Dactylis glomerata*), tall fescue (*Festuca arundinacea*), reed canary grass (*Phalaris arundinacea*), European beach grass (*Ammophila arenaria*), and Scotch broom (*Cytisus scoparius*) (USFWS 2001). Exotic grasses at the study site tend to produce tall and dense stands that can eliminate native plants including the larval food plant of OSBs (Hammond 1994a).

Since 1985, the Rock Creek – Big Creek site has been managed for *Viola adunca* with the primary management technique of 3 annual mowing events, typically beginning late May and ending early July (Hammond 2008). Mowing temporarily provides control of non-native grass height, thatch accumulation, and control of salal and other woody species. OSB oviposition becomes limited to ideal egg laying locations with the encroachment of non-native grasses as they tend to "shade-out" *Viola adunca* plants making them inaccessible to gravid females for egg laying. Abundance of *Viola adunca* and levels of OSB oviposition have been inversely correlated with vegetation height and depth (Singleton 1989, McIver et al. 1991, Pickering et al. 1992). Although mowing has potentially reduced the impacts of invasive plants on the OSB, it is not considered a long-term solution for non-native species management (USFWS 2001), and mowing simultaneously reduces the number of nectaring plants for adults as it is a non-selective management tool.

OSB populations have been augmented with captive-reared species since 1999. The Nature Conservancy (TNC), the Oregon Zoo of Portland and the Woodland Park Zoo have managed a butterfly rearing program with the goals of maintaining genetic variability in the population and increase the likelihood of natural recovery (Oregon Zoo Conservation 2009). U.S. Fish and Wildlife Service (USFWS) (and other organizations) has initiated plantings of *Viola adunca* and nectar plants at the study site (A. Walker, personal communication, August 16, 2009). It appears that the more recent increase in population size at Rock Creek-Big Creek has been associated with the release of captive-reared OSBs (Patterson 2008), although this notion has not been quantified as there have been no efforts (such as marking) to decipher the difference from captive-reared and "wild" butterflies. The OSB counts for 2009 at Rock Creek – Big Creek, Bray Point, Cascade Head, and Mt Hebo are 437, 124, 1420, and 1411 respectively (Appendix 3).

Highway 101 and Traffic

Highway 101 begins in California, passes through Oregon and ends in Washington State. Construction of the Oregon section of Highway 101 took 15 years and was completed in 1936 (OCZMA 2008). Highway 101 at Rock Creek-Big Creek generally runs in a north-south direction, has few small unofficial pull-off areas, and is bordered by rivers to the north and south (Figure 1; Appendix 1). In 2008, the average annual daily traffic (AADT) for Highway 101 at this site was 2,100 vehicles (N. Testa, personal communication, February 5, 2010). With an increase in human population and travelers to the Oregon coast during the summer months it can be assumed that the AADT has increased and that the current AADT is an underestimate during August and September. It was estimated that by 2006 approximately 43% of OSBs that attempt to cross Highway 101 (at a 1500 foot section of road including the Big Creek bridge) would be hit by passing vehicles and most likely killed at Rock Creek – Big Creek (Powers 1988 as cited by Testa 1995).

Mitigation Types

Currently, the USDA Forest Service is pursuing four mitigation techniques to reduce potential vehicle-caused impacts sustained by OSBs at Rock Creek-Big Creek.

The mitigation types being considered are (Table 1):

1) **<u>Barrier installation (fences, netting, guardrails and/or concrete)</u>**

   Function: To reduce the number of OSBs flying into the road, to encourage butterflies to stay in the meadows longer, and in the case that OSBs do find their way into the road corridor, use barriers to force them to fly higher than they naturally would and effectively over vehicles driving on Highway 101

2) **<u>Earthen berms (addition or removal)</u>**

Function: To reduce potential sheltering from the wind in the road corridor where OSBs may congregate and essentially reduce the likelihood of a butterfly-vehicle collision

3) **<u>Flashing speed reduction sign installation</u>**

Function: To reduce the likelihood of an OSB-vehicle collision by slowing traffic and to reduce the societal effects of traffic calming by limiting speed reduction to the key times for OSB flight to values of environmental variables associated with OSB presence in the road

4) **<u>Vegetation manipulation</u>**

Function: to draw butterflies away from the road corridor or reduce incentive to cross the road or otherwise enter the road corridor

TABLE 1. Motivation, Management, Study Questions, Methods, And Sampling Effort.

Motivation	Management Informed	Question(s)	Methods	Sampling Effort (hrs)			
				Scan[a]		All Occurrence[b]	Oppor-tunistic[c]
				Meadow	Road		
Verify vehicles are killing OSBs; estimate the frequency at which mortality occurs.	Supports that management could be effective in reducing OSB mortality	Does vehicle-caused mortality occur?	Survey the road corridor, documenting confirmed and likely collisions with vehicles;	--[d]	32	16	16
Determine whether OSB presence can be predicted by environmental parameters	Environmentally triggered flashing speed-reduction sign installation	How does weather affect OSB flight?	Create a statistical model to predict OSB presence in the road	--	32	--	--
Determine if the road varies from the surrounding meadow in weather conditions and OSB use.	Management to reduce attractiveness of road (not explored here)	Are OSBs using the road more than expected based on their use of surrounding habitat?	Perform replicate weather readings and surveys in paired road and meadow plots to compare weather and number and behavior of OSBs.	32	32	--	--
Use OSB movement at the study site to determine where to put barriers along the Highway 101.	Barrier Installation	What is the spatial dispersion of road-crossings and is it correlated to environmental conditions in the road?	Identify location of OSB road crossings and document behavior and height of flight when in the road.	--	*32*	16	16
Determine if the road cut area creates a wind sheltered or warmer area that is preferentially used by OSBs.	Earthen berm removal	Does the road cut vary from surrounding corridor in its environmental conditions and OSB use?	Compare wind speed, temperature and number of OSB sightings in the road-cut plots to an equal number of adjacent plots to the north and south of the road-cut.	--	32	16	--
Determine if OSBs are drawn to the road because of flowering plants.	Vegetation manipulation	Is the abundance of roadside flowering plants correlated with OSB movement in the road?	Sample flowering plants adjacent to road plots and compare to number of OSBs.	--	32	16	16

[a]Instantaneous Scan Surveys, [b]All Occurrence Surveys in the road, [c]Opportunistic Sampling in the road, which was not used in statistical analyses, [d]Data not taken or not used

Questions Addressed in this Study

Several questions were asked in this study to determine if a particular mitigation option may be suitable to reduce mortality to the OSB (Table 1). Below are the four main questions asked along with synopses on how we plan to address each and the rationale behind our methods.

How does weather affect OSB flight?

Knowing when OSBs are active is a key first step to understanding the practicality of this mitigation option. The purpose of this question is to determine 1) whether OSB presence (especially in the road) can be predicted by a suite of environmental parameters and 2) if environmental variables are significantly different between the road and meadow is it possible that OSBs are drawn to the road when more ideal conditions exist there. Temperature, wind speed, humidity, and OSB presence were all recorded during both the meadow and road surveys. By identifying which variables best correlate with OSB presence mitigation options can be better modified to increase efficiency and effectiveness, and essentially reduce mortality. For example, OSB presence is hypothesized to be positively correlated with temperature in both the road and meadow as butterflies need relatively warm air (15.5^{o}C or 60^{o}F) to fly (McCorkle and Hammond 1988) and using these data to create a model for prediction would allow for an environmental-variable triggered speed reduction sign to activate only when the probability of OSB presence was highest. It's also hypothesized that OSB presence will have a negative relationship with wind speed and humidity, as both factors are known to inhibit butterfly activity and may support a finer tuned model (N. Testa, personal communication, March 25, 2009; USFWS 2001). There are other elements that must be understood to determine whether vehicle speed reduction will be capable of reducing butterfly vehicle-caused mortality. If OSBs do in fact show some predictable pattern of presence related to any of the documented parameters these parameters would then be used to dictate when speed reduction is prompted and in a fashion that lessens the amount of time vehicles were pointlessly reducing speed on days when conditions were not suitable for OSB flight.

What is the dispersion of OSB road-crossings and what is their behavior when doing so?

The goal of this question was to discover where OSBs are crossing in the road corridor so to better 1) understand their movement at the study site and, 2) determine where to put barriers along Highway 101. No known research has observed OSB movement at this site and it's believed that OSBs potentially cross the road at least 2 times a day, roosting in the forest fringe areas at night on the east-side of Highway 101, crossing the road to the west-side to access plants for oviposition and foraging, and returning to the east-side in the evening (P. Hammond, personal communication; June 12, 2009). To thoroughly answer the first part of this question, individuals would need to be marked, observed, and followed throughout the day, which was deemed impractical (discussed below). Rather, location of OSB road crossing was documented at the sub-plot level as well as behavior and height of flight when in the road. These results will allow inference of where barrier placement is feasible by determining where high crossing areas for OSBs exist. It's hypothesized that OSBs tend to cross the road in particular areas and that their dispersal from the meadows into the road is concentrated (P. Hammond, personal communication, 2009). If OSBs mainly display a flying behavior and are found to fly at low heights (relative to the road surface) when in the road, plots with these behaviors will be ideal areas for barrier placement. Barriers will serve to 1) keep OSBs in the meadows longer and 2) fly higher, over barriers, when in the road, presumably avoiding vehicle collisions. Again, more research will need to be performed to further understand how OSBs interact with different types of barriers.

Does the road-cut vary from surrounding the corridor in its environmental conditions and OSB use?

Research on this question addressed the concern that the warmer surface of the road and roadside creates a basking area, especially in the road-cut area. If this were the case, a change in the topography, especially of the road cut, such as by changing earthen berms, would be an appropriate management strategy which may also offer shelter from cross winds'. Research to address this question included two approaches. First, we compared wind speed, temperature, and number of OSB sightings in the road-cut area to the adjacent areas along the road to determine if relevant environmental conditions differ along different parts of the road. Second, we compared butterfly numbers and behavioral time budgets (for basking, flying, and interacting) between the road and identically sized strips of habitat in the adjacent meadow to determine whether butterflies favored the road or meadow for any behaviors. Duration of stay in the road relative to meadow would be a more direct measure but could not be assessed; the OSBs could not be marked (USFWS policy) and they interacted and flew in and out of the meadow plots, making impossible the reliable, extended focal observations needed for time budgets for each behavior.

Is the abundance of roadside flowering plants correlated with OSB movement in the road or in the meadow?

The purpose of this question was to determine if 1) flowering plants can explain OSB presence either in the meadow or in the road, and 2) if OSBs may be drawn to the road because of flowering plants. We hypothesize that an increased number of flowering plants in the meadows will translate to greater OSB presence in the meadow plots and\or adjacent road plots. For flowering plants immediately adjacent to the road we similarly hypothesize that an increasing number of flowering plants in the verge will correlate with increasing number of OSBs detected in road sub-plots as this species feeds on the nectar of several flowering plants at this site (USFW 2001). If this prediction is found to be accurate the removal of flowering plants adjacent to the road and plantings in the meadow could reduce the risk of vehicle collisions, as OSBs would less likely be attracted to the road and more so to the meadow. Managing vegetation along the roadside can be particularly important post-meadow mowing when there are fewer flowering plants in the meadows.

3.0 Methods

Figure 2. Road-cut area at Rock Creek – Big Creek Site, photo taken observing north from plot 8. Photo credit: Sara Zielin.

Site Location

The study took place in a salt spray meadow along the Oregon central coast at Rock Creek-Big Creek and the intersecting segment of Highway 101 (Figure 1). This area, which covers approximately 177.1 hectares, has been considered critical habitat since 1980 when OSBs were first detected at this site (USFWS 2001). Lands included as OSB critical habitat were areas known to be occupied by the butterfly at the time of designation. Section 7 (a) (2) of the Endangered Species Act (ESA 1973) requires Federal agencies to consult with USFWS if their actions may affect listed species or critical habitat (USFWS 2001). The Siuslaw National Forest manages approximately 20 hectares of potential butterfly habitat (USFWS 2001). The site is located roughly between the mouths of Rock Creek and Big Creek (USFWS 2001). Meadow is on both sides of Highway 101 starting approximately 200 m south of Big Creek continuing north to the south side of Rock Creek. In general, the east-side of the study area starts at a significantly higher elevation (340 feet) and with a steeper grade than the west-side (Appendix 1; Figure 1). As the meadow approaches the road on the east-side of Highway 101 the grade becomes less steep and even more so on the west-side (ocean-side) of the road (Appendix 4). In some sections of Highway 101 the road surface is significantly lower than the abutting meadow on both sides of the road (a road-cut) (Figure 2). This major road-cut area encompasses plots 8 (partial), 9, 10, and 11 (partial) (Figures 2 and 3) (Appendix 1).

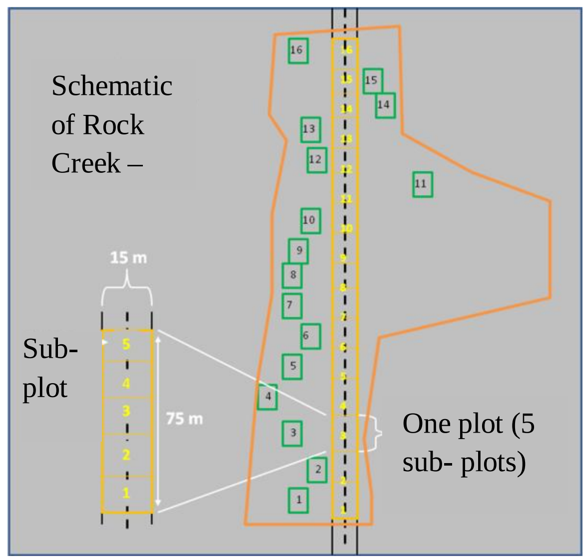


Figure 3. Schematic of study site. Road plots are in yellow, meadow plots are in green.

Study Design

Within the study area, a 1.2 km section of Highway 101 was divided into 16 plots (1 plot = 75m x 8m), each of which were divided into 5 subplots (1 subplot = 15m x 8m) (Figure 3). The purpose of dividing plots in to subplots was to allow flexibility when performing data analysis; we wanted more precise OSB location data, though prior to performing the surveys it was unknown whether enough OSBs would be observed at the subplot level to support a meaningful analysis. Additionally, the plot size was too large for scan surveys in the meadow due to varying topography and lack of line of sight. By breaking plots into subplots it became possible to detect all OSBs in a survey from a single location.

Corners of the subplot boundaries were marked in meadows using orange pin flags (1m long, 10 x 12.5 cm flags). In the road, plot corners were marked with pin flags and subplot corners were designated using marking paint. Each road plot was paired with a meadow plot of the same dimension. The meadow plot was kept at the same latitude as the road plot, subdivided like the road plots (5 subplots per plot), and placed at a random distance from the centerline of Highway 101 and the outer edge of the surrounding meadow habitat.

Sampling Surveys

Surveys were conducted between 17 August and 19 September 2009 on road plots or on plots in the surrounding habitat. Surveys were not conducted on days when it was raining to minimize over-inflation of zeros and low values attributable to weather that was unsuitable for flight (McCorkle and Hammond 1988). Two types of surveys were performed (Appendix 5). Instantaneous Scan Sampling, determined spatio-temporal OSB presence patterns and provided comparison of meadow plots vs. road plots. The plot size was chosen to minimize extremely low numbers of butterflies encountered. All road and meadow plots were sampled with instantaneous scans four times throughout the study. Preliminary observations identified that focal individual sampling of these unmarked butterflies, given that they could not be marked, did not yield enough consecutive observations of individuals to be used for analysis. The All Occurrence Survey's primary purpose was documenting any OSB activities when sightings occurred in the road. We also opportunistically recorded all sightings of OSBs in the road.

Road-meadow comparisons: Instantaneous Scan Survey

At the beginning of each subplot survey, the following factors were measured:

- OSB presence, height of flight (road only), and behavior; nectaring, basking, perching, flying, mating, ovipositing, and interacting with conspecifics (Table 2)
- Environmental variables (wind speed and direction, temperature, humidity, and % cloud cover). Environmental factors and time were recorded with a Kestrel 4500 Pocket Weather Tracker
- Date and time

Table 2. OSB behavior types and descriptions as described by Arnold (1988) with adaptations for this study

Behavior Type	Description
Nectaring	Intake of nectar through proboscis while perched on a flower
Basking	Wings are held open like an airplane (dorsal) or closed like a solar panel (lateral) as to catch sunlight to warm the body
Perching	Standing upright with wings folded over body not oriented to receive sunlight
Flying	Any flight behavior (did not distinguish between male patrolling flight, foraging flight, oviposition flight, and predator avoidance flight)
Mating	The terminal segments of the male and female abdomens are joined
Ovipositing	Female performs abdominal probing and/or actual egg laying
Interacting	Two or more conspecifics either chasing or swarming for a few seconds

We counted the number of butterflies in each subplot engaged in each behavior at the instant of the scan. Therefore, nectaring included only butterflies on flowers, while those flying between flowers to nectar were classified as flying. Scans started at the south end of each meadow or road plot, systematically surveying each component subplot (Figure 3) (Appendix 1). Once the whole plot was scanned, this procedure was repeated again for a total of ten times for the plot being surveyed. Once either the road or meadow plot was completed, a survey of the paired plot was undertaken using the same protocol. Three or four pairs of plots were surveyed each day (weather permitting) with plots randomly selected using a random number generator in Microsoft Excel. Four replicates were conducted for each of the 16 pairs of plots, totaling 3200 data points for meadow and 3200 for the road (16 plots x 5 subplots x 10 scans x 4 replicates).

