Validation of the Oregon slender salamander habitat suitability model and map for the west slope of the Oregon Cascade Range

Nobuya Suzuki
1-1060 Southgate Street, Victoria, BC V8B 2Z2 Canada

Deanna H. Olson
Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331

July 26, 2012

ABSTRACT

Conservation of rare species with small geographic ranges, such as the Oregon slender salamander (*Batrachoseps wrighti*), is a concern for conservationists and managers who face challenges of balancing multiple-use objectives of stakeholders in rapidly changing environment. To accommodate the conservation effort for Oregon slender salamanders in the west slope of the Oregon Cascade Range on the federal land, we developed a landscape habitat suitability model using a generalized additive model (GAM) approach and projected four habitat suitability classes (low, moderately low, moderate, and high) onto a map. Herein, we assessed the applicability of the habitat suitability map and the performance of the GAM-based habitat suitability model using 2009 field validation data. The field validation data assessed salamander presence using a standard survey protocol at a stratified random sample of 84 sites, using the strata of the four habitat suitability classes. A large proportion (76%) of Oregon slender salamander detection sites fell within either the high or moderate habitat suitability class. A fair amount (37%) of non-detection sites were also in these 2 upper classes of habitat suitability probably because either not all suitable habitats were occupied or it is inherently difficult to detect a rare species, such as the Oregon slender salamander, even if it is present. Zero-inflated negative binomial regression analyses along with 95% confidence intervals verified that significantly high non-detection rates of Oregon slender salamanders were associated with the low habitat suitability class, whereas significantly high detection rates were associated with the moderate and high habitat suitability classes. On average, the GAM model correctly classified 67% (Kappa = 32%) of field-validation data. At the cutoff value of 0.45, the model achieved the best balance between sensitivity (67%) and specificity (67%). The receiver operating characteristics (ROV) curve suggested a moderate predictive power for the GAM model with an area-under-curve (AUC) value of 0.73. It is highly likely that critical habitat features that are typically measured on the ground and difficult to quantify across landscapes in GIS layers, such as abundance of down wood, would further affect the occurrence and spatial distribution of the Oregon slender salamander beyond which GIS-based habitat models and maps can predict. Managers and conservationists can use the current GIS-based landscape model and map to first define initial geographic area of potential conservation concern for Oregon slender salamanders. After the initial selection of potential conservation areas, locally available site-specific biological/ecological information or GIS insensitive-habitat information (e.g., down wood occurrence) could be carefully assessed by additional field work to further prioritize areas of conservation concerns.

INTRODUCTION

Previously, a landscape habitat suitability model for Oregon slender salamanders (*Batrachoseps wrighti*) was developed for the west slope of the Oregon Cascade Range (Suzuki 2008). Using a Generalized Additive Model (GAM) based on the relationship between location information of known Oregon slender salamander sites and a suite of habitat attributes that were available in Geographic Information Service (GIS) coverages (Table 1), the best habitat model emerged with inclusion of four landscape-scale habitat elements: precipitation, minimum daily temperature, forest stand height, and basal area of Pacific silver fir (Table 1). Using this model, habitat suitability of Oregon slender salamanders was mapped for the west slope of the Oregon Cascade Range on federal lands to aid the conservation of this rare, narrowly endemic species (Figure 1). After the habitat suitability map was developed, federal agencies conducted field surveys of the Oregon slender salamander in 2009 to validate the applicability of the habitat suitability map (Appendix 1, 2, and 3). Surveys were conducted using a stratified random site selection, in order to have inference to the survey area on the west side of the Cascade Range crest. Herein, we use the field validation data (Appendix 3) to quantitatively assess the performance of the Oregon slender salamander habitat suitability model, to validate the applicability of habitat suitability map (Figure 1).

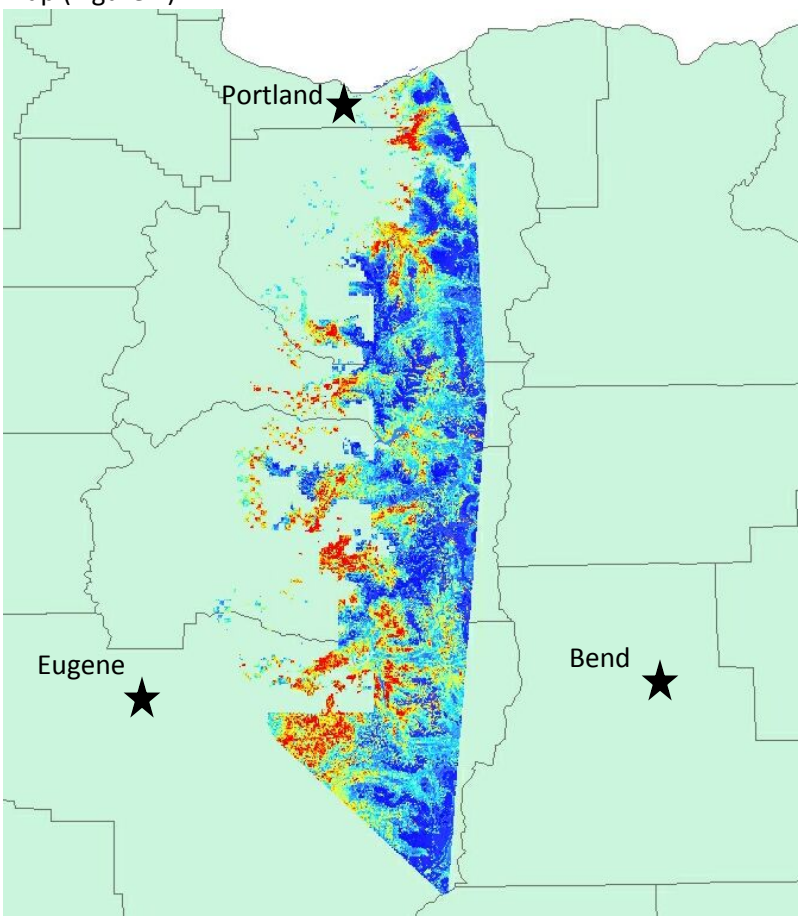


Figure 1. Habitat suitability map for Oregon slender salamanders on federal lands in the western Cascade Range ecoregion of Oregon based on the best landscape habitat suitability model (Suzuki 2008) with the GIS-attributes: minimum daily temperature, annual precipitation, forest stand height, and Pacific silver fir basal area. Highly suitable habitats are in red and unsuitable habitats are in blue. Gray lines show county boundaries. Reprinted from Figure A1.4a, Suzuki 2008).

Table 1. Landscape attributes examined for development of the Oregon slender salamander habitat suitability model (Suzuki 2008). Yellow = components of the best model in predicting salamander occurrences. From Suzuki 2008; original caption: Effects of habitat attributes on presence of Oregon slender salamanders in the western Oregon Cascade Ecoregion based on comparisons between 211 known salamander sites (Salamander) and 211 random sites (Random) in Wilcoxon rank-sum tests and univariate logistic Generalized Additive Models (GAM). Variables in bold letters indicate consistently low P-values (P<0.05) for both Wilcoxon tests (P-WRS) and GAM (P-GAM). The ranking (RK) of Akaike Information Criterion values (AIC) from GAM provides evidence of support for each variable relative to other variables (lower the RK value, higher the level of support).