Detection Probability in meadow

While the ease of visibility in the road left little doubt as to the efficacy of OSB detection during road subplot scan surveys, the potential for difficulties in OSB detection in the more visually heterogeneous meadow habitat warranted additional scrutiny. Detection probability surveys in meadow subplots were performed in order to quantify the effectiveness of individual observers detecting butterflies during instantaneous scan surveys. These surveys were done after the instantaneous scan surveys in the meadow and at unscheduled intervals when time permitted. These surveys entailed scanning a series of five subplots (identical methods to those of the instantaneous scan surveys). However, once the last subplot was scanned the observer would then begin to zigzag back through each subplot all the way to the initial subplot, theoretically flushing any butterflies missed during the scan, and counting all butterflies encountered during the zigzag walk. Observers had a high detection probability: Observer 1 was 97.6% (83 subplots surveyed, 2 previously unrecorded butterflies detected during the zigzag walk); and Observer 2 was 97.2% (109 subplots, 3 additional butterflies observed during a zigzag walk). These detection probabilities were considered sufficiently high to assume that the detection rate was representative of the actual OSB presence.

Inter-observer Reliability

Inter-observer reliability was calculated between the two observers performing surveys as consistency is important for recording accurate data. The detection probability data were used to assess reliability as these surveys were performed simultaneously during scans and zigzags. The percent agreement between the observers was 91% (31/34) and 97% (33/34) for scans and zigzags respectively.

All Occurrence sampling for OSBs in road plots

The all occurrence survey was exclusive to the road. Each road plot was observed four times throughout the season, totaling 64 15-minute observations of roads for crossings in addition to the 64 scan sampling periods by standing at the south end of a designated road plot and observing any OSB activity while looking north for 15 minutes. For every sighting of an OSB in the road the following variables were documented:

- OSB presence and behavior; nectaring, perching, basking, flying, mating, ovipositing, and interacting with conspecifics (Table 2)
- Environmental variables (wind speed and direction, temperature, humidity, and % cloud cover)
- Date and time

- Location (subplot where OSB was initially detected)
- Direction of flight (using the road as a north-south reference)
- Duration (recorded by counting seconds OSB was in the road)
- Distance flew (estimated using the known plot dimensions and the road edge and pin-flags as a reference for the plot boundaries)
- Rate of flight (calculated using duration of flight and distance flew in the road)
- Height of flight (estimated by placing a 3.5 m telescoping staff marked in half meter increments in the middle of the plot along the road edge)
- If a collision occurred

'Duration' in the road was documented by counting the seconds an OSB was in the road beginning when it was first detected over top of the pavement until it could no longer be seen or until it left the pavement. 'Distance flew' in the road was estimated by documenting OSB ingress and egress into and out of the road and by using the known plot dimensions as well as the road edge and pin-flags as references. 'Rate of flight' was calculated post-observation by dividing the distance estimate by the duration estimate. Last, 'height of flight' was estimated by placing a 3.5 m long telescoping staff marked in half meter increments at the road edge (at the approximate center of the plot) as a reference height.

A digital voice recorder was used to document sightings of OSBs to minimize error from drawing eyes away from the target species. A Kestrel 4500 Pocket Weather Tracker was used to measure environmental variables and time of day.

Opportunistic sampling

Opportunistic sampling was performed haphazardly with no set study design. Once at the study site, if OSBs were observed in the road outside of the actual survey period and the surveyor was prepared to record all the variables, the sighting was documented. The purpose of this sampling was to gather as much data as possible on the occurrence of this rare species over the road. Although these data were not used statistically, they were used to show total number of crossings observed per plot and they may assist with the development of future study designs and hypothesis formation.

Vegetation Surveys

The number of flowering plants was quantified for all meadow subplots and a sub-sampling of road subplots. In the meadow, 3 samples were taken per 15m x 8m subplot. Sample locations were selected by dividing each subplot into 480 square meter sections, assigning each section a number 1 through 480, and using random number generator in Microsoft Excel to select three numbers for each subplot to be surveyed. A square meter PVC reference frame with 10 nylon strings per side, creating 100 subdivisions, was used to quantify flowering plants. Every flowering plant detected at a string intersection was counted.

The number of flowering plants was also quantified for a sub-sampling of road subplots. A stratified random sampling design was used and was based on the number of OSB crossings at subplots. 3 levels of OSB crossing were established: low, medium and high. Low crossing included subplots with zero observed OSB crossings; medium crossing were those with 1-2 observed crossings, and high crossing subplots were those with 3-7 observed crossings. Five subplots were sampled from each level of crossing type and were selected using the random number generator in Microsoft Excel. Three samples were taken within the 15m x 1m area immediately adjacent and parallel to the road subplot where the pavement ended and the vegetation began. The road subplot area was divided into 60 square meter sections, assigned a number 1 through 60 for each section, and 3 sample locations were selected using random number generator in Microsoft Excel. Selection for sample location within the subplots was identical to the meadow subplots but with a reduced area (15m x 1m) because vegetation is not growing in the actual road subplot area but was directly next to the road in the roadside verge.

Statistical Analyses

For all data, we used the Shapiro-Wilk test to check normality and a VIF test and an F-test for equal variance to determine if the data met the assumptions of parametric analyses, once transformed. A lag test examined the possibility of spatial autocorrelation of the plots. Data approximated the normal distribution when data were pooled across subplots, replicates, and individual scans ($n=16$; Road: $W=0.9144$, $P=0.1373$; Meadow: $W=0.9878$, $P=0.9973$). A partial ACF test on the residuals of the linear model, plotting the relationship between OSB abundance and plot number, indicated there was not strong spatial dependence for the road or meadow plots (Figures 4 and 5).

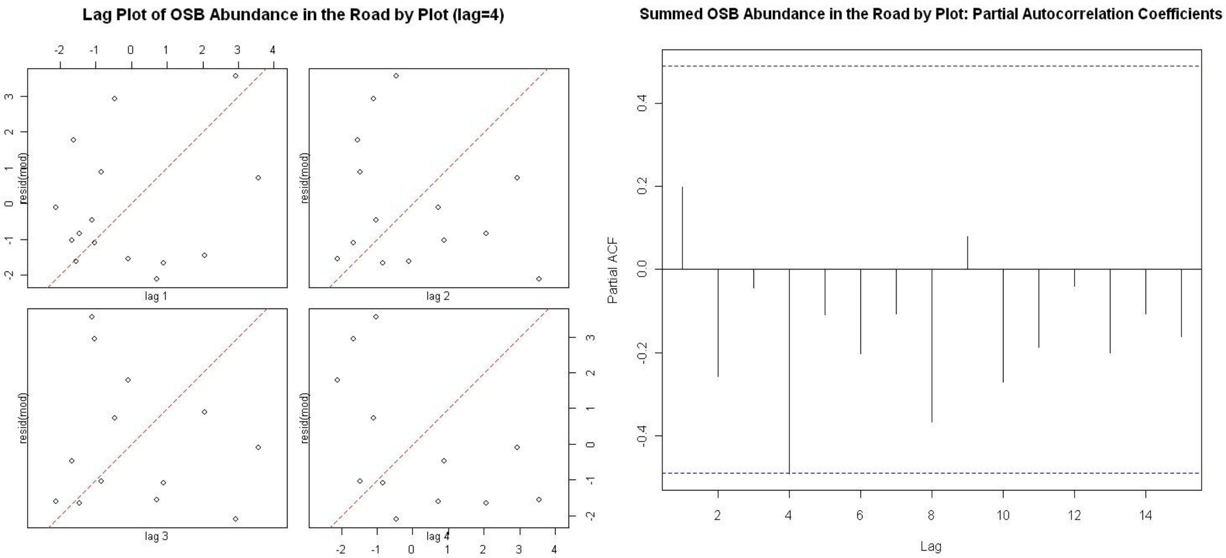


Figure 4. Lag test for spatial independence for the 16 plots in the road. *(left)* Lag plots for lag 1-4. *(right)* Partial autocorrelation chart for lag 1-15.

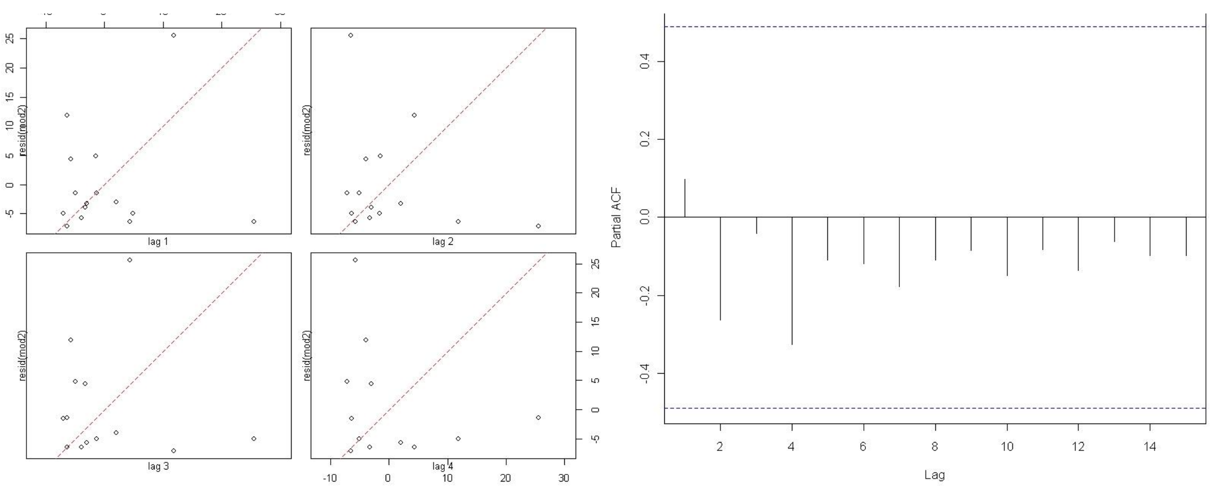


Figure 5. Lag test for spatial independence for the 16 plots in the meadow. *(left)* Lag plots for lag 1-4. *(right)* Partial autocorrelation chart for lag 1-15.

A correlation plot and Shapiro-Wilk test of the 320 points (data were pooled and the logic is discussed below) from the road and the meadow suggest that the response variable is not normally distributed (Figure 6). An F-test shows that the road and the meadow data have equal variance (p-value=0.1659, F-value=0.4793). Multicollinearity was tested with a VIF (Variance Inflation Factor) test, and revealed that temperature and humidity were not substantially correlated, with VIF values of 2.6 and 2.2 for the road and meadow respectively.

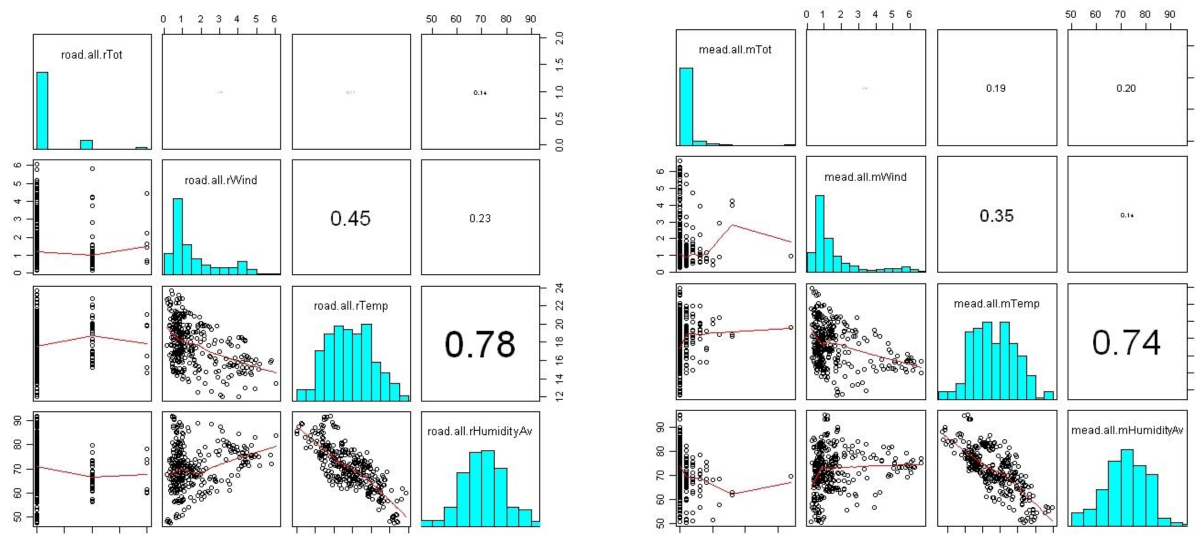


Figure 6: Correlation matrix of OSB presence and environmental variables. (*left*) Raw road data with all ten contemporaneous replicate surveys merged; 320 datapoints total. Predictors displayed are OSB abundance (rTot), wind speed in m/s (rWind), temperature in ºC (rTemp), and percent relative humidity (rHumidityAv).(*right*) Raw meadow data with all ten contemporaneous replicate surveys merged; 320 datapoints total. Predictors displayed are OSB abundance (mTot), wind speed in m/s (mWind), temperature in ºC (mTemp), and percent relative humidity (mHumidityAv).

Instantaneous Scan

Logistic regressions examining the relationship between OSB flight and the environmental variables required pooling to reduce the zero-inflated data. Data were grouped from the ten scans from each plot/day, yielding 320 groups (16 plots x 5 subplots x 4 times surveyed) for the meadow and also for the road plots for the entire survey period. Environmental variables at this resolution were averaged. Because survey scans were always taken in immediate succession and all completed within a 30 minute time span, little resolution in temporal variance was sacrificed by pooling these data.

To determine whether OSB presence (log) was statistically different for the road vs. meadow, a paired t-test was used comparing 16 road plots vs. 16 meadow plots (averaged using the 4 replicates for each plot). A nested anova was performed to determine if the environmental variables (temperature (log), humidity, and wind speed) was statistically different for OSB presence (log) in the road vs. meadow. Four subsamples were performed for every plot in both meadow and road (16 plots in each) and environmental variable values were averaged for the duration of each replicate survey period (30 min). Plots were then nested within habitat type (either meadow or road).

Flashing Speed Reduction Sign: OSB presence and environmental measurements along the road

We used logistic regression to determine if any of the measured environmental variables correlated with OSB presence. Only behaviors that could be performed in the road (i.e. “flying”, “basking”, and “interactive”) were included in the analysis. As above, scans were pooled per plot per day, yielding N = 320 (16 plots x 5 subplots x 4 replicates). Three separate logistic regressions of OSB abundance (the response variable) versus temperature, wind, or humidity were performed separately for road and for meadow to determine correlation. In addition, a full logistic model was created and included all the environmental variables as OSB predictors. Wind direction was not assessed as predictor of OSB presence as the kestrel meter recordings were not accurate.

Table 3. Confusion table kappa and PCC values for each logistic regression with critical values reported.

Regression:	Kappa	PCC	Crit. Val
Road Temperature	0.16	72%	0.14
Meadow Temperature	0.15	58%	0.22
Road Humidity	0.09	69%	0.13
Meadow Humidity	0.19	66%	0.26

Confusion tables, which assess the ability of each of our logistic regressions to predict the presence or absence of OSBs accurately, suggest the logistic regression models predicting presence based on environmental conditions were at best fair models (Table 3). Cohen's kappa and percent correctly classified (PCC) measures were reported. Cohen's kappa value is the extent beyond random chance to which the model correctly predicts OSB presence; PCC is the percentage of the data that the model correctly predicts (Forbes 1995). The critical values were picked to maximize the explanatory power over random (kappa) of each model yet kappa was always < 0.2. The critical value provides a prediction threshold of the model above which presence and below absence of OSBs was predicted**.** The kappa value for temperature was negligibly higher for the road model than was found for the meadow model. These higher kappa values also translated to higher PCC values where again temperature had the higher PCC (72% and 58% for the road and meadow respectively). Wind was not evaluated as it was found to have no significant correlations with OSB presence.

To determine if the proportion of OSBs detected in the road relates to a difference in temperature between paired road and meadow plots a logistic regression was created. The response variable (proportion of OSBs) was calculated by dividing the number of OSBs detected in the road by the sum of OSBs detected in both the road and meadow for each survey day for each of the 16 plots. The predictor variable (temperature difference) was calculated as the difference in average temperature between the paired road and meadow plots for each survey day for all 16 plots. Records where no OSBs were detected in both of the paired plots on the same survey day were omitted to reduce zero-inflation.

Earthen Berm (removal or addition) – Road-Cut Analyses

To determine if a sheltering effect was occurring in the major road-cut area along Highway 101, student's t-tests were performed. These tests compared subplots within the road-cut area (subplots 37-51) to an equal number of subplots to the immediate north (subplots 52-66) and south (subplots 23-36) of the road-cut. These tests examined whether the number of OSBs mean wind speed, and mean temperature in the road-cut area differed from the surrounding road sections. Data from both the instantaneous scans and all occurrence surveys were pooled to analyze the change in OSB presence. Data from the instantaneous scan sampling were used to analyze the difference in wind speeds and temperature as this dataset is much larger (3200 records compared to 64) and better represents the variance of these environmental variables.

Vegetation Manipulation – Road-side Vegetation Analysis

Meadow flowering plants

Scatterplots were created to assess the relationship between meadow flowering plants and OSB presence in the meadow and in the road.

Road flowering plants

A linear regression determined if the number of OSBs crossing the road (log transformed) at the subplot level was a function of the number of flowering plants adjacent to the road.

4.0 Results

Road Mortality

There was one confirmed account of an OSB-vehicle collision: it occurred on August 19th at 11:02 am in plot 7 (subplot 34) (Figure 7). The road-killed OSB, which was sexed as a female, entered the road from the west and crossed both lanes of Highway 101 to the east-side of the road, flew north, then when it attempted to cross back to the west it collided with a southbound SUV type vehicle. Another dead OSB was found on the walkway at the north end of the Big Creek Bridge by the Siuslaw National Forest wildlife biologist and may have been killed by a passing vehicle (Randy Miller, personal communication, September 2009). Also, other animal-vehicle collisions were witnessed throughout the field study and included: a barn swallow (*Hirundo rustica*), an unidentified dragonfly, and bumble bees (*Bombus sp.*). Last a dead bat (*Myotis sp.*), vole (*Microtus sp.*), and unidentified passerine, moth and other butterfly species were found along Highway 101 throughout the study period.

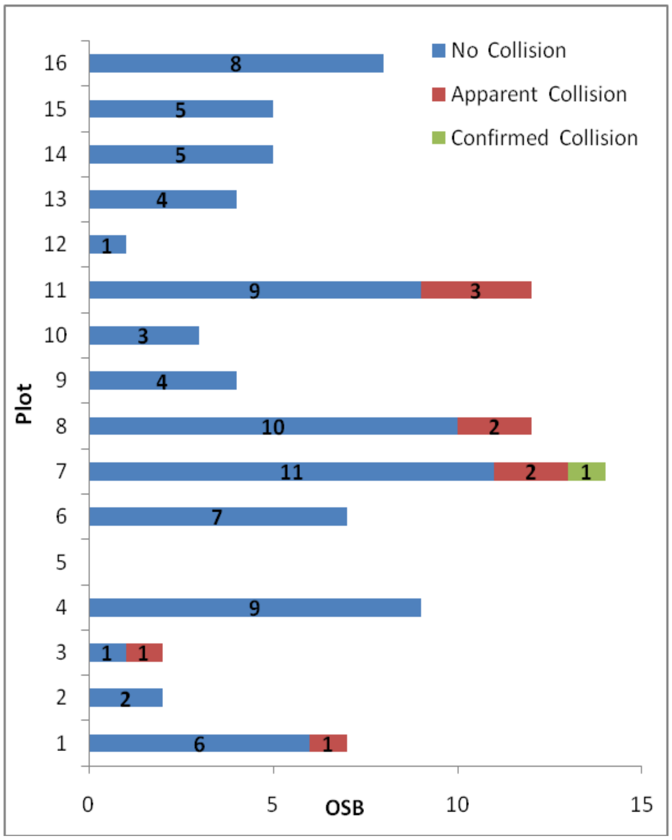


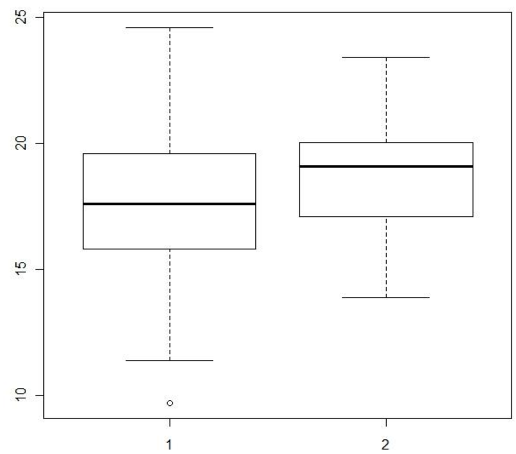
Figure 7. Vehicle and OSB interactions (no collision, apparent collision, confirmed collision) by plot for all accounts of detection either during surveys (scan or all occurrence) or opportunistic sightings. Across plots, 49 observations were from Instantaneous scan sampling, 24 were from all-occurrence surveys, and 22 were from opportunistic sampling.

There were additional potential butterfly-vehicle collisions, though no others led to a confirmed mortality. There were 9 instances where OSBs likely collided with a vehicle (apparent mortality); these collisions could not be confirmed although the butterfly was not seen after the car had passed and in each case the vehicle was moving away from the observer where the vehicle grill could not be examined (Figure 7). In all of the apparent mortalities of OSBs the road and roadside verge were inspected immediately after the vehicle had passed to see if the butterfly had landed on the road surface or adjacent vegetated area along the road and none were found. When witnessing bumble bee-vehicle collisions the carcasses or severely disoriented individuals were scavenged by ants almost immediately. On several occasions ants attempted to drag bumble bees off the road although they were still alive but unable to fly.

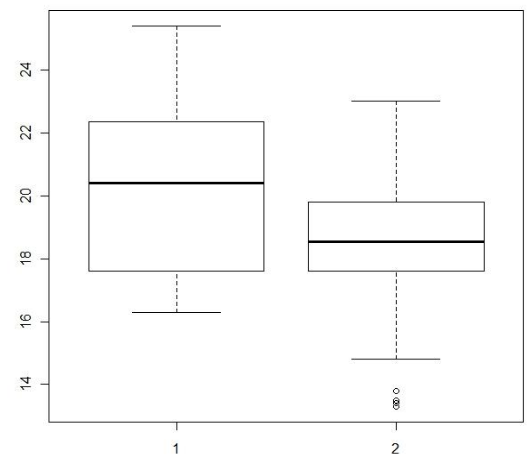
Environmental Parameters of OSB Flight

No OSBs were detected in the road below 13.9°C (57°F; Figures 8a-f). Also, no OSBs were detected below 56.5 % relative humidity or above 79.6 % in the road. Lastly, no OSBs were observed at wind speeds above 7.5 m/s (16.8 mph).

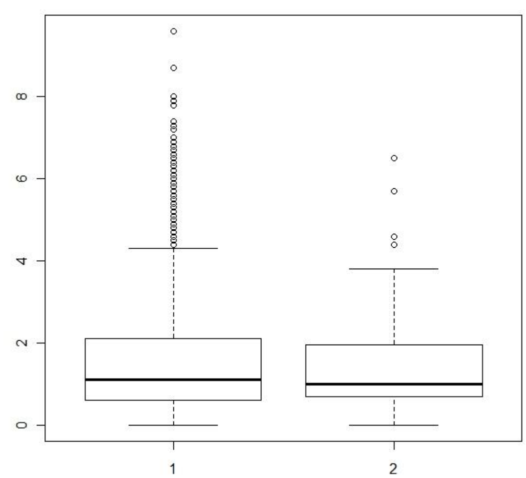
a) Road temperature



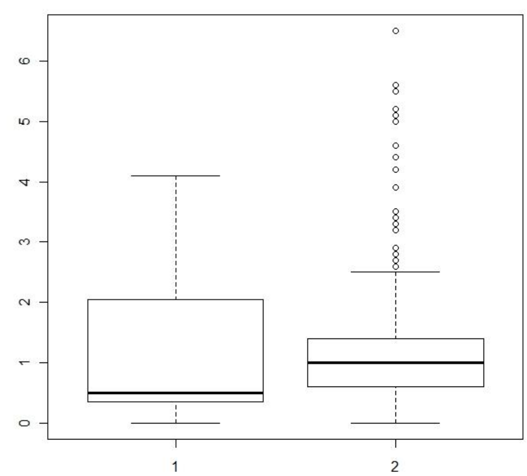
b) Meadow temperature



c) Road wind speed



d) Meadow wind speed



e) Road humidity **f) Meadow humidity**

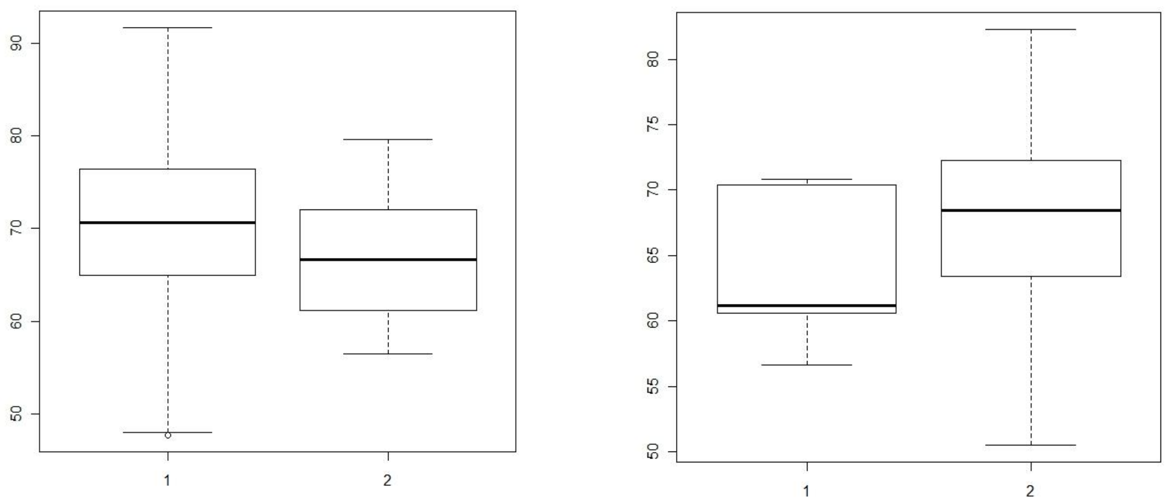


Figure 8a-f. Box plots of temperature (°C), wind (m/s), and humidity (%) with no OSB presence (1) vs. OSB presence (2) for the road and meadow (a) temperature in the road, b) temperature in the meadow, c) wind speed in the road, d) wind speed in the meadow, e) humidity in the road , and f) humidity in the meadow).

Road Versus Meadow Plots

Environmental Conditions

None of the environmental variables were significantly different in the road vs. meadow. (humidity: χ^2=2.2, df=1, p=0.137; wind(ln): χ^2 =0.07, df 1, P=0.793; temp:□□^{2} =2.64, df 1, P=0.104) there was much more variation across plots (humidity: χ^2=54.57, df 30, p = 0.004; wind(ln): χ^2 =45.48, df 30, p =

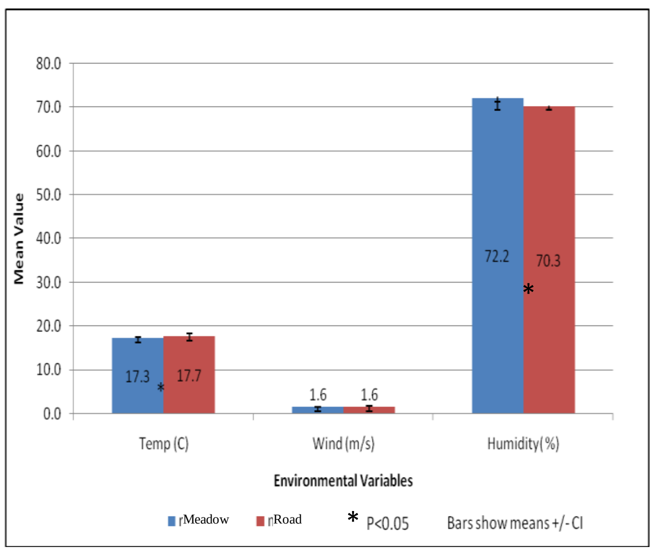
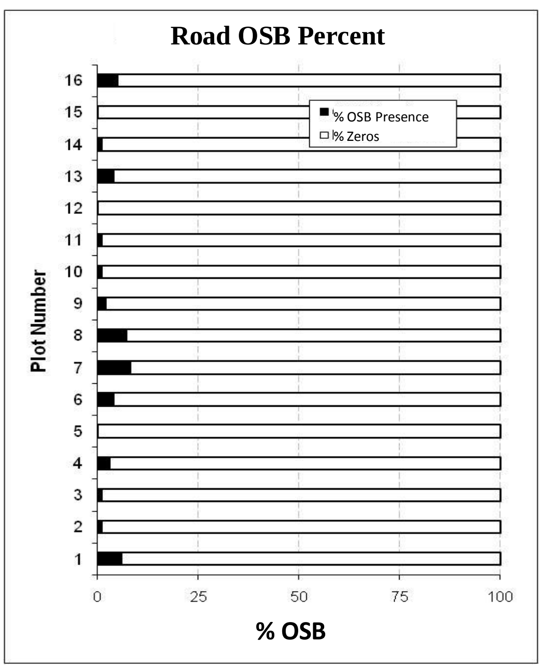


Figure 9. Mean values of environmental variables in the road and meadow (bars show +/- 95% C.I.; n=3200).

0.035; temperature: χ^2=84.77, df 30, p < 0.001).

OSB Behavior

49 OSBs were sighted in the road out of 3200 scans across 21 surveys days, whereas 178 OSBs were sighted in the meadow per 3200 scans (149 of which were behaviors that could be performed in the road), p-value = 0.013; Figure 10). OSB presence was significantly higher in the meadow than in the road (paired t-test: t = -2.815, df=15, P =0.013; nested ANOVA: Meadow $F_{1,120}$=8.78, P =0.004), with ~3 times as many sightings of OSBs in the meadow (149 of 178 sighted doing behaviors that could occur in the road) than the road), with four times as many sightings of butterflies in the meadow than the road when examining only butterflies engaged in behaviors that could be found on the road (same area and time observed). This result indicates preferential use of the meadow either by more butterflies or for longer durations.



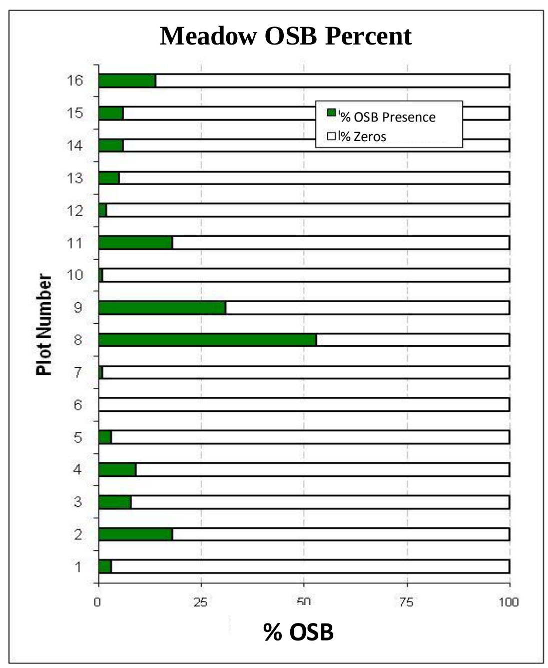


Figure 10. Percent OSB presence over road (*left*) and meadow (*right*) showing number of zeros (plots with no OSBs) by plot. Plot number 1 is at the south end of the site while plot number 16 is the farthest north.

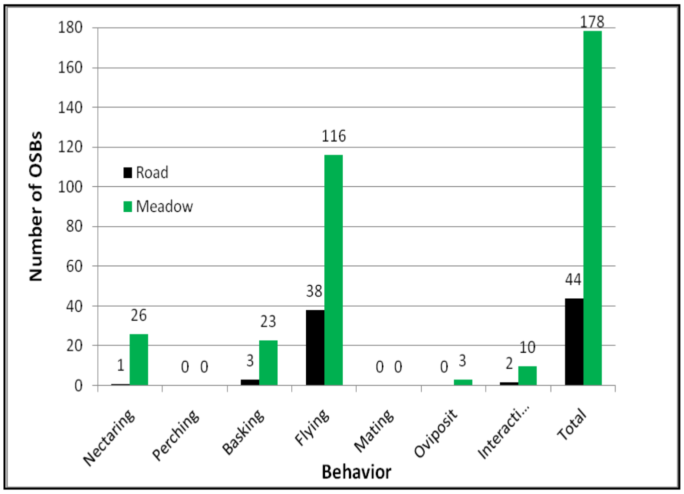


Figure 11. Total number of OSBs by behavior type in the road vs. meadow

There were only four behaviors observed in the road "nectaring", "basking", "flying" and "interactive" (Figure 11). The predominant behavior in both the road and meadow was "flying," accounting for 86.4% of observations in the road and 65% of those in the meadow. OSBs do not seem to be attracted to the road for basking as 6.8% of the butterflies in the road were basking while 12.9% of the butterflies in the meadow were basking. "Basking" behavior was only observed a total of 3 times in road plots 1, 7 and 8 (always 75 min of 12:00 PM: at 13:12 am, 11:10 am, and 12:50 am respectively). It was initially thought that if the road temperature was in fact warmer than the meadow temperature that OSBs may be attracted to roads, particularly in times such as early morning before the meadows warm up. Clearly they are not displaying basking behavior more in the road than in the meadow although timing of behavior was not analyzed as simultaneous surveys of both the meadow and road were not typically performed and surveys were not performed in increments throughout the day to answer this question.