	Salamander		Random					
Variable	Mean	SE	Mean	SE	*P*-WRS	*P*-GAM	AIC	RK
Climate								
Min Temp (°C)	**3.45**	**0.09**	**2.92**	**0.10**	**<.0001**	**<0.0001**	**563.13**	**2**
Max Temp (°C)	**14.22**	**0.10**	**13.60**	**0.11**	**<.0001**	**<0.0001**	**563.75**	**3**
Precipitation (mm)	**2097.44**	**23.60**	**2186.74**	**27.21**	**0.0084**	**0.0001**	**571.76**	**6**
Topography								
Latitude-Longitude (UTM)	N/A	N/A	N/A	N/A	N/A	0.2911	593.84	33
Elevation (m)	**733.25**	**20.23**	**871.78**	**22.87**	**<.0001**	**<0.0001**	**567.60**	**4**
Aspect (degree)	195.47	7.15	175.53	7.12	0.046	0.1079	587.43	22
SW aspect (0.0-1.0)	0.54	0.02	0.51	0.03	0.3199	0.0214	583.51	16
E or W aspect (0.0-1.0)	0.63	0.02	0.60	0.02	0.3582	0.6317	592.44	32
South aspect (0.0-1.0)	0.50	0.02	0.51	0.03	0.5831	0.3909	590.90	30
Hill Shade	222.06	1.96	222.61	1.98	0.6669	0.2829	589.98	25
Slope (%)	31.94	1.54	33.67	1.52	0.3001	0.3826	590.84	29
Land curvature	0.00	0.06	0.09	0.06	0.0557	0.3495	590.57	27
Flow accumulation	37.70	12.66	62.97	36.17	0.2828	0.0239	583.77	17
Stand Structure								
Tree canopy (%)	73.73	0.55	72.30	0.82	0.7052	0.0034	579.26	9
Conifer canopy (%)	69.93	0.70	69.31	0.94	0.6286	0.0046	579.95	11
Hardwood canopy (%)	**9.83**	**0.68**	**7.86**	**0.64**	**0.0044**	**0.0297**	**584.28**	**19**
Small down wood (m3/ha)	213.89	6.15	213.60	7.23	0.9803	0.3437	590.68	28
Medium down wood (m3/ha)	196.21	6.04	195.51	7.13	0.9491	0.2873	590.02	26
Large down wood (m3/ha)	138.24	5.32	136.48	6.15	0.7135	0.5021	591.86	31
Tree diameter (cm)	**47.79**	**0.93**	**43.26**	**1.06**	**0.0035**	**0.0013**	**577.12**	**7**
Conifer diameter (cm)	**49.44**	**0.93**	**44.52**	**1.05**	**0.0012**	**0.0015**	**577.46**	**8**
Hardwood diameter (cm)	**9.20**	**0.60**	**6.79**	**0.53**	**0.0027**	**0.0173**	**583.02**	**15**
Stand height (m)	**26.89**	**0.45**	**24.12**	**0.52**	**0.0003**	**0.0001**	**571.57**	**5**
Stand age (yr)	**84.17**	**3.25**	**73.91**	**2.67**	**0.0294**	**0.0262**	**584.01**	**18**
Tree basal area (m2/ha)	44.21	0.85	41.45	1.02	0.076	0.0055	580.41	12
Conifer basal area (m2/ha)	41.97	0.91	39.82	1.07	0.2087	0.0133	582.40	13
Hardwood basal area (m2/ha)	**2.24**	**0.18**	**1.62**	**0.15**	**0.0012**	**0.0151**	**582.70**	**14**
Tree Species Basal Area								
Douglas-fir (m2/ha)	27.30	0.92	24.98	1.01	0.0434	0.0606	586.00	20
Western hemlock (m2/ha)	7.32	0.48	8.52	0.56	0.0912	0.1182	587.62	23
Western redcedar (m2/ha)	2.57	0.31	2.45	0.26	0.4848	0.0947	589.02	24
Pacific silver fir (m2/ha)	**1.27**	**0.40**	**2.77**	**0.45**	**<.0001**	**<0.0001**	**561.11**	**1**
Red alder (m2/ha)	**1.06**	**0.15**	**1.01**	**0.17**	**0.0435**	**0.0389**	**586.31**	**21**
Big-leaf maple (m2/ha)	**1.06**	**0.19**	**0.56**	**0.08**	**0.0051**	**0.0031**	**579.33**	**10**

METHODS

Analyses of validation data

First, we examined the performance of the habitat suitability map to predict occurrence of the Oregon slender salamander. The map was comprised of pixels coded with one of the following four habitat suitability classes: low, moderately low, moderate, and high. We used odds of salamander detection predicted from the Generalized Additive Model (GAM) of Oregon slender salamander habitat associations for classifying a habitat suitability class of each pixel. By comparing odds of each pixel to the median, 25 percentile, and 75 percentile values of odds among all pixels in the map, we classified habitat suitability as: 1) low when pixel odds < 25 percentile odds; 2) moderately low when 25 percentile odds value $\leq$ pixel odds < median odds; 3) moderate when median odds $\leq$ pixel odds < 75 percentile odds; and 4) high when pixel odds $\geq$ 75 percentile odds.

Selection of field validation sites was based on stratified random sampling. Using random selection of longitudes and latitudes, we attempted to establish 20 validation sites in each of four habitat suitability classes mapped across the landscape (Appendix 1 and 2). We assessed detection/non-detection of salamanders as well as number of salamanders detected per sampled site: i) among the four habitat suitability classes; and ii) between habitat suitability below median (low and moderately low combined) and above median (moderate and high combined) classes. We used descriptive statistics, t-tests, and Wilcoxon rank-sum tests to determine the difference in detection/non-detection and number of detections between classes above and below median habitat suitability. For the analysis of four habitat suitability classes for detection/non-detection and number of salamander detections, we used descriptive statistics, zero-inflated negative binomial regression analysis, and zero-inflated Poisson regression analyses. These zero-inflated regression models can assess excess zero (non-detection) as well as number of salamander detections across four habitat categories to assess the differences across four habitat classes. Zero-inflated regression models generally show better performance over traditional Poisson regression models, especially when datasets contain a large number of zeros (salamander non-detections).

Second, using the new field validation data, we examined the quantitative performance of the Generalized Additive Model which we used to produce the original habitat suitability map. We used the validation data and ran the GAM model to produce predicted probabilities from the validation data. Validation sites were classified into detection sites and non-detection sites based on the predicted probabilities and cutoff values, from which an above-cutoff value would be classified as detection and a below-cutoff value would be non-detection. We tested four cutoff probability values (0.5, 0.45, 0.4, and 0.39) to compare model performance at different cutoff values. The most typical cutoff value was 0.5 by default; however, lowering the cutoff values to test two additional values (0.45 and 0.4) is realistic because of the known low detection rate of Oregon slender salamanders. Additionally, we included the cutoff value of 0.39, which is based on the ratio of number of detected sites to total number of sites surveyed (33/84) for the validation data. We calculated sensitivity, specificity, total correct classification rate, and kappa statistics. Sensitivity is the proportion of number of agreements between the predicted salamander detection sites by the model and confirmed detection sites in the field, over the total number of sites where salamanders were detected. Specificity is the proportion of number of agreements for non-detection sites between the model and field confirmation, over the total number of non-detection sites. Total correct classification rate is the proportion of agreement between model prediction and field observation among the total number of sites. Kappa statistics is the measure of agreement between model prediction and field observation without considering the agreement based

on chance. Sensitivity, specificity, and total correct classification levels were plotted over a range of probability cutoff values to determine the best cutoff values for the model. We generated a receiver operating characteristics (ROV) curve to assess general performance of the GAM habitat model.