"Nectaring" and "interactive" OSB behaviors were observed once each in the road. The one account of "nectaring" occurred where a flowering plant was hanging over the guardrail and overtop of the pavement. The "interactive" behavior involved one OSB chasing another directly across the road in the north end of plot 13 (subplot 64) from the east side of the road to the west.

Table 4. Total OSB road ingress (from east and west) and egress (from the east and west) for all road plots combined. Ingress and egress were not determined for every instance an OSB was detected in the road due to obstacles obstructing clear lines of sight.

Total	East	West
Ingress	37	44
Egress	40	46

OSBs were observed entering and exiting the road from both the west and east sides with an overall even pattern (Table 4) (Figure 12).

Assessment of OSB movement in plots 7 and 8

Although overall butterfly ingress and egress was nearly even, it was not consistent among plots (Figure 12; Figure 7), and this implies that there may be some pattern to OSB movement that can be used for ideal barrier placement. Some plots showed nearly the same number of OSBs entering and exiting from either the east and west side of the highway. In

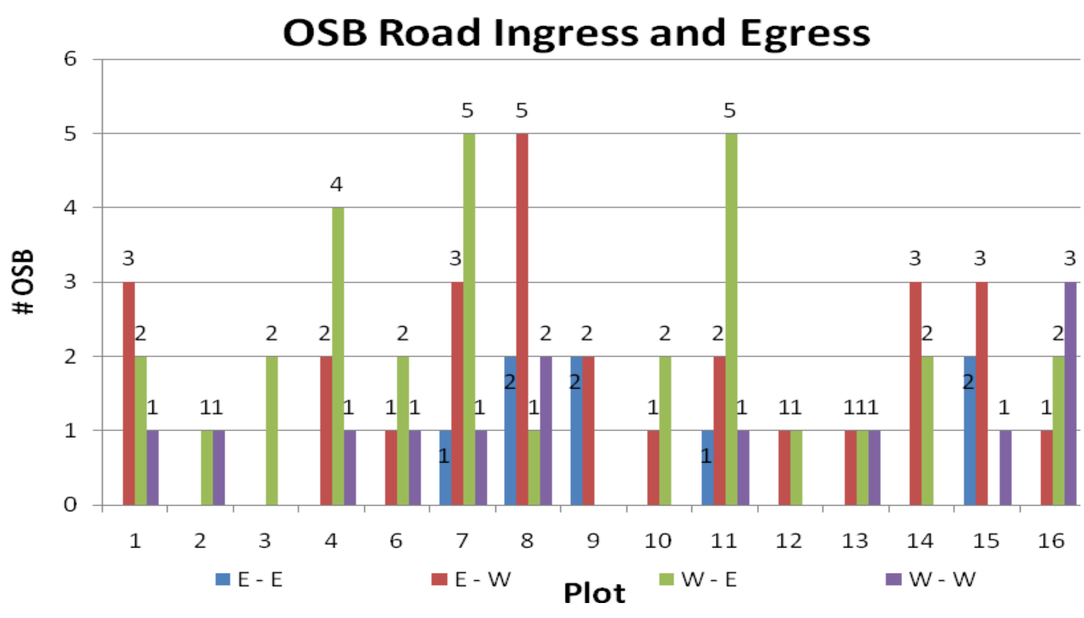


Figure 12. OSB road ingress and egress by plot. E-E, OSB entered the road from the east and exited to the east. E-W, OSB entered the road from the east and exited to the west. W-E, OSB entered the road from the west and exited to the east. W-W, OSB entered the road from the west and exited to the west. Notice plot 5 was omitted from chart as no OSBs were documented in this road plot. Direction of flight information was not determined for every OSB observation in the road because at times obstacles obstructed line of sight.

contrast, for example, two adjacent plots, 7 and 8, showed a circular pattern of movement wherein OSBs entered the road at plot 7 from the west and exited the road to the east, whereas they were primarily heading west when crossing the road in plot 8 (entering from east and exiting west) (Appendix 6).

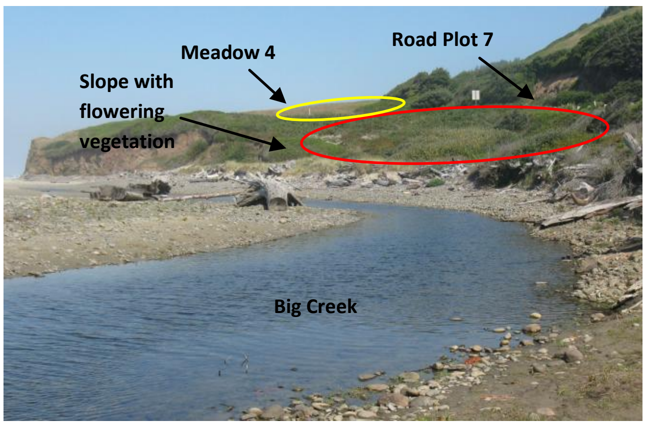


Figure 13. Photo of flowering vegetation adjacent to road plot 7 and south of meadow area 4. Photo credit: Sara Zielin.

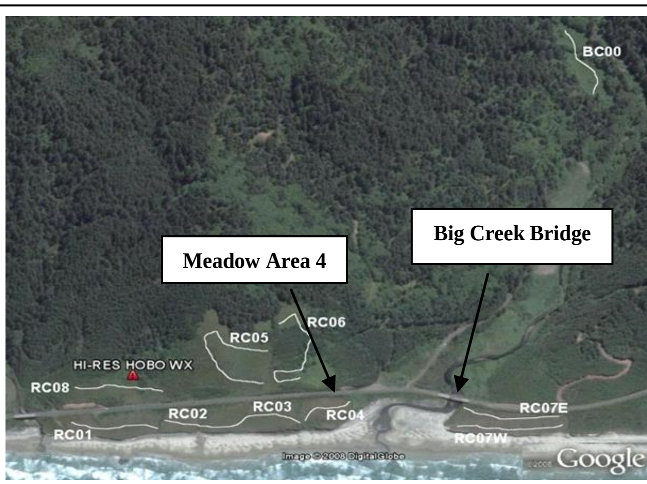


Figure 14. Aerial photo of OSB annual census transects and meadow areas at Rock Creek – Big Creek. Photo credit: Google (modified by Mike Patterson and again by Sara Zielin).

In some locations along Highway 101 the road surface is significantly lower than the adjacent meadows creating a walled corridor (road-cut) made of earth and vegetation reaching well over 5 m in height relative to the road surface (Figure 2). Plot 7 and the southern section of plot 8 were immediately south of the longest walled corridor at this site and north of the Big Creek Bridge. These same plots are also a location in which the road surface of Highway 101 slopes. The road begins to drop in elevation at the southerly end of the walled corridor (plot 8) and continues to slope downward toward the south at a moderate grade to the north-side of the Big Creek Bridge where the road levels again (plots 5 and 6) (Appendix 1).

The area west of the road plot 7 has many flowering plants (including *Rubus* sp.), but is not considered meadow and is more of a sloping transitional zone from meadow area 4 to Big Creek (Figure 13). This area, especially on windy days, seems to serve as shelter from the wind and OSBs were observed accumulating just south of the meadow area 4. Presumably, OSBs were taking shelter at this location when winds were very high in the more exposed meadow area (Figure 14). Indeed, OSBs may have been pushed there by northwest winds (Appendix 7). Meadow area 4 was also the location where the highest densities of OSBs (over 130 individuals/ha) were calculated during the 2009 OSB census surveys (Appendix 8 and 9) (Patterson 2009).

Differences between Road Sections

Overall results from All-Occurrence surveys

24 OSBs were detected from the all-occurrence surveys (64 survey periods). These were observed in all road plots except plot 5 (Figure 15), which was beyond the Big Creek Bridge. The mean temperature and wind speed were slightly higher than those reported for the road scan surveys (Figure 16).

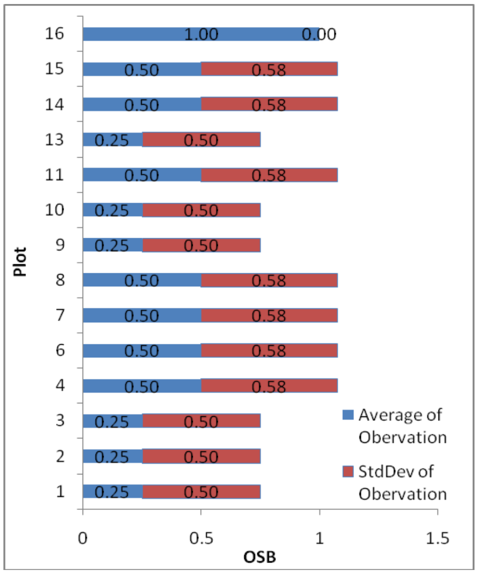


Figure 15. Mean OSB presence in road plots across days observed for all

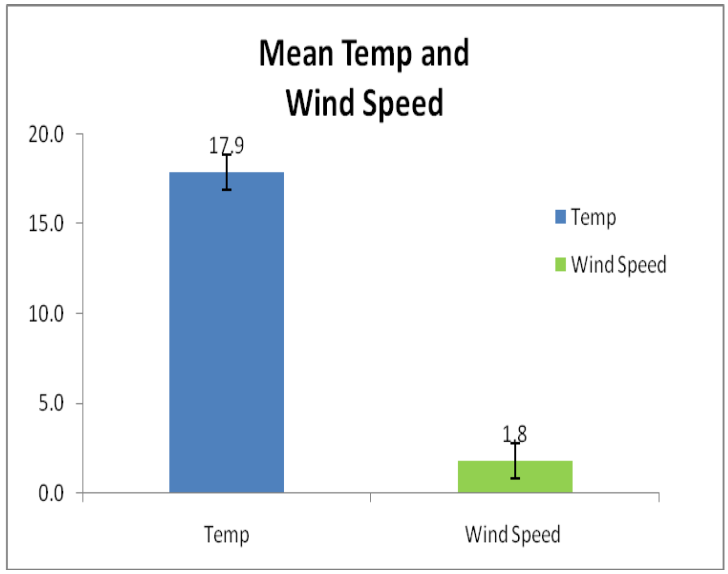


Figure 16. Mean temperature and wind speed for all occurrence surveys (+/- SD)

Barrier Installation and Earthen Berms

Areas of road crossed most - informing Barrier Installation

Five main locations of OSB road crossing, encompassing 7/16 plots (43.8%), which accounted for 72.6% (69/95) of the crossings, are apparent within the project area, excluding the opportunistic sightings (22 instances), the same five areas were prominent and accounted for 72.6% (53/73) of the 73 crossings (Figure 17). OSB height of flight among all the road plots ranged from 0.5 m – 4.5 m (relative to the road surface) and did not vary greatly (1.6 m ± 0.8, mean ± SD). It

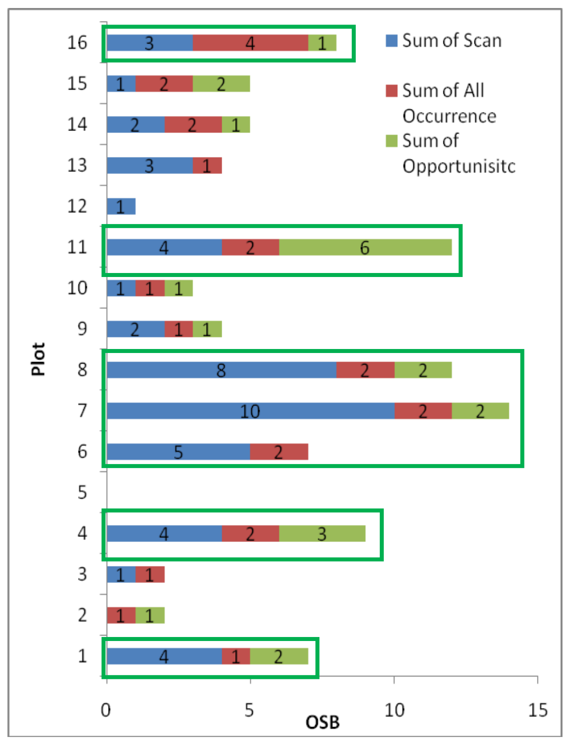


Figure 17. Number of OSBs by road plot for all accounts of detection either during surveys (scan (49) or all occurrence(24)) or opportunistic sightings (N=22) and the five main OSB crossing areas.

should be mentioned that it was difficult to estimate flight height above the staff height (3.5 m) which was used as a reference. OSBs tended to fly directly across the road without lingering, and 55 (55/95, 57.9%) flew directly across the road. Most other OSBs continued to fly the length of the road but either eventually returned back to the side where they initially entered the road or exited across the road. Egress was not documented for every OSB sighted in the road as visual obstructions sometimes impeded line of sight.

Areas of road crossed most - informing Earthen Berms

No difference was detected between OSB presence in the road-cut subplots vs. subplots to the immediate north and south (log of number of OSBs in road-cut = 0.64 ± 0.16 vs. log of number outside of road-cut = 0.59 ± 0.12; t-test: $t = -0.27$, $n = 45$, $p = 0.7884$).

Differences in environmental conditions among road sections – informing Earthen Berms

The road-cut subplots had significantly lower wind speeds and warmer temperatures than the subplots immediately adjacent to the north and south (log of wind speed in road-cut = 0.90 ± 0.04 versus log of wind outside of road-cut = 1.06 ± 0.03; t-test: $t = 3.59$, $n = 45$, $p = 0.0006$; mean temperature in road-cut = $18.6 \pm 0.24^{o}C$ versus outside of road-cut = $17.1 \pm 0.17^{o}C$; t-test: $t = -4.76$, $n=45$, $p<0.0001$).

Differences in Flower Availability

Flowers in meadow

We counted 5,601 flowering plants in the meadow (n = 80 subplots); subplots averaged 1.8 ± 2.59 (SD) flowering plants. Scatterplots revealed there was no strong linear relationship between the number of flowering plants in the meadow plots and the number of butterflies in those meadow plots or in the matched road plots (Figure 18).

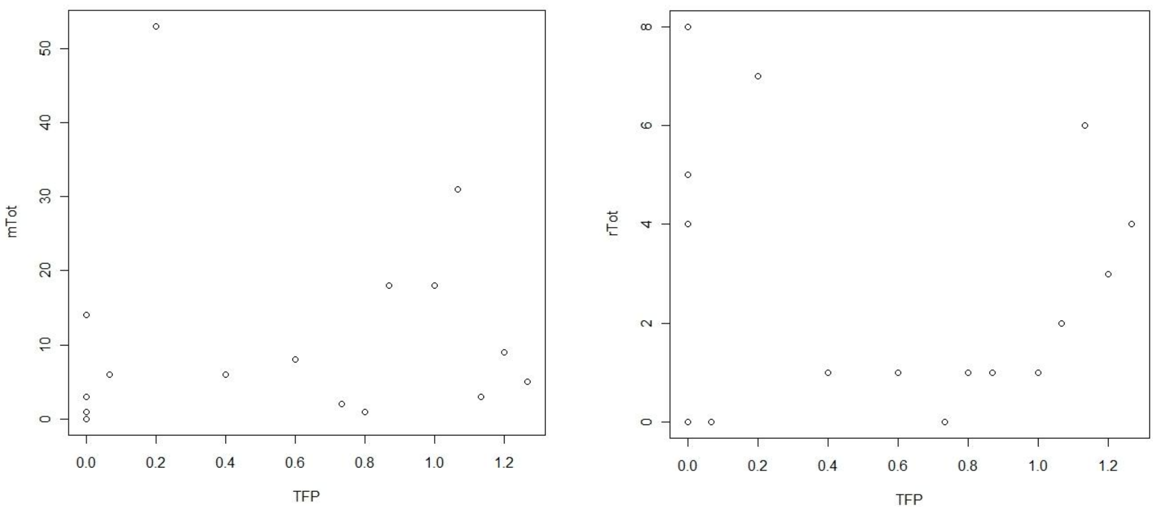


Figure 18. Scatterplots of OSBs detected in the meadow vs. flowering plants in the meadow (left) and OSBs detected in the road vs. flowering plants in the meadow (right)

Flowers along road

However, OSB presence in the road was positively correlated to flowering plants in the road.

More OSBs were found in subplots that had more flowering plants (Figure 19; linear regression: $r^2 = 0.51$, $t = 3.71$, $n = 15$, $F_{1,13} = 13.76$, $p = 0.003$, $y = 0.126X + 0.245$). Importantly, one OSB was observed performing "nectaring" behavior in the road; this occurred on the west-side of plot 7 where a large flowering plant was overhanging the guardrail into the road.