RESULTS

Validation Sampling Locations and Habitat Suitability Classes

Although it was initially planned to establish 20 validation sites in each of four habitat suitability classes, the number of validation sites per class was altered due to validation of site classes for this report. A few sites pre-selected in the high habitat suitability class were found to be actually in another class either due to management activities or lack of precision of GIS-based landscape projections of habitat elements. Consequently, surveys were conducted for salamanders at 17 sites in the high suitability class, 23 sites in the moderate suitability class, 23 sites in the moderately low suitability class, and 21 sites in the low suitability class.

Comparisons of Detections vs. Non-Detections across Habitat Suitability Classes

Oregon slender salamanders were detected in 33 of 84 (39%) validation sites surveyed. A large number of detections (25 of 33, 76%) occurred in sites classified as moderately suitable or highly suitable habitat classes, which comprise above-median habitat suitability. Number of detection sites as well as proportion of detected sites closely corresponded to four habitat suitability classes; these values were highest in the high habitat suitability class, became gradually lower in successive classes, and reached the lowest in low habitat suitability class (Figure 2 and Table 2). Number and proportion of non-detection sites followed the opposite trend; the highest proportions and numbers of non-detection sites occurring at both low and moderately low habitat suitability classes, gradually became lower in successive classes, and reached the lowest in high habitat suitability class. There was a fair amount of non-detection in moderately suitable and highly suitable habitat classes combined (37%, 19 of 51 non-detection sites).

Both the zero-inflated negative binomial regression model and the zero-inflated Poisson regression model produced very similar results. There was no difference in performance between these two models based on the Likelihood Ratio Test ($P = 0.095$) and the Vuong Test ($P = 0.164$). We present results from the zero-inflated negative binomial regression model, as this model produced a slightly lower AICc value (230.694) than the Poisson model (AICc = 230.967). However, interpretations were virtually identical between the two models.

A significantly large number of non-detections were associated with the low habitat suitability class, suggested by the positive coefficient of the low habitat suitability class in the zero-inflated part of the negative binomial regression (Table 3). In contrast, negative coefficients indicated that there were significantly higher detection rates of Oregon slender salamanders in moderate and high habitat-suitability classes, relative to low habitat-suitability classes. The observed proportion of non-detection sites closely matched predicted probability of non-detection from the zero-inflated negative binomial regression model for Low, Moderate, and High habitat-suitability classes (Figure 3). The model prediction did not correspond with the observed proportion for the Moderately Low habitat-suitability class, which is also reflected by the high p-value in the zero-inflated part of the model for this class.

Mean odds of not-detecting salamanders in the Low habitat-suitability class was approximately 11 to 1 (Table 4). Odds of non- detection in the High habitat-suitability class and in the Moderate habitat-suitability class were only 4% (96% decrease) and 7% (93% decrease, respectively) of the odds of non-detection in the Low habitat-suitability class (96% decrease in odds of non-detection). There was no difference in odds of non-detection between Moderately Low and Low habitat suitability classes. Odds of not-detecting a salamander in the Low habitat-suitability class against the three other habitat classes ranged from 14-26 times to 1. The odds of non-detection in the Moderately Low habitat suitability class were 1.8 times higher than those of the High habitat-suitability class (Table 5).

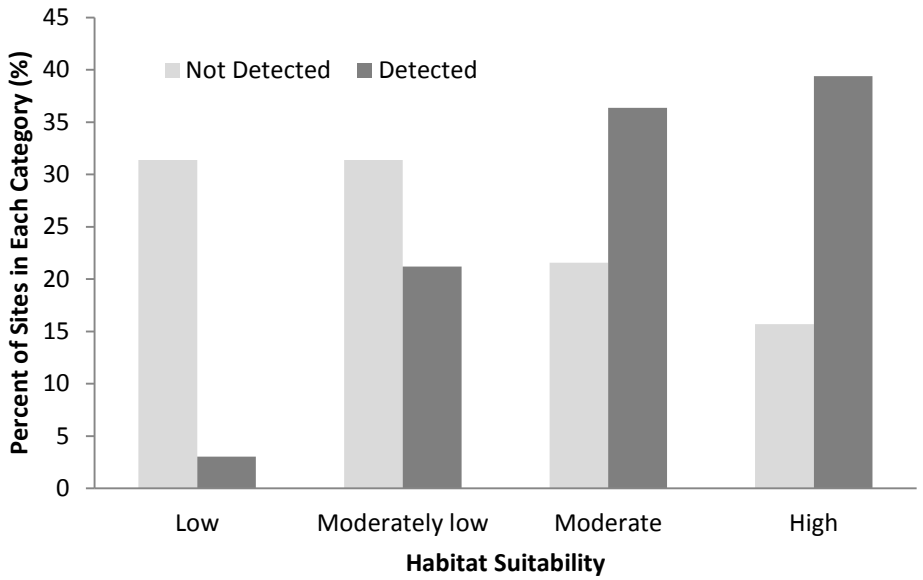


Figure 2. Difference in proportion of sites where Oregon slender salamanders were detected (n = 33) or not detected (n =51) among four habitat suitability classes.

Table 2. Opposite trends between frequencies and proportions of sites where Oregon slender salamanders were detected and not detected across four habitat suitability classes.

Habitat Suitability Class	Detected	Not Detected	Detected (%)	Not Detected (%)
High	13	8	39.39	15.69
Moderate	12	11	36.36	21.57
Moderately low	7	16	21.21	31.37
Low	1	16	3.03	31.37
Total	33	51	100.00	100.00

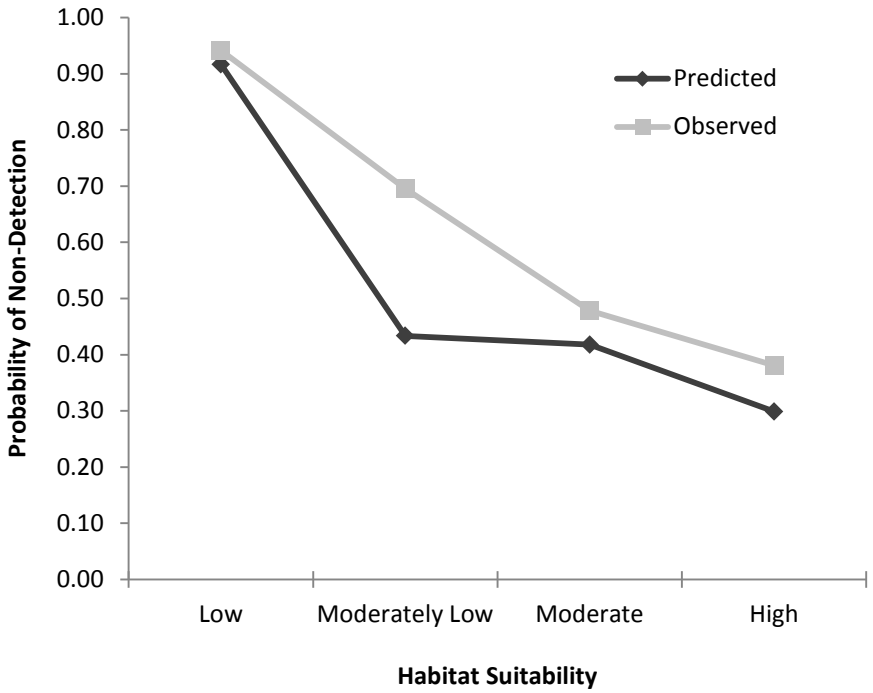


Figure 3. The predicted trend for probability of salamanders not being detected from the zero-inflated negative binomial regression model for sites in four habitat suitability classes compared with the observed trend based on field validation data, indicating the close correspondence for Low, Moderate, and High habitat-suitability classes. The Moderately Low habitat-suitability class does not show close correspondence.