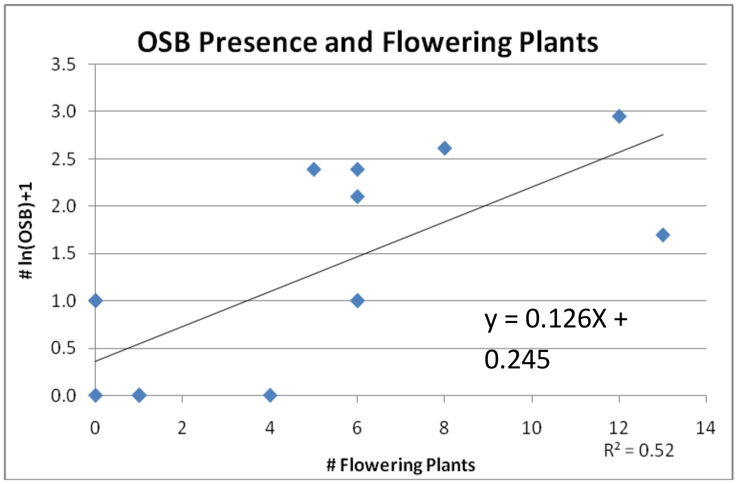


Figure 19. Linear regression of OSB presence vs. flowering plants in the road

OSB Presence/Absence versus Environmental Conditions

Both temperature and humidity were significantly related with OSB presence in both the road and the meadow. More OSBs were sighted at warmer temperatures (Figure 20; Logistic regression: positive relationship; road: $z = 2.349$, $df = 318$, $p = 0.0188$, and meadow: $z = 4.711$ $df = 319$, $p = 2.47 \times 10^{-6}$). The critical temperature determined for prediction of OSB presence was ~19°C (66°F) and no OSBs were detected below 13.9°C (57°F). Temperature when OSBs were sighted averaged 19.1 °C ± 2.1. Fewer OSBs were found at higher humidity (Figure 21; negative relationship; road: $z = -2.68$, $df = 318$, $p = 0.0073$, and meadow: $z = -4.390$, $df = 319$, $p = 1.13 \times 10^{-5}$). The critical relative humidity value was ~65.0 %, where OSB presence becomes less likely above this value. Also, no OSBs were detected below 56.5 % relative humidity or above 79.6 % in the road (Table 5). Mean humidity during periods when OSBs were present was 65.5% ± 15.0. Wind was not significantly correlated with OSB presence in this dataset (road: $z=-0.677$, $df=318$, $p =0.498$, and meadow: $z=-1.835$, $df=319$, $p =0.758$) but it should be noted that no OSBs were observed at wind speeds above 7.5 m/s (16.8 mph; survey range = 0 10.1 m/s). Mean wind speed when OSBs were present was 1.4 m/s $\pm$ 1.5 (3.1mph +3.4).

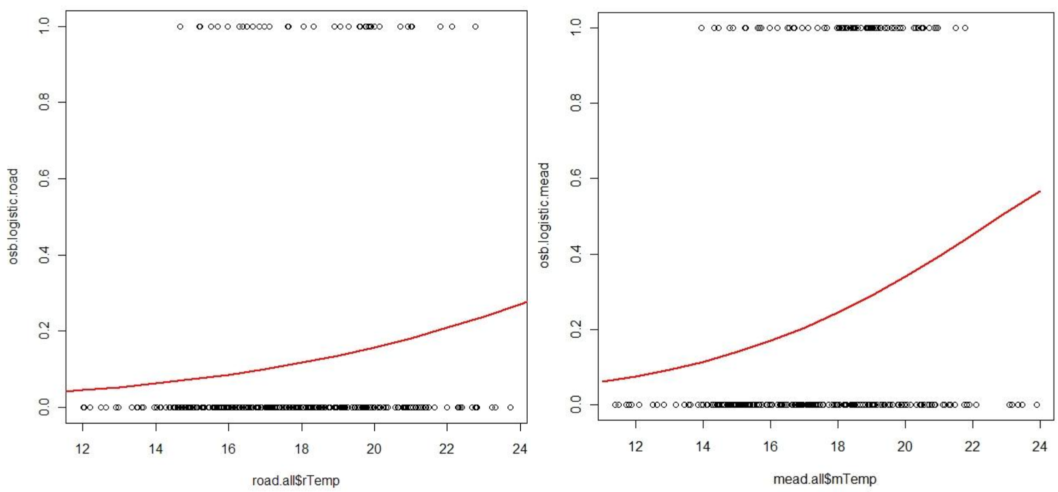


Figure 20. Logistic regression of OSB presence only for behaviors that can be performed in the road (i.e. "flying", "basking", and "nectaring") and temperature (ºC) in the road *(left)* and in the meadow *(right)*. (Dataset reduced to 320 groups).

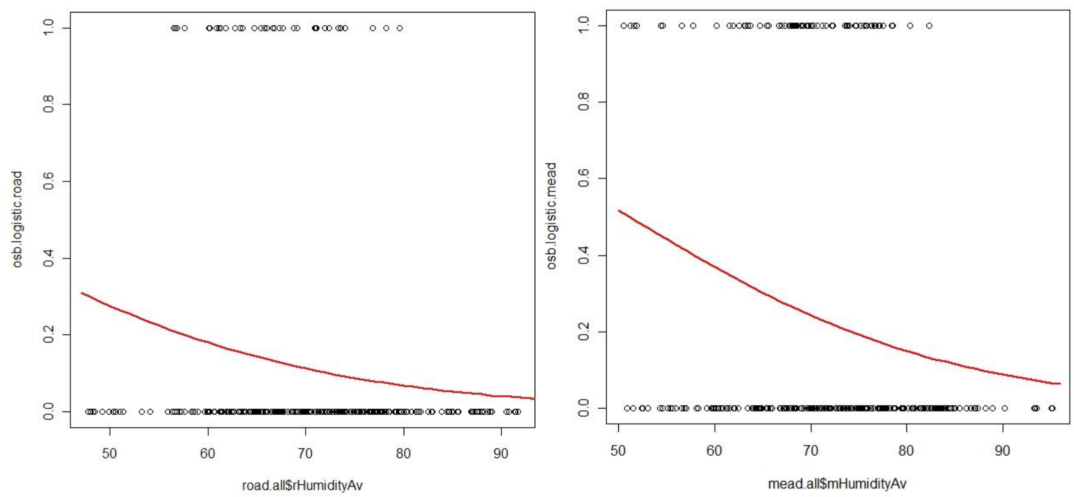


Figure 21. Logistic regression of OSB presence only for behaviors that can be performed in the road (i.e. "flying", "basking", and "nectaring") and relative humidity (%) in the road *(left)* and in the meadow *(right)*. (Dataset reduced to 320 groups).

Table 5. Relative humidity (%) range, median, and mean for OSB presence vs. absence.

	Meadow		**Road**	
	OSBs Present	**No OSBs**	**OSBs Present**	**No OSBs**
Range	50.5 – 82.3	50.5 – 95.2	56.5 – 79.6	47.7 – 91.7
Median	68.5	72.9	66.6	70.6
Mean	67.9	72.4	66.8	70.5

5.0 Discussion of Prioritized Mitigation Types and Management Suggestions

One fifth of OSBs observed in road and meadow-plot surveys ventured outside their preferred habitat of the meadow and onto Highway 101, presumably to access habitat on the other side. This high proportion of road crossings suggests the OSBs at Rock Creek – Big Creek are highly vulnerable to vehicle-butterfly collisions. Risk of road mortality is likely the most severe during August when traffic, temperature, and OSB abundance all peak. During this study, which was mostly conducted during this peak risk time, one instance of vehicle-caused mortality was confirmed (of 95 butterflies seen in the roadway). In addition, nine instances (10 %) were recorded for which vehicle-related mortality was likely but death could not be verified (apparent mortality) even though the road and adjacent vegetation was searched immediately after a butterfly-vehicle interaction. It's possible that the nine apparent mortalities of OSBs stuck to the grills of passing vehicles upon collision.

Several management options are being considered to reduce the risk of butterfly mortality due to vehicle-butterfly collisions. This study on butterfly use of the road was conducted to help identify where and when butterflies use the road in order to inform choices from the different management options being considered. Here, we use the study results as a first attempt to identify which management options may be suitable to pursue for future application or for research. Below, the mitigation options are listed in order of priority (from highest to lowest) based on study results and other literature.

Vegetation Manipulation – High Priority

Vegetation manipulation has been established as high priority as it offers a benefit at an assumed relatively low, though on-going, cost. Several recommendations for manipulating vegetation are supported by our data and additional observations. First, the verge could be cleared of flowering plants, especially during the season of OSB flight. There were significantly more OSBs found in plots with more flowering plants along the road (Figure 19), and an OSB also was found nectaring in the road. Butterflies likely would reduce their time on the road and perhaps also their number of crossings if the roadside had fewer available nectaring opportunities. Although it is assumed that even with vegetations removed from each side of the road some will randomly fly into the road corridor or cross to access alluring plants in opposite meadows. Not only did we find more butterflies in roadside areas with more plants, other studies have documented change in butterfly movement rates and resident time per microhabitat based on their preference or motivation for that habitat type. For example, Kuefler and Haddad (2006) found that the movements of four species of bottomland butterflies were influenced by boundary type, stream proximity, and host plant abundance. In addition, Schultz (1998) reports that butterflies may increase movement rates to escape through hostile or non-preferred habitat.

Second, the verge could be mowed in coordination with meadow mowings. The Forest Service manages OSB habitat at the study site by implementing a mowing regime in the meadow. Periodic mowings at key times throughout the year are performed to subdue mostly non-native grasses (and salal) that outcompete the larval food plant (*Viola adunca*) of the butterfly. Oregon Department of Transportation (ODOT) also manages vegetation along roadsides throughout the state including Highway 101 but not necessarily in coordination with the Forest Service mowings. Two opportunistic observations, which should be followed up with quantified data, are relevant. It seemed the meadows had lower flowering plant diversity than the roadside. After the summer mowing, the main flowering plant noticed in the meadows was *Hypochaeris radicata*. Coordinated mowing would decrease this disparity. Anecdotal observations also indicated that, after a meadow mowing, there was a higher frequency of dense patches of flowering plants along the roadside than the meadow. If these patterns are real, butterflies may be attracted to the road more often and for a longer time than expected when there are fewer or lower diversity of flowering plants in their preferred habitat.

Third, the Rock Creek – Big Creek site is considered critical habitat, any modification of such habitat would require consultation with USFWS and concurrence with the process prior to modification. Although the intent of all the mitigation options is to reduce mortality and essentially support the recovery of the OSB, evaluating any potential changes made to the critical habitat is mandated under the National Environmental Policy Act (NEPA). As a result mitigation options may need to be modified to comply with USFWS and NEPA.

Last, although a significant positive relationship was apparent between OSB presence and flowering plants (Figure 19) follow up testing in the verge should be performed to a) determine if these same hotspots for crossing are found once the mowing regime has changed, and b) manipulate distribution of roadside flowers by moving potted plants to different plots and determining if this affects where OSBs enter and cross the road.

Management Suggestions for Vegetation Manipulation

1) Remove all potential nectar plants along the road corridor at the study site;
2) Coordinate mowing efforts between the USDA Forest Service (meadow management) and ODOT (roadside management);
3) Increase nectar plants in meadows by manipulating meadow mowing regime (dates and/or locations) or by planting additional nectaring plants away from the road;

4) Create preferred habitat in meadows on both sides of Highway 101 that include forest fringe and nectar and larval food plants so butterflies do not have to cross the road to access a resource not available on one side.

5) Perform a follow-up test on OSB presence vs. flowering plants in the roadside verge to corroborate our results acquired from only one sampling season and to determine if these results change once the mowing regime is in place.

Due to these recommendations, ODOT mowed the verge the following summer; subsequently no butterflies were found nectaring near the road or loitering on the road and all crossings were straight across the road and were attributed to resource use (V. Bennett, personal communication, 2010).

Barrier Installation – High to Moderate Priority

Barriers are prioritized as high to moderate priority as this mitigation type is likely to be successful, but at a greater cost than vegetation manipulation. Barriers have the ability to manipulate movement of wildlife. One example of a successful barrier implementation is with the royal tern (*Sterna maxima*) in Sebastian Inlet State Park, Melbourne Beach, Florida. There the barrier is a visual one, with 122 3-m-long metal poles spaced 3.7 m apart with no fencing or netting linking them together and installed along both sides of a 13.1 m high two-lane bridge over an inlet (Bard et al. 2002). Bard et al. (2002) evaluated the effectiveness of this barrier in reducing the incidence of collisions between royal terns and vehicles along the bridge. The poles served as a ‘visual barrier’ to the terns; i.e., perceived as an impermeable or undesirable route for them to cross. The birds responded by flying higher; over the bridge and poles, effectively avoiding vehicles on the bridge. Bard et al. (2002) found that significantly fewer terns (64% decrease) were killed post-barrier installation.

Although birds and butterflies are very different species, parallels may be drawn between the two in relation to how they interact with roads and barriers. Severns (2008) studied Fender's blue butterflies (*Icaricia icarioides fenderi*) along a narrow two-lane, paved road 10 km west of Eugene, Oregon, that bisects the butterfly habitat. He observed the response of Fender's blue butterflies to roads and physical barriers (particularly hedgerows) to determine if either of those retarded butterfly movement between the south and north habitat patches. The results indicate that the road does not act as a barrier for movement of the Fender's blue butterfly and this remains consistent with other published research (Munguira and Thomas 1992; Ries and Debinski 2001). However, the hedgerows did appear to serve as a barrier to butterflies as 1.2 % (less than 2% of males and 10% of females) flew over the hedgerows. Nearly 97% of butterflies observed crossed the road from the south to north, approached and tracked the length of hedgerow for approximately 5 m before they crossed back over the road to the south field. An additional 1.9% of butterflies observed followed the same general path but returned immediately to the south once they approached the hedgerow. No collisions were observed during the surveys and the probable cause for this is the very low number of vehicles observed using the road (3 vehicles) and the low speed (40 km/hr) of vehicles traveling on the road. It appears, therefore, that barriers, man-made or natural, can be used to manipulate movement of wildlife.

Fences, netting, guardrails, and/or concrete (temporary or permanent) structures in key locations could manipulate movement of butterflies, ideally keeping OSBs in meadows longer or forcing them to fly higher over the road and vehicle turbulence than they otherwise would, while allowing access to all habitats. Four lines of evidence suggest this management would be effective here. First, butterflies were not seeking out the road to use as a habitat, except for nectaring on the verge: they basked less in the road and spent much less time in the road than the surrounding habitat. Second, height of flight above the road ranged from 0.5m – 4.5m and typically depended on the height of vegetation or land on either side of the road. Third, OSBs tended to follow the most direct route across the road, and typically did not loiter. Fourth, five road segments (across seven plots) accounted for the majority (72%) of OSB crossings (Figure 17 and Table 3), suggesting that strategic placement of relatively narrow barriers could be effective. These plots had higher densities of flowering plants alongside, were adjacent to areas where captive-reared OSBs were released (and counts were historically high), and may be travel routes due to the topography and resource distribution. Thus, these areas have promise as potential locations for barrier placement, with higher priority of placement going to areas that have a negative slope on one side of the road and a positive slope immediately across the road to complete a continuous and natural path over the road (S. Jacobson, personal communication, January 10, 2010). It may be necessary to extend the length of barriers beyond prioritized plot locations to prevent circumvention of the barriers, such as with fences for ungulates (Clevenger at al. 2001). In fact, OSBs were observed following edges and on several occasions butterflies followed the length of the salal hedge that lines some sections of the Highway 101 and when OSBs approached a break in the hedge they flew into the road.

OSB census report data can be used as a guide for timing of temporary barrier placement to coincide with the peak of OSB flight (Patterson 2009). Further research is needed to evaluate barrier types and placement. Table 6 identifies the degree of habitat match and crossing rate along with an associated ranking for priority of barrier installation. The actual barrier should be positioned on the negative slope side of the road to elevate OSB crossing height.

Table 6. Prioritization of barrier placement by plot location, OSB count, average crossing height, and match of ideal topography

Priority	Plot Location	OSB Crossing Count	Average Height of Crossing	Level of Ideal Topography Match
High	11	12	1.7 m	Best
High	7/8	14/12	1.5/1.9 m	Moderate
Moderate	16	8	1.9 m	Moderate
Moderate	4	9	1.1 m	Poor
Low	1	7	1.6 m	Poor

Management Suggestions for Installing Barriers

1) Place barriers along the roadside of Highway 101 to reduce the # OSBs entering the road and to increase the height of flight when crossing the road, to reduce vehicle-butterfly collisions;

2) Perform research evaluating barrier types and strength with the goal of successfully reducing OSB presence and manipulating flight height on Highway 101;

3) Use barrier placement prioritization results (Table 6) as a starting point for actual barrier placement and testing;

4) Use OSB census data as a guide for timing of temporary barrier placement to coincide with the peak of OSB flight (Appendix 8 and 9);

Flashing Speed Reduction Signal – Moderate Priority to Low Priority

An environmentally triggered flashing speed reduction sign as a mitigation option was considered moderate priority because uncertain effectiveness, inconvenience to travelers, and high cost may hinder feasibility. Animal detection systems along with speed reduction are being investigated in several areas to reduce large animal-vehicle collisions (Huijser et al. 2008), but these systems are still considered experimental, and none have been used for animals invisible to drivers, or for animals whose danger to the driver does not motivate speed reduction. A speed limit of 15 mph was implemented for the Hine's emerald dragonfly (*Somatochlora hineana*), a federally-listed endangered species that experienced impacts from vehicle and railway traffic (Soluk and Moss 2003). Driver response to speed limit reduction is key to success, but it is unknown if drivers will respond to an unusual, and invisible, reason for speed reduction. Linking speed reduction to timing and environmental conditions typical of OSB flight would reduce impacts to traffic and likely increase compliance.