Table 3. Associations between habitat suitability classes and number of salamander detections and probability of non-detection assessed from zero-inflated negative binomial regression with three dummy variables (n-1) of four habitat suitability classes. A negative coefficient (P<0.05) in the zero-inflated part of the Model refers to a higher likelihood of detecting at least one Oregon slender salamander at a site relative to that at a site of habitat suitability without a statistical significance. The count part of the model tests whether the number of detections is associated with any of the habitat suitability classes.

	Zero-Inflated Part (Non Detection)			Count Part (Number of Detections)		
Habitat Suitability	Coefficient	95%CI	P	Coefficient	95%CI	P
High	-3.25	-5.86 to -0.63	0.015*	0.68	-1.51-2.87	0.542
Moderate	-2.73	-5.24 to -0.21	0.033*	0.75	-1.44-2.95	0.502
Moderately Low	-2.66	-5.77-0.44	0.093	-0.51	-2.89-1.87	0.674
Low (Intercept)	2.40	0.06-4.73	0.044*	0.34	-1.81-2.50	0.756

Table 4. Incident ratio of not-detecting salamanders in high, moderate and moderately low habitat suitability categories relative to the low habitat-suitability category. Values < 1 indicate the decrease in detection failure by the factor of incident ratio relative to the low habitat suitability class.

Habitat Suitability	Incident Ratio	95%CI	P
High	0.04	0.00-0.53	0.015*
Moderate	0.07	0.01-0.81	0.033*
Moderately Low	0.07	0.00-1.56	0.093
Intercept (odds at Low Habitat Suitability)	10.97	1.06-113.22	0.044*

Table 5. Odds Ratio (odds of class in row/odds of class in column) showing odds of not detecting an Oregon slender salamander in one habitat suitability class over another. Odds ratio indicates the number of times field observers more likely fail to detect salamanders in the habitat suitability class from the row of the table. Odds ratio >1 indicates greater odds of fail-to-detect in the row habitat suitability class than the column habitat suitability class. Odds ratio <1 indicates odds of detection is greater in the column habitat class relative to the row habitat suitability class.

	Odds Ratio of Non-Detection (odds of row class/odds of column class)			
Habitat Suitability Classes	Low	Moderately Low	Moderate	High
Low	1	14.32	15.27	25.71
Moderately Low	0.07	1	1.07	1.79
Moderate	0.07	0.94	1	1.68
High	0.04	0.56	0.59	1
Odds of non-detection for each class in column	10.97	0.77	0.72	0.43

Comparison of Number of Salamanders among Habitat Classes

The number of salamanders detected was equally high in the moderate and high habitat suitability classes. These two habitat suitability classes recorded 86% of the total number of salamanders detected (81 of 94, Figure 4, Table 6). Mean number of salamanders detected was higher in moderate and high classes relative to the low habitat-suitability class, indicated by non-overlapping 95% confidence intervals (Figure 5, Table 7). There also was a probable separation of mean between the high and moderately low suitability classes. For these two classes the lower bound of high suitability and upper bound of moderately low suitability had exactly the same value (Table 7).

When the two classes above (High and Moderate) and two classes below (Moderately Low and Low) median habitat suitability were combined and compared, the mean number of salamanders detected per site was greater in moderate and high suitability classes combined than in moderately low and low

habitat suitability classes combined (Figure 6, Tables 8 and 9). The count part of the zero-inflated negative binomial regression model predicted that sites in above-median habitat suitability (moderate or high) would increase the expected number of salamanders detected by the factor of somewhere between 1.2 and 8.5 (Table 10), whereas the observed factor was 5.65 higher in the moderate and high suitability combined class relative to the number of detections in moderately low and low classes combined (1.13/0.2=5.65 on the average, Table 8), which was within the confidence limit.

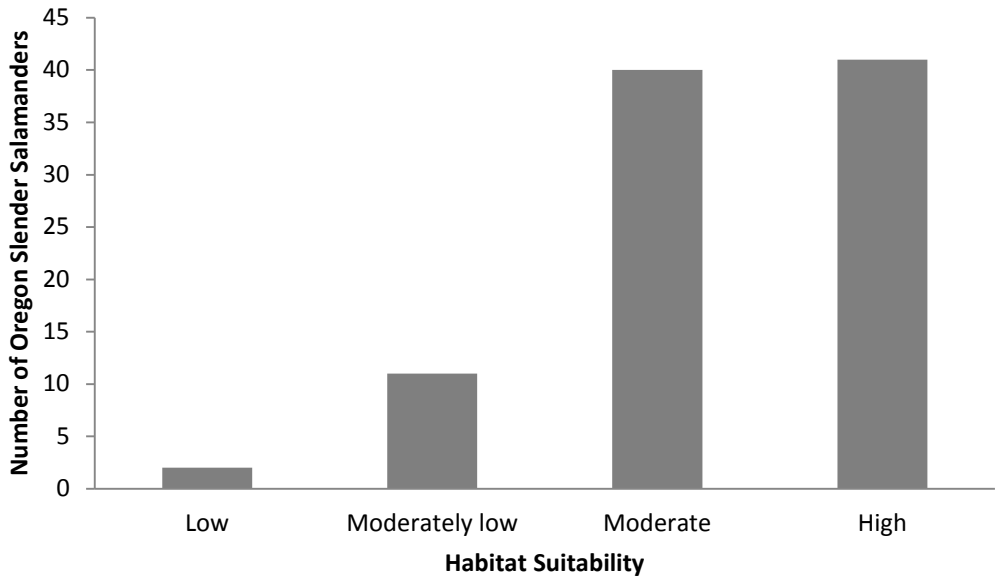


Figure 4. The increasing trend in frequencies of Oregon slender salamanders detected from low to high habitat suitability classis. Eighty one out of 94 salamanders (86%) were detected in moderate and high suitability classes combined.

Table 6. Number and percent of Oregon slender salamanders detected across four habitat suitability classes showing 86% of total salamanders detected (81 of 94) were from moderate and high habitat suitability classes combined.

Habitat Suitability Class	Number of Salamanders	Percent
High	41	43.62
Moderate	40	42.55
Moderately low	11	11.70
Low	2	2.13
Total	94	100.00

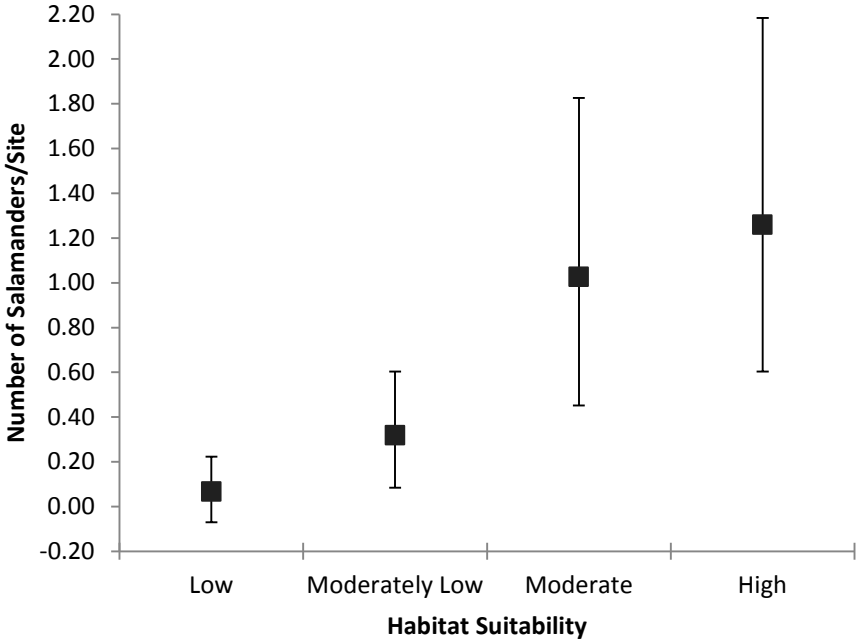


Figure 5. Ninety-five percent confidence intervals for mean number of salamanders/site showing clear separation of the low habitat suitability class compared to the moderate and high habitat suitability classes.

Table 7. Comparison of mean number of Oregon slender salamanders detected per site among four habitat suitability classes.

Habitat Suitability	Mean	95% CI
Low	0.07	-0.07 to 0.22
Moderately Low	0.32	0.08 to 0.60
Moderate	1.03	0.45 to 1.83
High	1.26	0.60 to 2.18

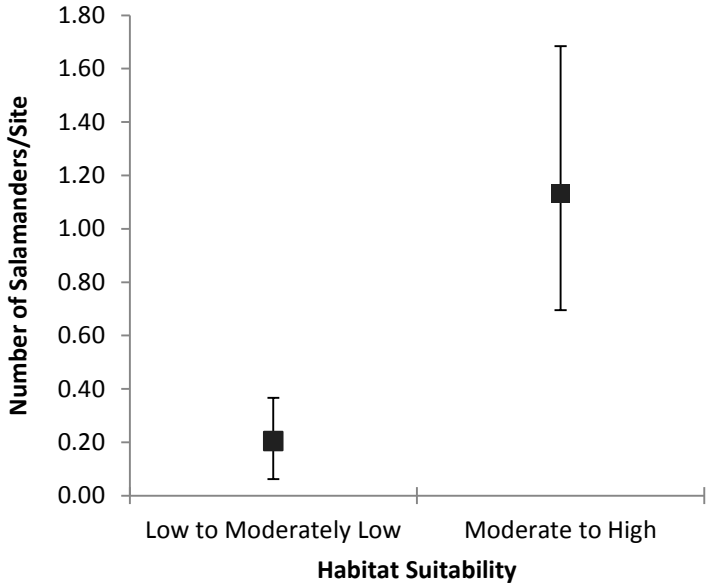


Figure 6. Ninety-five percent confidence intervals for the mean number of Oregon slender salamanders per site showing a clear difference between below-median habitat suitability classes (low and moderately low suitability classes) and above-median habitat suitability classes (moderate and high suitability classes).

Table 8. Difference in mean number of Oregon slender salamanders detected per site between below-median habitat suitability (Low to Moderately Low habitat suitability classes combined) and above-median habitat suitability (Moderate and High suitability classes combined).

Habitat Suitability	Mean	95%CI	P(t-test)	P(Wilcoxon)
Low to Moderately Low	0.20	0.06-0.37	<0.0001	0.00013
Moderate to High	1.13	0.70-1.68		

Table 9. Association between habitat suitability classes and number of salamander detections and probability of non-detection assessed from zero-inflated negative binomial regression with a dummy variable of two habitat suitability classes, one above-median habitat suitability (Moderate to High) and another below-median habitat suitability (Low to Moderately Low).

	Zero-Inflated Part (Non Detection)			Count Part (Number of Detection)		
Habitat Suitability	Coefficient	95%CI	P	Coefficient	95%CI	P
Moderate to High	-1.17	-2.64-0.31	0.120	1.15	0.16-2.14	0.023*
Low to Moderately Low(Intercept)	0.60	-0.74-1.94	0.383	-0.09	-1.05-0.88	0.857

Table 10. The incident ratio of the zero-inflated negative binomial regression for the count part of the model indicated that on average 3.15 times more salamanders were expected to be detected in the habitat classes of Moderate and High suitability combined relative to the Low to Moderately Low classes combined.

Count Model	Incident Factor	95%CI	
Moderate to High	3.15	1.17-8.46	0.023***
Intercept	0.92	0.35-2.40	0.857

Quantitative Performance and Validation of Generalized Additive Habitat Model for Oregon Slender Salamanders

At the probability cutoff value of 0.5, the GAM model correctly classified 55% (18 of 33, sensitivity) detection sites and 75% (38 of 51, specificity) non-detection sites with a total correct classification rate of 67% (56 correct out of 84) (Tables 11 and 12). At this cutoff value, specificity was noticeably higher than sensitivity; therefore, the model tended to correctly classify more non-detection sites than detection sites of Oregon slender salamanders. Lowering the probability cutoff value to 0.45 increased correct classification of detection sites from 55% to 67% (22 of 33, sensitivity), decreased the correct classification rate of non-detection site from 75% to 67% (34 of 51, specificity), but maintained the total correct classification rate at 67% (56 correct of 84 sites, Figure 7). At the cutoff value of 0.45, the model achieved the best balance between the sensitivity and specificity without sacrificing the total correct classification rate. At the cutoff values of 0.4 and 0.39, the correct classification rate for detection sites was 79% (sensitivity, 26 of 33 for both cutoff values) and exceeded that for non-detection sites (specificity, 30 and 28 of 51 non-detection sites for 59% and 55 % at cutoff probabilities of 0.4 and 0.39). The frequency distribution of detection sites and non-detection sites revealed that non- detection sites were distributed widely across the entire range of detection probabilities, whereas detection sites peaked around 0.5 and none were detected at or below 0.15 (Figure 8).

Kappa statistics (0.29-0.35, Table 11) for the range of cutoff probabilities tested suggested that the GAM model improved correct classification rates by 29-35% without relying on chance. The gradual increment of the receiver operation characteristics (ROC, Figure 9) curve with the value of area under the curve (AUC = 0.73) showed the moderate predictive power of the GAM model relative to that of a hypothetical model with a strong predictive power (AUC > ~0.85) and to that of a hypothetical model with very little or no predictive power beyond chance alone (AUC =0.50).