Figure 22. Photo of speed reduction traffic sign for the endangered Hine's emerald dragonfly (*Somatochlora hineana*). Photo credit: Dan Soluk

Mortality studies of the dragonfly were performed by Soluk et al. (2003) in 1997 and 2002 and death rates ranged from 0-16.4 fatalities/km/day. Data were collected from multiple roads with varying posted speed limits and found a significant decrease in mortality with declining speed limits but the cause of this correlation remains untested.

Although the effect (or exact relationship) of vehicle speed reduction on vehicle-caused mortality of the Hine's emerald dragonfly has not been studied, managers were asked to suggest an ideal speed limit for vehicles traveling on a road adjacent to dragonfly habitat (to essentially avoid any dragonfly "take" caused by vehicle collisions) (D. Soluk, personal communication, April 10, 2009). Managers of the dragonfly recommended a speed limit of 15 mph based on their expertise related to the species and overall sense of how the dragonfly interacts with vehicles from observations (Figure 22). Although no follow up research observing the relationship between vehicle speed and mortality has been performed with the Hine's emerald dragonfly, future research of this sort related to butterflies and other invertebrates should be performed to better understand if there is in fact a predictable relationship between vehicle speed and collisions with flying organisms and how it varies with flight speed.

One of the goals of this research was to determine the thresholds for flight and OSB presence in the road relative to key environmental variables. These data provide a scientific basis for recommendations regarding environmental conditions that would activate a speed reduction sign when conditions were favorable for butterfly flight, if this mitigation option were pursued. We examined the possibility of using temperature, wind speed, and humidity as predictors of OSB presence.

OSB presence in the road increased with increasing temperature and decreased with increasing humidity and wind speeds. No OSBs were found in the road at temperatures under 13.9^{o} C, and this provides a conservative threshold option. An alternate possible threshold is to use a cut-off of two standard deviations from the mean, which in our study was 19.1 ^{o} C $\pm$ 4.2. This cut-off would encompass all but 2.2% of the observations below the cut-off and thus would greatly reduce risk of butterfly-vehicle collision but still greatly limit the hours when the speed limit was reduced. A third option would be to use the temperature threshold predicted for flight by the road logistic regression model (19.0°C). The logistic regression approach is a strong one based on the best available empirical data, but our models had weak predictive power so in this case may not provide the best option for a cut.

The positive relationship between OSB presence and temperature over the road or meadow is consistent with other studies that indicate that butterflies are more likely to fly when temperatures exceed 16 °C (60°F) (McCorkle and Hammond 1988). In general, most *Speyeria* require high body temperature to engage in normal activities and they typically suspend flight unless there is full sun or if the ambient air temperature is higher than 21 °C (70 °F) when it is cloudy (McCorkle and Hammond 1988). OSBs use solar heating to raise their body temperature when ambient air temperature is ≤16°C (60°F) to fly effectively and perform behaviors such as foraging, mate seeking, predator evasion, and oviposition (Douglas 1978; Watt 1968). They behaviorally thermoregulate by using a dorsal basking position where their wings are open in a horizontal plane and their dark basal suffusions are exposed to the sun (McCorkle and Hammond 1988). Heat is absorbed by the basal suffusions, then transferred to the thorax, and is retained by a thick coat of long hairs which serves as insulation for thoracic heat (Douglas 1978; McCorkle 1980).

Humidity may impact OSB flight as more water vapor in the air may cause higher rates of evaporative cooling and keep butterflies below the threshold body temperature to fly. Fog and rain, common at the Oregon coast, can also negatively affect butterfly flight (McCorkle and Hammond 1988; USFW 2001; Haughton et al. 2003). In our study, 65% relative humidity was determined to be the critical humidity value from the logistic regression, below which OSBs were more likely to be active (no OSBs were detected below 56.6 %). The mean humidity value during periods when OSBs were present in the road was 65.5 % ± 15.0 (SD).

In this study OSBs were not observed either in the road or meadow at wind speeds above 7.5 m/s (17 mph). Two standard deviations from the mean, 1.4 m/s $\pm$ 3.0, again provides another possible cutoff. Similarly, other observations have found that wind speeds of 6.3 m/s (14 mph) inhibit butterfly flight (N. Testa, personal communication, March 25, 2009; USFW 2001). Box plots in Figure 8 depict environmental variables when OSB was not present as compared to when OSB was present. Values for the road showed that temperature was higher when OSBs were present, wind speeds were the same regardless of presence, and humidity was lower when OSBs were present.

Temperature and wind speed are recommended variables to use to trigger a flashing speed reduction sign. Humidity is strongly correlated with temperature and statistical models (logistic regression) on humidity were not as robust as those with temperature. Temperature and humidity were stronger predictors of OSB presence than wind speed in logistic regression models on our dataset, although even those models did not have high explanatory power. All the modeling efforts suffered from the fact that survey times were selected to maximize butterfly occurrence and therefore did not have many sample points near or beyond the environmental thresholds. For example, the average wind speed in our study (2.5 m/s or 5.6 mph) was much lower than the wind speeds that inhibit flight.

Speed reduction to reduce OSB mortality is an intriguing mitigation option that warrants further study as little is known about the effectiveness of speed reduction to reduce mortality (Huijser et al. 2008) or the effectiveness of engaging driver response to a benign target. Further research may be needed to support this option, however. A study examining the relationship between vehicle speed and butterfly mortality would help identify the maximum speed limit that could substantially decrease mortality. The ideal reduced speed to alleviate OSB vehicle-kills is unknown especially considering the fragility of butterflies in turbulent air caused by passing vehicles. Assuming a given speed reduction, reducing traffic speed when temperatures are above 19.0°C and wind speeds are below 7.5 m/s would minimize the amount of time speed reduction is implemented.

Road-kill Analysis

The one documented vehicle-caused death of an OSB likely underestimates mortality as this was documented from only 48 hours of survey time across 21 days of observations on the road. There were approximately 59 days during the summer of 2009 when OSBs could have been present based on the first detection on July 22 and last detection on September 18 (data from this study and from OSB census data, Patterson 2009) although this estimate doesn't exclude days when weather was unsuitable for butterfly flight (i.e. raining or other unfavorable weather). OSBs were detected as early as 9:30 a.m. and as late as 16:30 p.m. although they may have been active at times other than this timeframe but surveys were not typically performed outside of this range. Also, three or four paired plots were surveyed per day and it's possible that OSB presence may be exceedingly underestimated for plots that were surveyed at times further from the warmest part of the day. Last, there were 9 occasions of apparent mortalities where no carcasses were found after vehicles passed and it's speculated that these butterflies collided with and stuck to the grills of passing vehicles. All apparent mortalities occurred when vehicles were driving away from the observer and OSBs crossed the road on the distal side of the vehicle furthest away from the observer (so the potential collision was not visible to the observer). Again the road and roadside verge were investigated for OSB carcasses immediately after vehicle-butterfly interactions and none were found.

The estimated range for OSB vehicle-caused mortality for any given year may fluctuate considerably depending on various factors and OSBs may experience the greatest impact when high vehicle traffic volume (McKenna and McKenna 2001) and a high number of eclosing OSBs coincide. Peak flight for OSBs during the 2009 season was August 13th with 112 individuals detected (Appendix 9) (Patterson 2009). Peak summer traffic counts are unknown for this site but the AADT along this stretch of Highway 101 is 2100 vehicles. AADT at the Rock Creek-Big Creek site is most likely an under estimate of actual vehicles traveling on the road when OSBs are present. It is probable that the OSB flight season does indeed overlap with peak summer travel (July through September) as most families take their summer vacations during this time and because the Oregon coast is a desired vacationers destination. In fact, visitation numbers to the Cape Perpetua Visitor Center (a nearby destination approximately 7 miles north of the study site) indicates that July, August and September are the months with the highest visitation, with the peak visitation month in August (36,827 visitors) (D. Dunn, personal communication, 2009).

Based on the 2008 AADT up to 124,000 vehicles could be impacted by reduction in speed at the study site although this would only occur if the traffic change was implemented 24 hours a day for the entire flight season (~59 days). The number of impacted vehicles could be even higher as AADT is not corrected for the assumed increase in summer traffic volume. With an environmental variable triggered traffic signal there would likely be times and perhaps even full days, even within peak OSB flight, where the traffic signal may not be because of unfavorable environmental conditions for flight. The ability to trigger a speed reduction sign only when necessary is a great selling point for this mitigation option for several reasons: 1) it slows traffic when OSBs are most likely present and reduces the potential for vehicle collision, 2) it only slows traffic when the probability of OSB presence is at its highest which in turn reduces the amount of unnecessary traffic build up, and 3) may keep local drivers stimulated and less likely to disregard the traffic signal change. The low speed likely required to reduce butterfly-vehicle collisions substantially on this coastal highway, however, keeps this option a low priority.

Management Suggestions for Flashing Speed Reduction Signal

1) Perform research to understand the relationship between vehicle speed and butterfly mortality to determine what vehicle speed is necessary to reduce or eliminate mortality due to vehicle collisions;

2) Reduce traffic speed when the temperature reaches 19°C, relative humidity is below 65%, and when wind speeds are below the maximum wind speed where OSBs were observed (7.5 m/s or 17 mph);

3) Perform a more comprehensive study to determine a predictor of OSB presence by using other butterflies at the study site as a surrogate for OSBs, and test other predictor variables not included in this study (such as solar radiation).

Earthen Berms – Varied Priority

Removing Berms – Not a Priority

The removal and addition of earthen berms as a mitigation option was established as a low priority because no "sheltering" effect of OSBs was detected in the road-cut, despite its lower wind speed and higher temperature, and OSB habitat is protected under the ESA as "critical habitat" (ESA 1973).

Significantly more sightings of OSBs occurred in the meadow than in the road. They use meadow habitat on both sides of the road for foraging, mating, and oviposition during the summer (McCorkle and Hammond 1988; Arnold 1988). Most oviposition, however, occurs west of the highway and much of the foraging occurs to the east (P. Hammond, personal communication, June 12, 2009). Behaviors that could occur on the road, such as flying, interacting, nectaring, or basking, also were much more frequent in the meadow. These data suggest OSBs are not drawn to the road for basking or shelter.

Initially it was thought that the road-cut areas were serving as shelter for OSBs when high winds persist and that butterflies were essentially loitering in the road. If this were the case, removing the berms on the ocean-side would theoretically eliminate the dead air that was allowing butterflies to linger effortlessly in the road since the primary wind direction is from the northwest (Appendix 7, Weather Underground 2009).

Although there was no difference in the mean wind speed and temperature between the meadow and road, there was a significant difference in the road-cut subplots and those to the immediate north and south. The road-cut subplots had a lower mean wind speed and higher mean temperature than the surrounding subplots; however this did not translate into more OSBs in the road-cut area. One reason for this may be that the difference may not have been great enough for the butterflies detect. In addition, air funneled through the road-cut as if it were a tunnel independent of prevailing wind direction, albeit at lower wind speeds than the adjacent plots. This was true even when the wind direction was perpendicular to the road-cut. For example, on September 15th the average wind direction was 270^{o} (Weather Underground 2009) and on that same day plot 10 (which has an azimuth of roughly 0^{o}; Appendix 1) was surveyed within the road-cut and the range of wind directions recorded was from 351^{o} to 43^{o}. This continual movement of wind through the road-cut indicates that, although the mean wind speeds are different from the road-cut subplots to the adjoining subplots, this area does not necessarily represent a shelter from wind.

Adding Hedges – High Priority

OSBs were observed loitering immediately south of meadow area 4 (next to road plot 7) particularly on windy days (Figures 13 and 14). Although the flowering vegetation may have drawn them there, anecdotal observations suggested that OSBs seemed to congregate in this location on particularly windy days. This would indicate that OSBs may seek shelter from the wind and that creating sheltered areas within or along the meadow may be a suitable solution to keep OSBs in the meadow.

Although berms were not assessed as a barrier to butterflies here, other studies found that hedgerows can act as a barrier to butterfly movement (Severns 2008). This did not seem to be the case with OSBs at the study site. OSBs were observed flying over the road-cut or walled corridor (typically from the west-side meadow), over Highway 101, to the habitat on the other side of the road. They were also observed flying within the main road-cut corridor, generally moving in a south-to-north direction starting from plots 7 or 8, and sometimes they would fly up and out of the walled-corridor into the adjacent meadow. One possible explanation why OSBs did not respond to hedgerows or berms the same way as the Fender's blue butterfly (*Icaricia icarioides fenderi*) does may be due to the topography at the study site and the gradual transition from meadow to hedge area.

Severns' (2008) findings that hedgerows are a barrier to butterflies may have been a function of the abrupt transition in height from ground to hedgerow. If there was no other vegetation acting to guide butterflies up towards the top of the hedges and the angle where the hedgerows meet the ground is close to 90^{o} butterflies may be more likely to perceive this as a barrier. In contrast, at the Rock Creek-Big Creek site the road-cut/salal hedge from the meadow-side is more transitional and less abrupt. If this observation is accurate, then it would be expected that the road-cut may be more of a barrier for OSBs when they are attempting to exit the road than when they are entering it.

Last, the removal of berms seems unnecessary because OSBs do not appear to be loitering in the road-cut area. However, the addition of a berm or hedge in the meadows may be practical when implementing as shelter. In this case, it still may not be necessary to remove existing berms but rather plant hedges as the potential for an accidental "take" of OSBs during construction or removal of a berm still exists. OSBs may be in some form of the larval or pupae phase nearly year round at the Rock Creek – Big Creek site. This mitigation option may in fact negate the purpose of its own efforts if not implemented with caution as there would be impacts to larvae. Hedges would be less destructive to the critical habitat at the study site because plantings would theoretically take up less space and disturb less earth where larvae reside. Since the dominant winds at the study site are from the northwest (Appendix 7) placement of hedges on the western boundary of the west-side meadow may be the most suitable location to create safe wind sheltered areas.

Management Suggestions for Earthen Berms

1) Do not use the addition or removal of earthen berms to manipulate wind in the road unless future research suggests OSBs start congregating in the road cut area;

2) Future research related to the road-cut area should include recording weather data using fixed instruments in both the road and meadow. At a minimum weather meters should be placed in the road (within the road-cut area and outside the road-cut area) and in the meadow (adjacent to the suggested placement locations in the road).

3) Use hedgerows to create sheltered locations within the west-side meadows particularly in meadow area 4 where the highest density of OSBs were detected;

Potential Risks Of Mitigation Suggestions

An in depth analysis on the potential negative impacts from mitigation measures is difficult when there are multiple unknowns. This fact makes monitoring necessary and adaptive management extremely valuable. Evaluation from the USFWS Endangered Species Biologist actively working to restore OSB populations indicated no major risks of mortality or negative effects are expected to be sustained by OSBs from the outlined management suggestions and the management may have a positive effect on OSBs in the long term, assuming monitoring is employed to assess project implementation and outcomes (A. Walker, unpublished data).

7.0 Conclusion

The Oregon Silverspot Butterfly is a threatened species that resides in four locations along the Oregon coast, including Rock Creek – Big Creek. Highway 101 bisects the OSB habitat at this site and poses the threat of vehicle collision when OSBs attempt to cross the road. One vehicle-butterfly collision was documented during this study in the month of August and resulted in the death of a female OSB. Four mitigation options are being considered to reduce vehicle-caused mortality to OSBs at this location. Although determining which mitigation measures should be pursued to minimize the impact of roads on the surrounding animal community is not always straight forward. We evaluated potential management techniques to determine which should be pursued further by gathering information on the behavioral ecology of our target organism. We found using ecological observations with mitigation options in mind an effective technique for prioritizing management options and identifying what related future research is most needed. Approximately ¼ of the amount OSBs observed in the meadow plots were observed in the road plots indicating that the road was not preferred habitat as was suspected.

Vegetation manipulation was designated as the highest priority among the mitigation options, as it appears to be an effective and relatively inexpensive option that will reduce OSB presence in the road and presumably reduce vehicle-caused mortality. Barrier installation was chosen as the second priority, as it also appears to be an effective mitigation option but with an expected higher cost. The flashing speed reduction sign was set as a moderate priority because it may be expensive and intolerable to motorists, and the actual effectiveness is difficult to quantify without understanding how butterflies respond to reduced vehicle speeds. The removal of earthen berms in the road cut area was given a low priority as it appears unnecessary to manipulate wind flow in the road-cut area as no “sheltering” effect was detected. However, the addition of hedges in the meadow was made a high priority, as these areas may serve as shelter within the meadow area.

Future Research

Future research with the OSB related to road ecology includes performing a mortality study to determine if reducing vehicle speed decreases vehicle-caused mortality to butterflies or other flying insects in road corridors during the spring of 2010. Also**,** creating a traffic flow model at the Rock Creek – Big Creek site should be performed to better understand probability of mortality at different traffic volumes and to better understand the relationship between speed and traffic volume. In creating the previously listed task data must be obtained on distributed traffic volume by time of day and time of year so to overlap with when OSBs are active. Next, research is planned to test the effectiveness of different barrier types and their interchangeable extensions (along Highway 101 at Rock Creek-Big Creek) to: 1) keep butterflies out of the road and 2) force them to fly higher when in the road corridor. Last, marking or tagging of adult captive-reared OSBs released at sites should be preformed since this is not currently being done and it would allow observers the ability to differentiate between the augmented and wild populations of OSBs. Since OSBs are not marked there is no way to determine if the recent increase in population index can be attributed to the captive-rearing program. Bee tags or another technique devised by Severns using a felt tipped pen can be used to identify groups and individuals (Paul Severns, personal communication, 2009).

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10.0 Appendices

Appendix 1 – Rock Creek – Big Creek Site Maps

Overview Map

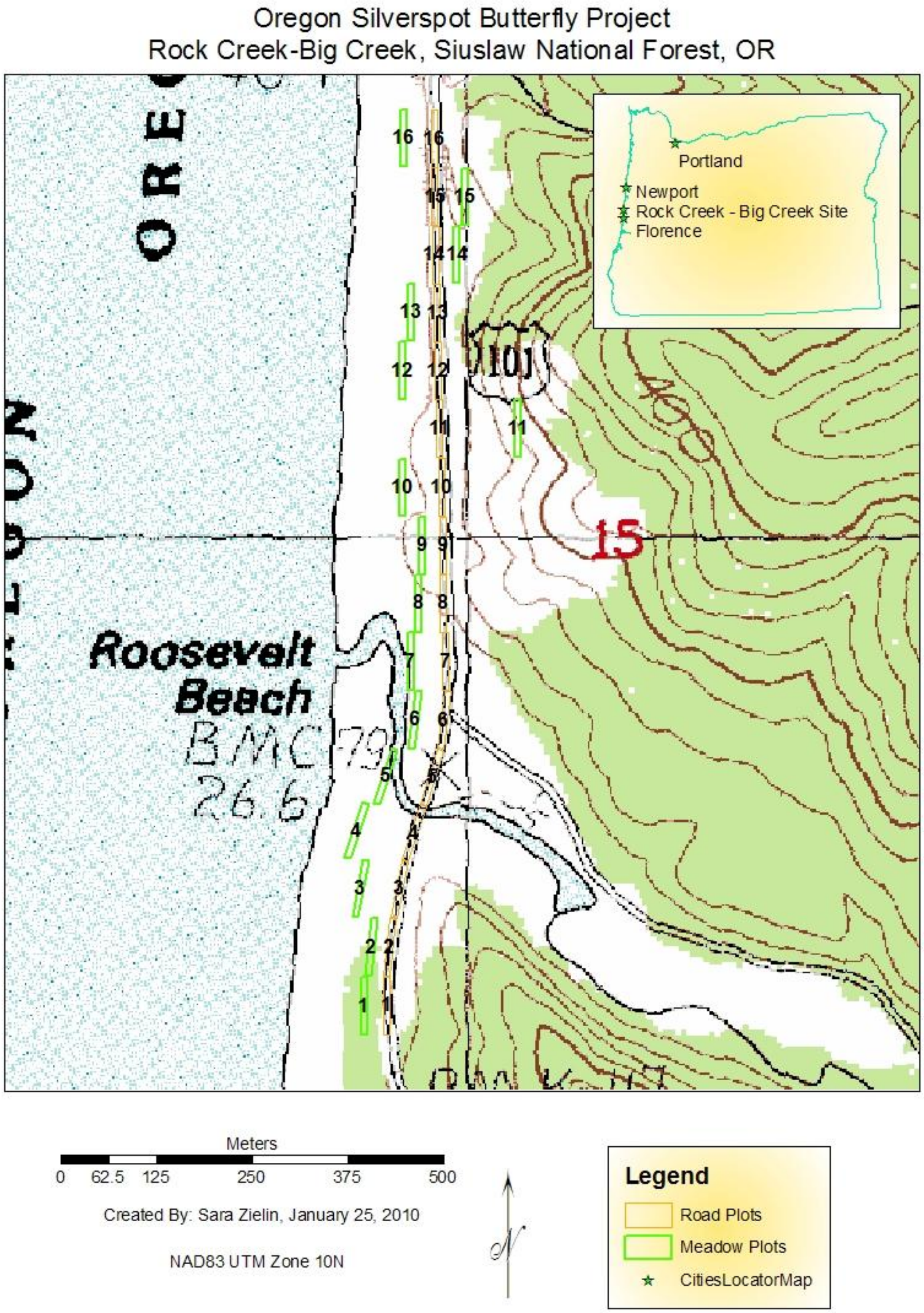
Meadow and Road Plots 1-4

Meadow and Road Plots 5 - 8

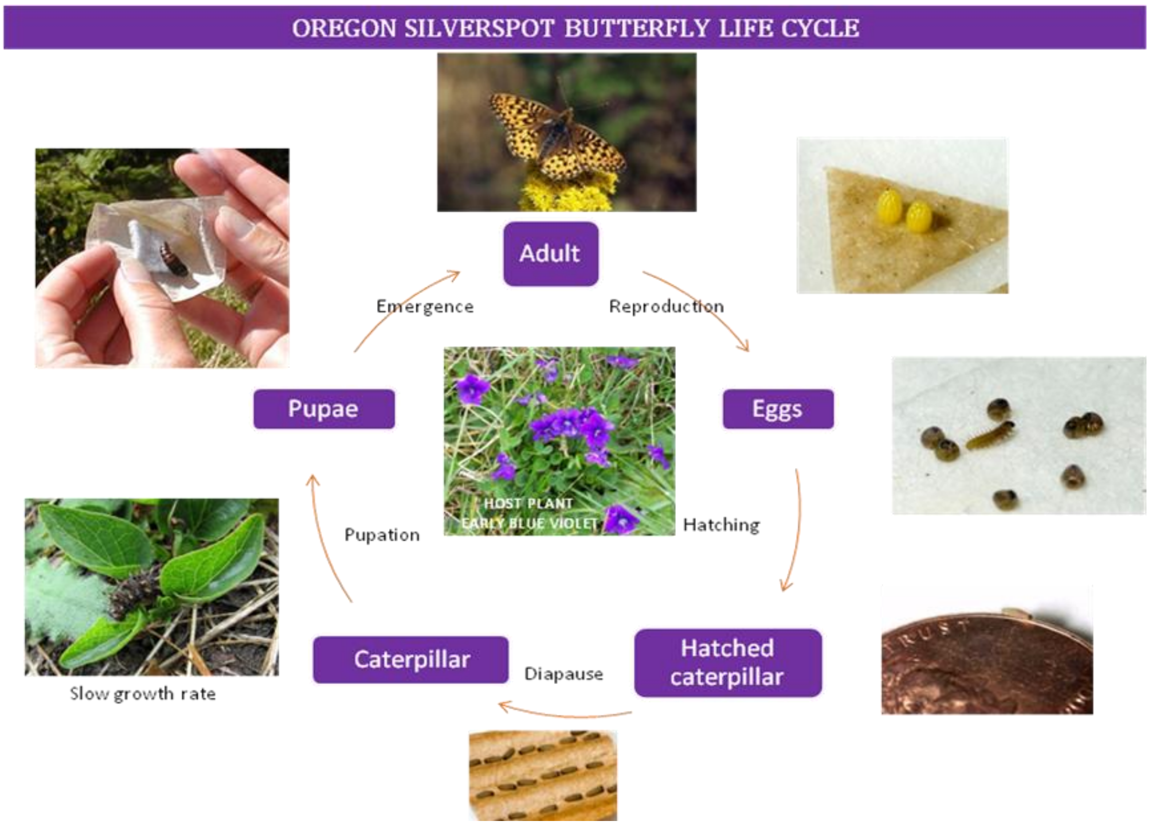
Meadow and Road Plots 9-12

Meadow and Road Plots 13-16

Overview DRG Map



Appendix 2 – OSB Lifecycle (Walker 2010)

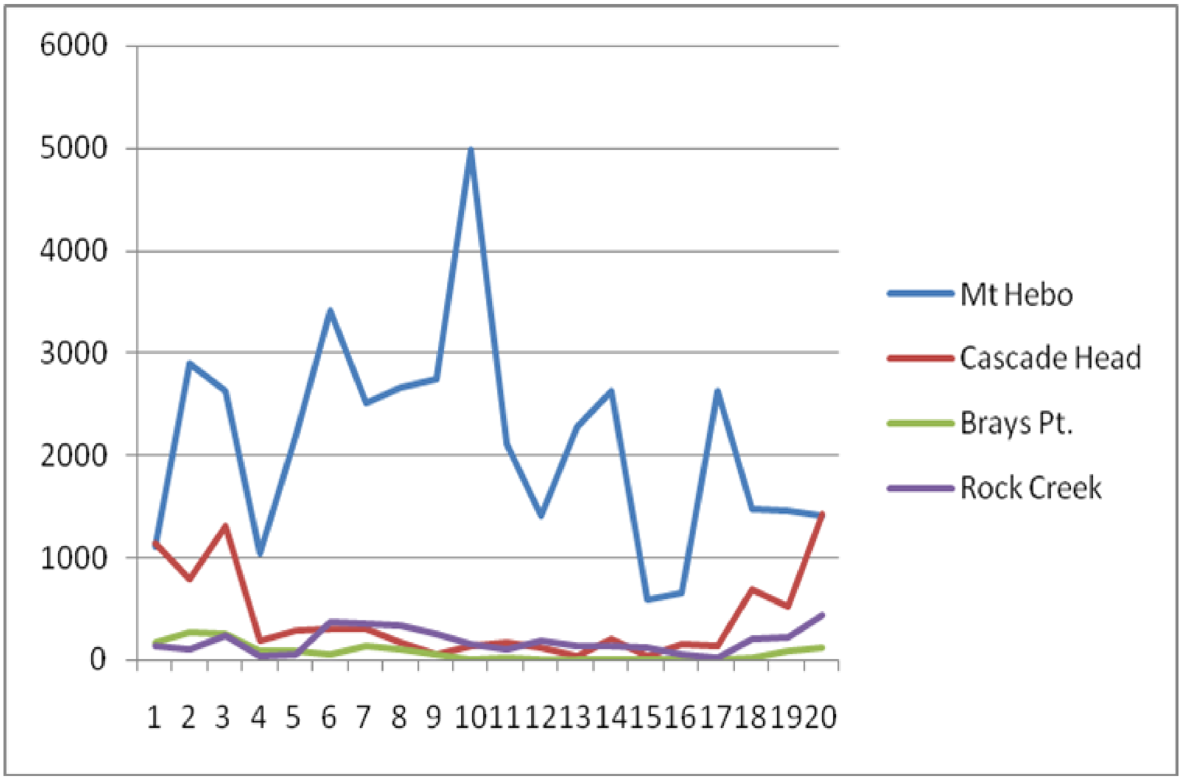


Appendix 3 – Oregon OSB Index Count 1990 to 2009

OSB Index Count Table (Walker 2010)

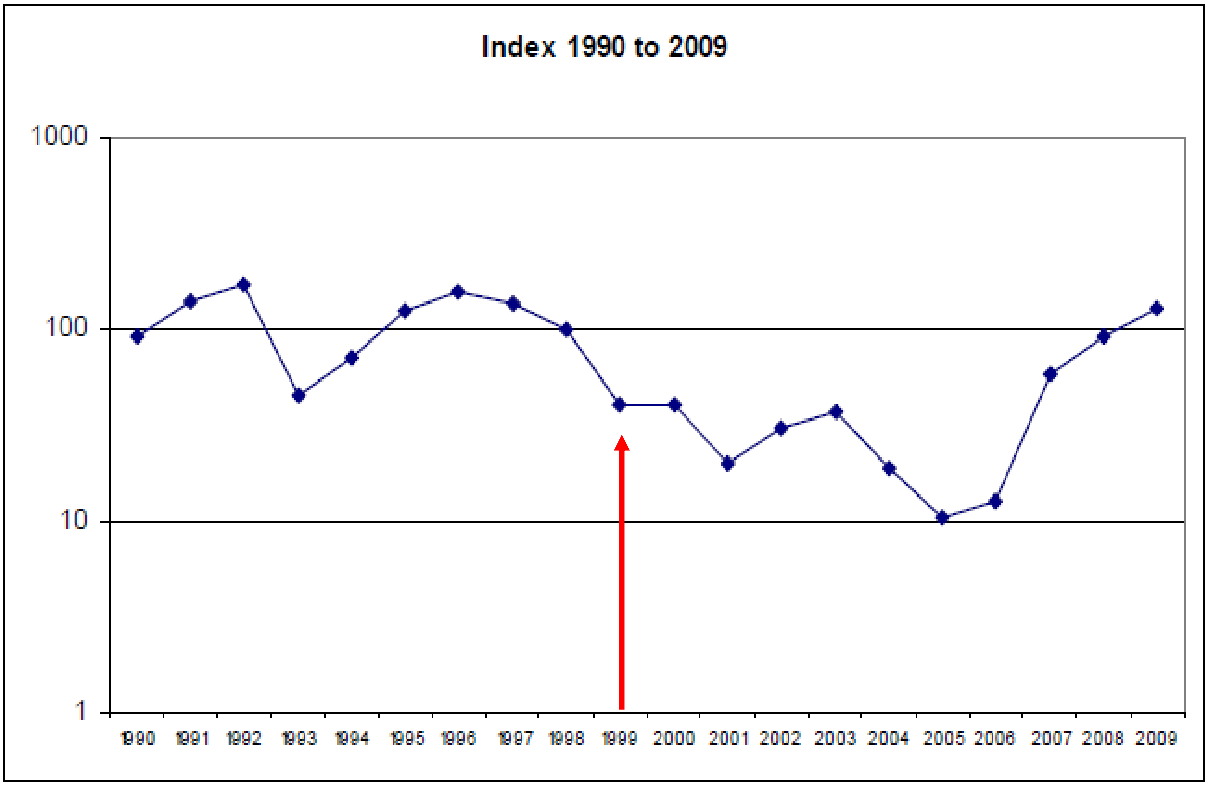
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Mt. Hebo	1100	2888	2628	1041	2200	3413	2507	2664	2743	4983	2111	1402	2272	2625	588	657	2624	1473	1452	1411
Cascade Head	1138	790	1295	184	284	302	302	164	57	132	160	118	34	206	36	147	130	686	521	1420
Brays Point	169	280	265	81	81	53	146	101	46	2	9	0	2	3	2	0	0	21	82	124
Rock Creek	142	113	242	35	65	374	356	332	257	149	108	192	139	136	131	55	25	202	219	437
Totals	2549	4071	4430	1341	2630	4142	3311	3261	3103	5266	2388	1712	2447	2971	757	859	2779	2803	2274	3392

OSB Index Count Graph (Walker 2010)

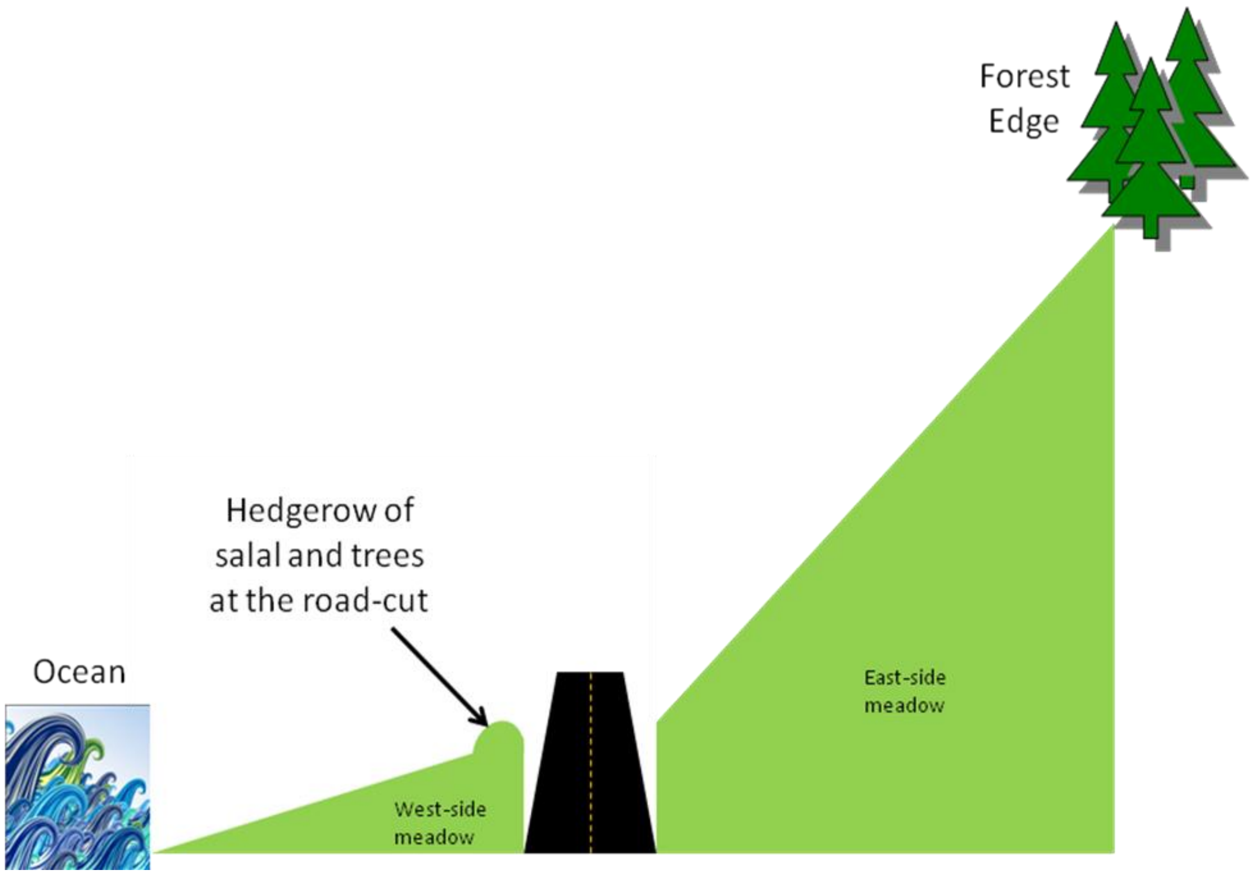


*Note that the y-axis is the number OSBs and the x-axis is year (beginning with year one of data collection through year 20 of data collection.