Table 11. Relationship between model performance and four levels of cutoff probability value for the GAM habitat classification model of Oregon slender salamanders.

	Cutoff Probability Value			
	0.5	0.45	0.4	0.39
Sensitivity (%)[a]	55	67	79	79
Specificity (%)[b]	75	67	59	55
Total Correct (%)[c]	67	67	67	64
Kappa[d]	0.29	0.32	0.35	0.31

[a]Sensitivity is the proportion of agreement between field detection and predicted detection over the total number of field detection (n = 33 sites detected).
[b]Specificity is the proportion of agreement between non-detection in the field and predicted non-detection over the total number of non-detection in the field (n = 51 non-detection sites)
[c]Total correct classification rate is the proportion of agreement between model prediction and field observation among the total number of sites (n = 84).
[d]Kappa statistics is the measure of agreement between model prediction and field observation without considering the agreement based on chance. Model performed 29-35% better than the classification based solely on chance.

Table 12. Correct and incorrect classification frequencies of Oregon slender salamander detection sites based on GAM model predictions and field validation data at four levels of cutoff probability values. Among 84 validation sites, Oregon slender salamanders were detected at 33 sites and were not detected at 51 sites.

Cutoff Probability Value	Correct Detection[a]	False Detection[b]	Correct Non-Detection[c]	False Non- Detection[d]	Total Correct[e]
0.50	18	13	38	15	56
0.45	22	17	34	11	56
0.40	26	21	30	7	56
0.39	26	23	28	7	54

[a]Number of sites where model correctly predicted detections of salamanders.
[b]Number of sites where model incorrectly predicted detections of salamanders.
[c]Number of sites where model correctly predicted no-detections of salamanders.
[d]Number of sites where the model incorrectly predicted no-detections of salamanders.
[e]Number of sites where the model correctly predicted either detection or non-detection of salamanders (Sum of correct positive and correct negative).

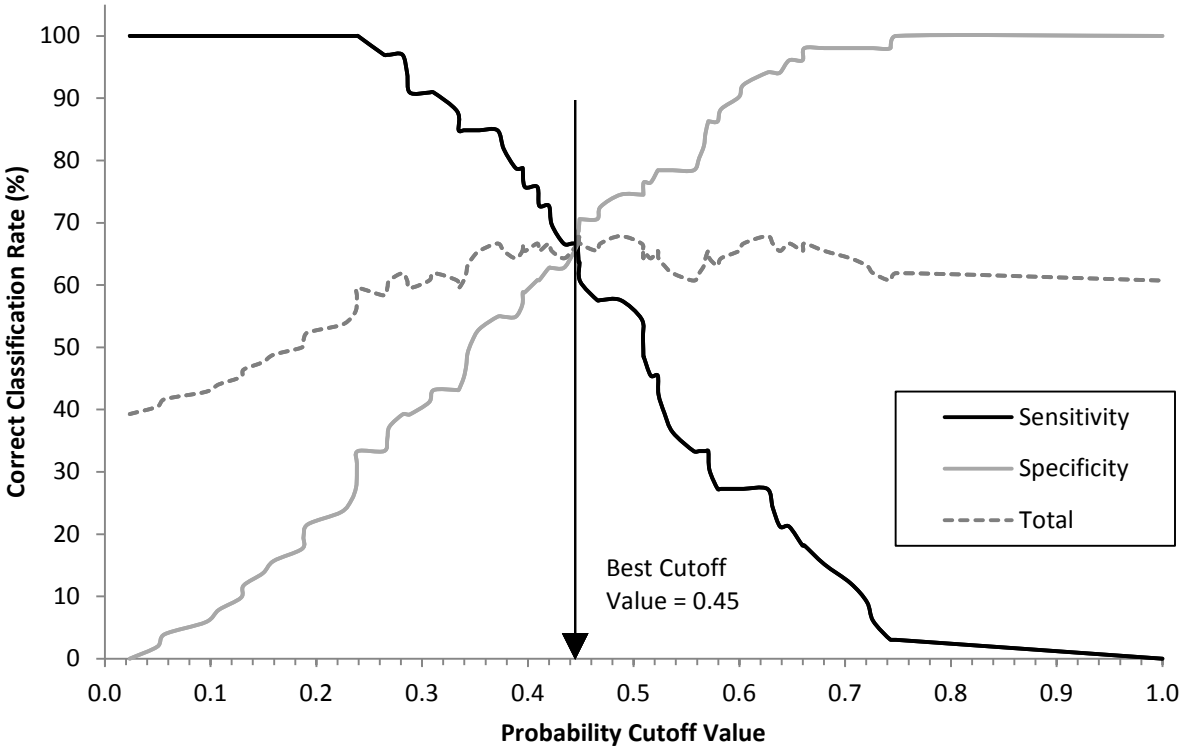


Figure 7. Relationship between correct classification rates and probability cutoff values showed that the model achieved well-balanced correct classification rates between detection sites (sensitivity) and non-detection sites (specificity) of Oregon slender salamanders with the highest level of overall correct classification rate at the cutoff probability of 0.45, the value slightly below the default classification cutoff probability of 0.5.

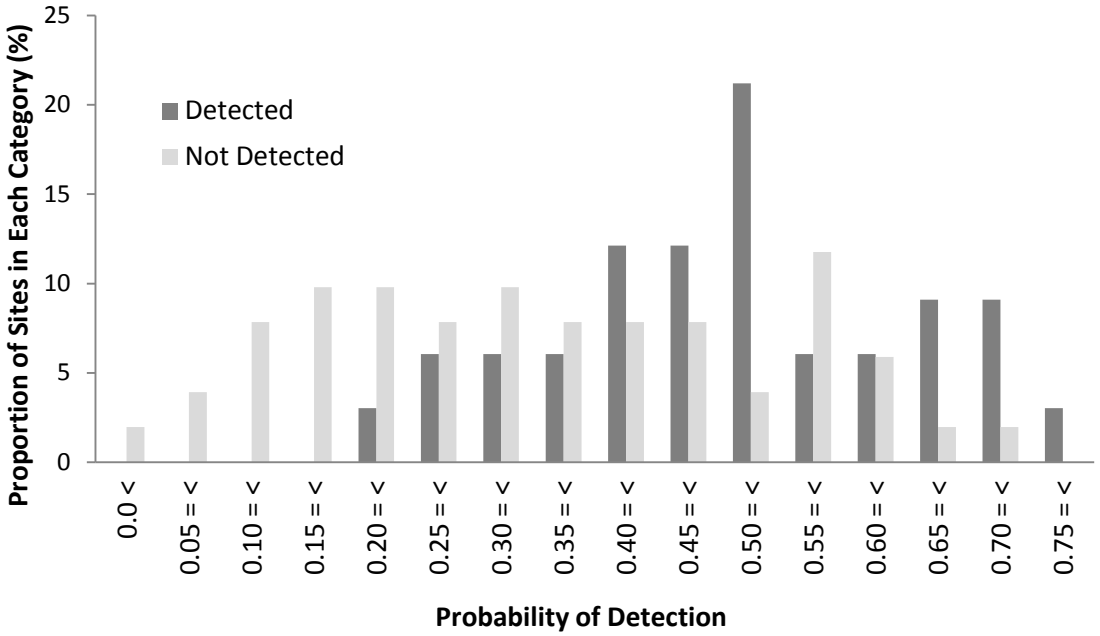


Figure 8. Relative frequency distribution of probability of detection scores for 33 detected sites and 51 non-detection sites for Oregon slender salamanders.