OSB Composite Index from 1990-2009 (Combining Rock Creek, Bray Point and Mt. Hebo plotted on a logarithmic scale) (Patterson 2009 and adapted by Sara Zielin). Note that the red arrow indicates the beginning of captive-reared OSB release.



Appendix 4 – Meadow Slope Diagram



Appendix 5 – Survey Datasheets

Instantaneous Scan Survey Page 1

Obs:		Date:					F=Flying			B=Basking			N=Nectaring
Plot:		Start Time:					P=Perching			O=Ovipositing			I=Interaction
		End Time:					M=Mating			FP=Patrolling			FN=Non-Patrolling
Weather:				Notes:									
Scan	Segment	Weather Time	N	P	B	F	FP	FN	M	O	I	Total#	Notes
1	1												
1	2												
1	3												
1	4												
1	5												
2	1												
2	2												
2	3												
2	4												
2	5												
3	1												
3	2												
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4	3												
4	4												
4	5												
5	1												
5	2												
5	3												
5	4												
5	5												
6	1												
6	2												
6	3												
6	4												
6	5												

Instantaneous Scan Survey Page 2

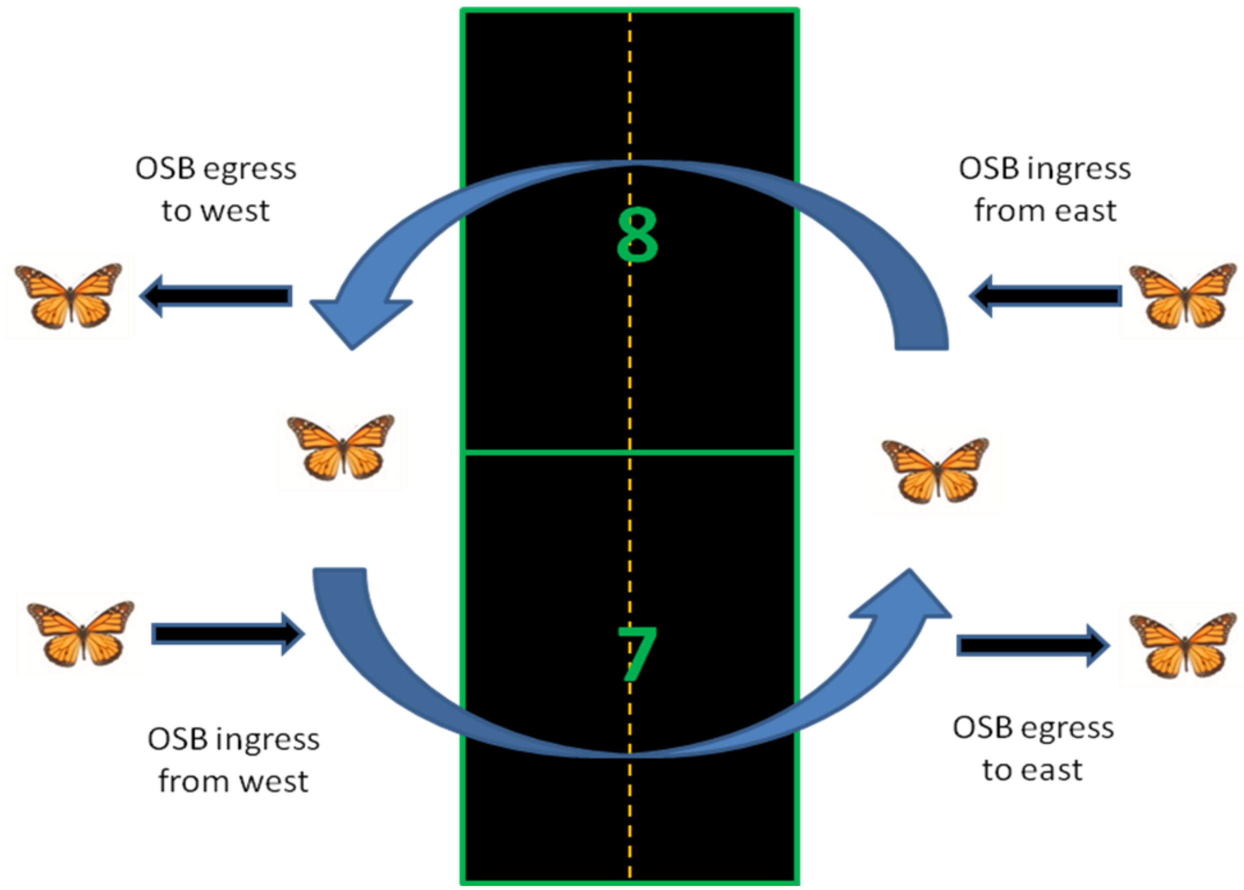
Scan	Segment	Weather Time	N	P	B	F	FP	FN	M	O	I	Total#	Notes
7	1												
7	2												
7	3												
7	4												
7	5												
8	1												
8	2												
8	3												
8	4												
8	5												
9	1												
9	2												
9	3												
9	4												
9	5												
10	1												
10	2												
10	3												
10	4												
10	5												

Rock Creek-Big Creek Oregon Silverspot Butterfly All Occurrence Road Surveys

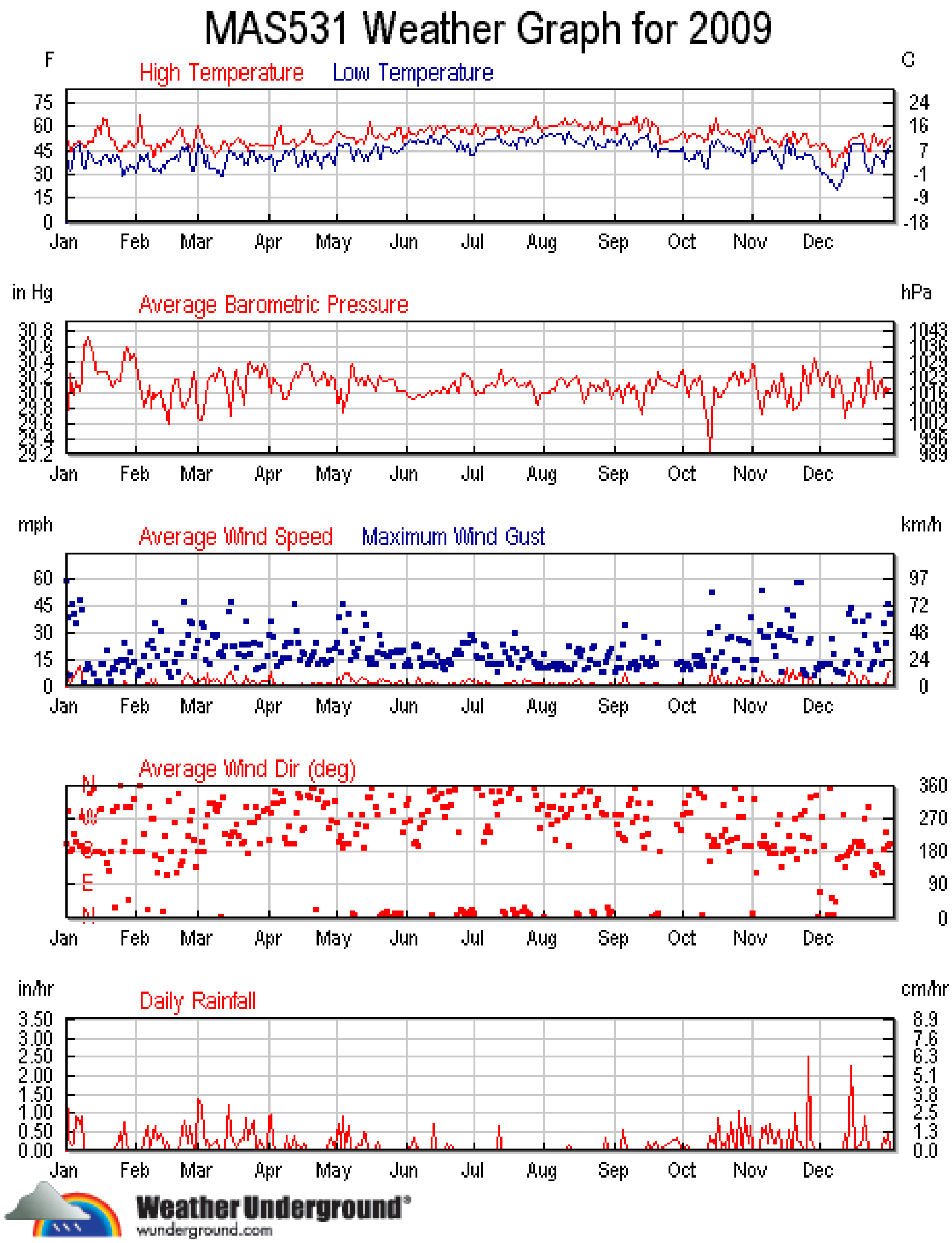
Surveyor: ________________ Date: ________________ Plot ID (1-16): ________________
Time Start: _________ Temp: _________ Wind Speed: _____________ Humidity: _____________ Weather: ______________
Time End: _________ Temp: _________ Wind Speed: _____________ Humidity: _____________ Weather: ______________

Observation	Sex M/F/U	Height in road (m)	Duration (s)	Rate (m/sec)	Vehicle in Road (Y/N)	Vehicle Collision (Y/N)	Temp (C)	Wind Speed (m/s)	Humidity (%)	Cloud Cover (%)	Time	Notes
1												
2												
3												
4												
5												
6												
7												

Appendix 6 – Circular OSB Movement in Plots 7 and 8



Appendix 7 – Weather Data for Yachats, OR 2009 (Weather Underground 2009)



Appendix 8 – Density Comparison of OSBs by Transects at Rock Creek - Big Creek (Patterson 2009)

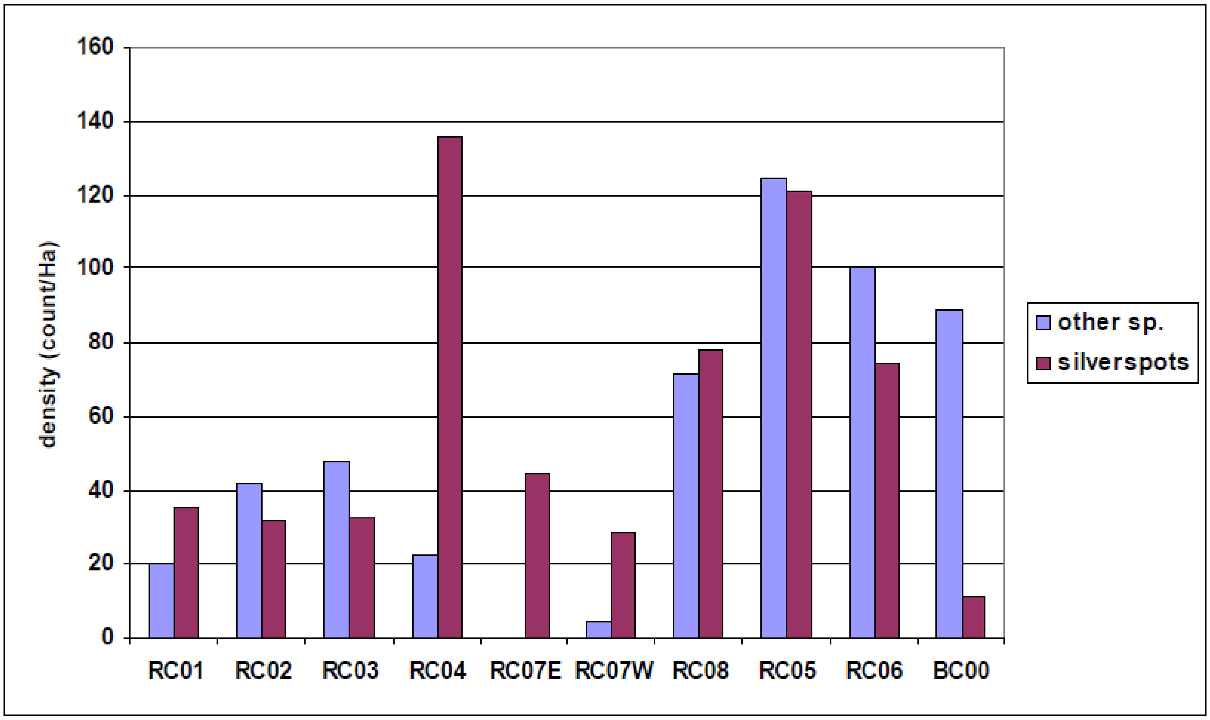


Figure 12: Density comparison of Oregon Silverspots to the combined density of all other species for transects at Rock Creek and Big Creek.

Appendix 9 – OSB Census Data Stacked by Transect and Date (Patterson 2009)

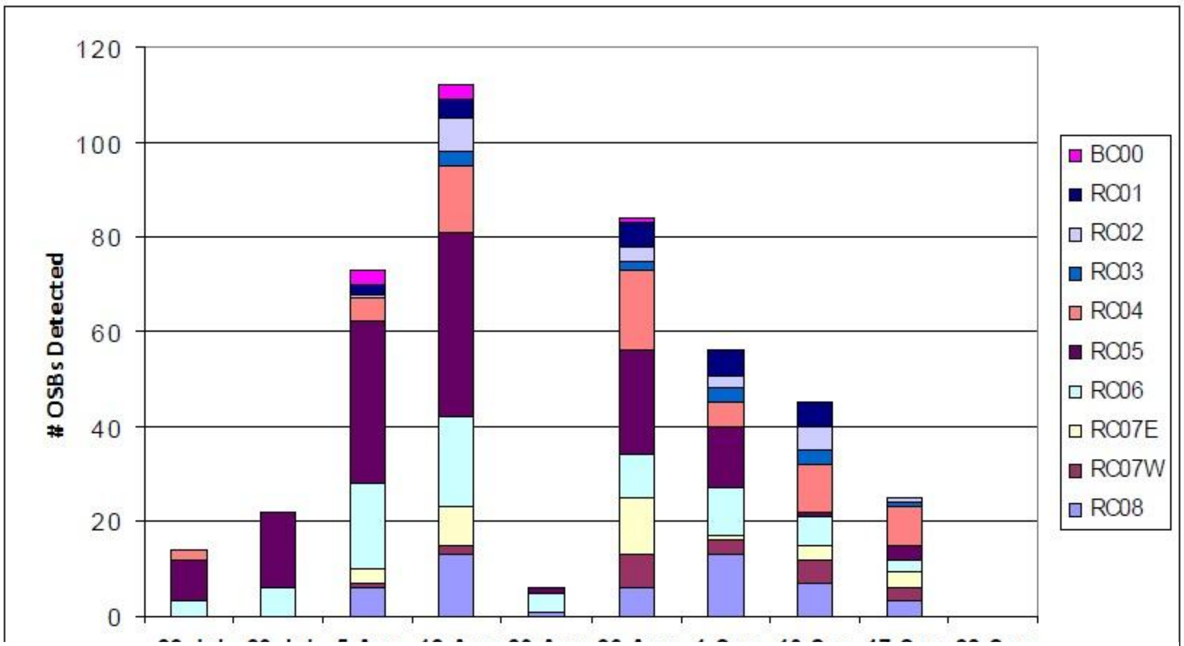


Figure 1: Rock Creek and Big Creek census data stacked by transect for the entire 2009 flight season. Note that transects RC05 and RC08 are in areas where captive-bred OSBs have been released.