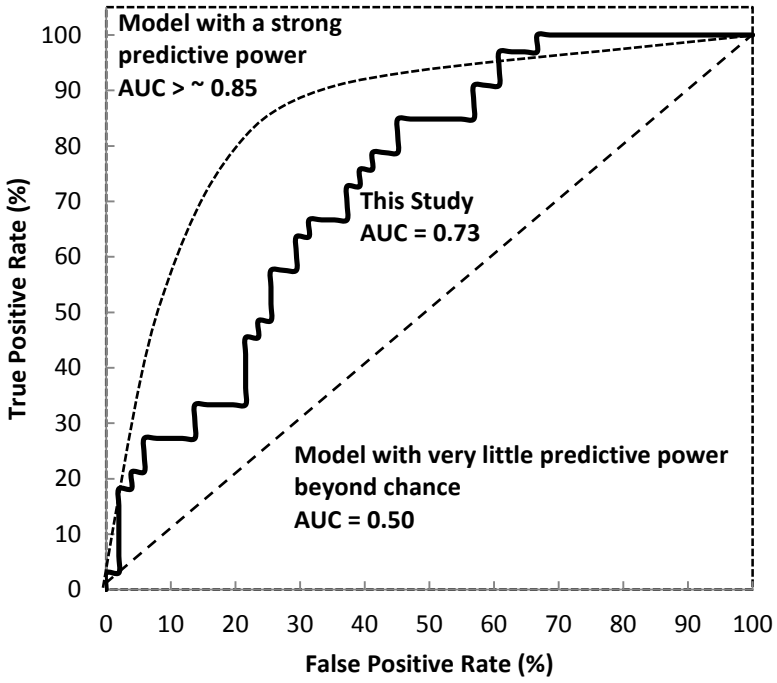


Figure 9. The receiver operating characteristics (ROV) curve of the GAM habitat model for Oregon slender salamanders. The solid line (in the middle) shows a moderate predictive power with an area under curve (AUC) value of 0.73, which is greater than that of a hypothetical model with very little predictive power beyond chance (AUC = 0.5, straight dashed line) but lower than that of a hypothetical model with a strong predictive power (AUC > ~0.85, the dotted curved line).

DISCUSSION

A large proportion (76%) of Oregon slender salamander detection sites were in the upper two habitat suitability classes, high or moderate habitat suitability. A fair amount (37%) of non-detection sites were in the upper two classes, probably because either not all suitable habitats were occupied or it is inherently difficult to detect a rare species, such as the Oregon slender salamander, even if it is present.

Zero-inflated negative binomial regression analyses along with 95% confidence intervals verified that significantly high non-detection rates of Oregon slender salamanders were associated with the low habitat suitability class, whereas significantly high detection rates were associated with the moderate and high habitat suitability classes. Model predictions of salamander detection did not correspond closely with the observed salamander detections for the moderately low habitat suitability class; however, predictions closely matched observed detections for high, moderate, and low habitat suitability classes.

We used the validation data set and tested the quantitative performance of the Generalized Additive Model (GAM) from which the original habitat suitability map was generated. On the average the GAM model correctly classified 67% (Kappa = 32%) of validation data at cutoff probability values of 0.4, 0.45, and 0.50. At the cutoff value of 0.45, the model achieved the best balance between the sensitivity (67%) and specificity (67%). At the cutoff value of 0.5, the model tended to correctly classify more non-detection sites than detection sites of Oregon slender salamanders; the specificity (75%) was noticeably higher than sensitivity (55%). In contrast, the model tended to correctly classify more detection sites than non-detection sites at the lower cutoff value of 0.4; the sensitivity (79%) was noticeably higher than specificity (59%).

The receiver operating characteristics (ROV) curve suggested a moderate predictive power for the GAM model with and area under curve (AUC) value of 0.73, which is greater than that of a model with very little predictive power beyond chance (AUC = 0.5) but lower than that of a model with a strong predictive power (AUC > ~0.85).

MANAGEMENT IMPLICATIONS

Moderate levels of predictive power from GIS-based landscape habitat models, such as the current model, are realistic and reasonable. For example, the current habitat suitability model and map are based on habitat attributes in landscape-scale GIS coverages that were either interpreted from aerial photographs, or interpolated or extrapolated from existing data points to cover the landscape. It is highly likely that critical habitat features that are typically measured on the ground and difficult to quantify across landscapes in GIS layers, such as abundance of down wood, would further affect the occurrence and spatial distribution of the Oregon slender salamander beyond which GIS-based habitat models/maps can predict. Instead of seeking perfect predictions from GIS-based landscape models, managers and conservationists can use the GIS-based landscape model to first define initial geographic areas of potential conservation concern for a species. After the initial selection of potential conservation areas, locally available site-specific biological/ecological information or GIS insensitive habitat information (e.g., down wood) could be carefully assessed by additional field reconnaissance to further prioritize areas of species-conservation concerns.

REFERENCES

Suzuki, N. 2009. Developing Landscape Habitat Suitability Models for the Oregon slender salamander (*Batrachoseps wrighti*) in the western Oregon Cascades. Appendix 1 *in*: Clayton, D.R. and D.H. Olson Conservation Assessment for the Oregon Slender Salamander (*Batrachoseps wrighti*) Version 1. Interagency Special Status and Sensitive Species Program, Portland, OR. Available at: http://www.fs.fed.us/r6/sfpnw/issssp/planning-documents/assessments.shtml

APPENDICES

Appendix 1: Olson, D.H. 2008a. Field validation of the Oregon slender salamander, *Batrachoseps wrighti*, habitat model. Research Proposal, 8 May 2008, submitted to the Interagency Special Status and Sensitive Species Program, Portland, OR.

Appendix 2: Olson, D. 2008b. Field validation of Oregon slender salamander habitat model: Minutes from conference call on December 8, 2008. [This file documents decisions on survey protocol and site selection procedures].

Appendix 3: Olson, D.H. 2009. ISSSSP Interim Report: Field validation of the Oregon slender salamander, *Batrachosepts wrighti*, habitat model. 8 October 2009.

Appendix 1. Olson, D.H. 2008a. Field validation of the Oregon slender salamander, *Batrachoseps wrighti*, habitat model. Research Proposal, 8 May 2008, submitted to the Interagency Special Status and Sensitive Species Program, Portland, OR.

Oregon Slender Salamander Research Proposal

PROJECT TITLE: Field validation of the Oregon slender salamander, *Batrachoseps wrighti*, habitat model

PROJECT LEAD(S): **Dr. Deanna H. Olson**, USDA Forest Service, PNW Research Station, Corvallis, OR; ph 541-750-7373, fax 541-750-7329, dedeolson@fs.fed.us

PROJECT OBJECTIVES: Conduct field validation of the habitat model for Oregon slender salamanders by surveying at modeled habitats with high suitability and low suitability scores in the western portion of the species range in Oregon.

BACKROUND: The Oregon slender salamander is an Oregon endemic species, restricted to the Oregon Cascade Range. This is terrestrial salamander which does not require streams or ponds for any part of its life history, and is a forest-dependent species with strong ties to down wood (e.g., Blaustein et al. 1995). It is a federal agency species of concern due to its restricted range and potential threats of multiple disturbances including forest management practices (Clayton and Olson 2007). Although several studies have found that the species was associated with down wood and older forest conditions (e.g., Bury and Corn 1988, Gilbert and Allwine 1991, Vesely et al. 1999, Suzuki 2008a), there remains uncertainty regarding its habitat associations.
The ISSSSP Conservation Assessment for this species (Clayton and Olson 2007) states an information need for this species includes a better understanding of the distribution of habitat across the species range. While a habitat model has been developed for the species, and this has been mapped for the western portion of its range (Suzuki 2008a) (Figure 1, from Suzuki 2008b), the model has not been field validated. We propose to field validate this model by conducting surveys of modeled habitats with high and low suitability index scores within the western portion of the range in Oregon. The benefits of this work will be threefold: 1) improved understanding of species-habitat requirements which may be affected by federal agency land management decisions; 2) habitat model assessment; and 3) validation of current version of habitat map for Oregon. Such a map could streamline field unit project environmental assessments and will help prioritize areas for potential field surveys.

STATEMENT OF WORK:

Project Area and Site Selection: Field surveys will be conducted west of the Cascade Range crest on federal lands in the area delineated as potential range in Suzuki 2008a. A minimum of 40 sites will be randomly selected. This may be sufficient to test the model, depending upon the effectiveness of surveys and occupancy of the species within the survey area. However a sample of 80 sites would be better, and 80 would allow a prospective model to be developed from the data. A sample site is defined as an area >30 acres that is modeled to have the same habitat

suitability score. To provide a geographically representative sample across the western species' range, the survey area will be divided into 40 equal longitudinal strips, and sites will be randomly selected from among those 40 strips (1 per strip with the minimum approach, and 2 per strip with the more intensive sampling). If more than 40 total sites but less than 80 sites can be surveyed with the resources provided, then additional strips will be randomly selected for sampling among the 40 strips, with not more than 2 sites per strip. If access to a site is an issue due to safety concerns or due to road blockages, that site will be dropped from the sample and another site will be chosen within the longitudinal strip. The habitat suitability score of a selected sample site will be determined from the habitat model.

Survey Methods: In January 2008, the federal working group for the Oregon slender salamander developed standard survey procedures for the species for another study aimed at understanding the southwest distribution of the species, east and southeast of Eugene, OR. Use of standard survey approaches across the species range will aid in inventory and monitoring of the species. The protocol has been in use previously for "mollusk surveys" conducted by federal biologists at the Salem District BLM office, and has appeared to be effective for these salamanders as well. I propose to use this standard protocol but with additional effort to avoid Type II errors.

The survey consists of a 3 person-hour search of habitat per site. A set of three 20-minute surveys summing to a 1 person-hour search will be conducted within a 10-acre forest area in the spring wet-season after snowmelt has occurred when site temperatures are above freezing. Two of these three 20-min surveys are "plot surveys", where a more intensive 20-minute time-constrained search is conducted at a targeted location of down wood. An additional 20-minute search is then conducted throughout the area in an opportunistic fashion, focusing on substrates, litter, moss, and other down wood features likely to harbor salamanders. Search methods include looking within and under surface cover items likely to harbor salamanders. Hand garden claws may be used to gently separate layers of down wood, moss or litter during the search, and these will be replaced after searching. For field validation of the habitat model, I propose that three of these 1-hr searches (3 person-hr total) be conducted at each selected site, in spring 2009, March to June, when site conditions are snow-free, above freezing and wet. Because these animals often occur at low densities or detectabilities, three samples per site is proposed to bolster sample sizes.

Site data collected will follow the data format for the BLM data requirements in GeoBob, as in the attached form. Oregon slender salamanders captured during searches will be measured for snout-vent length, total length, and weight. Gravid females will be noted. If nests are detected with a salamander in attendance, the length of the animal and clutch size will be estimated and the disturbance to the nest and its guardian will be minimized (few nests of this species have been found). All animals will be returned to their site of capture after handling. State permits for handling this Oregon State Protected Species will be obtained.

The null hypothesis that there is no relationship between modeled habitat suitability scores of sampled sites and salamander relative abundance, length/weight ratios, and size structure of populations will be examined. These three metrics are proposed to more fully test the interaction plethodontid species may have with habitat conditions (Welsh et al. 2008). Statistical consultation will be conducted to explore final avenues of analysis. The odds of correct

classification using the existing habitat suitability model can be determined from the results, and compared with the initial model. If sufficient data are collected, a prospective model can be developed.

Final Products: A report to the federal ISSSSP will be provided upon completion of the project. Journal article submission will follow. Field forms for surveyed areas will be provided to the ISSSSP at the Regional Office, including locations of target species for input to federal electronic data systems. If an update to the habitat suitability model is required for the species Conservation Assessment, an addendum or additional appendix will be written as an update to the Conservation Assessment.

Budget: It is estimated that a two-person crew can complete two sites in a single day, with the three 1-hr surveys per site, unless there is a huge travel distance or time between sites. Hence, it would take at least 20 survey days to complete surveys at 40 total sites, which is at least 5 weeks of work for a crew working 4 10-hour days per week. Weather, site conditions, and access may prolong the survey interval, so 2 months might be more realistically allocated to complete the field work. Statistical expertise is proposed to be contracted to assist with the validation. The Principal Investigator's (Olson) time to manage work and for reporting would be provided by PNW.

Field Crew Salary:
Minimum approach: 2 persons for 2 mo. @ GS-7 (annual salary $40k + $12.5k benefits) = $17,500
Approach with additional sampling: 4 persons for 2 mo. @ GS-7 (as above) = $35,000
Statistical consultant: Procurement request @ $2,500 = $ 2,500
Travel estimates (vehicle, some overnight per diem and lodging), Minimum approach = $ 2,500
Approach with additional sampling = $ 5,000
SubTotal Funding Request

Minimum Approach = $22,500
PNW Station Director's Office Overhead (8%) = $1,800

Approach with additional sampling = $42,500
PNW SDO Overhead (8%) = $3,400

Totals
Minimum Approach = $24,300
Approach with additional sampling = $45,900

REFERENCES

Blaustein, A.R.; Beatty, J.H.; Olson, D.H.; Storm, R.M. 1995. The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-337. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 98 p.

Bury, R.B.; Corn, P.S. 1988. Responses of aquatic and streamside amphibians to timber harvest: A review. pp. 165-18 1. In: Raedeke, K.J. (ed.), Proceedings of a symposium on streamside management: Riparian wildlife and forestry interactions, 11 - 1 3 February 1987, Institute of Forest Resources, University of Washington, Seattle, Contribution (59).

Clayton, D.R.; Olson, D.H. 2007. Conservation assessment for the Oregon Slender Salamander (*Batrachoseps wrighti*). Version 1.0. USDA Forest Service, Region 6, and Oregon BLM, Special Status Species Program. Available at: http://www.fs.fed.us/r6/sfpnw/issssp/planning-documents/assessments.shtml

Gilbert, F.F.; Allwine, R. 1991. Terrestrial amphibian communities in the Oregon Cascade Range. pp. 319-324. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H. (technical coordinators), Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285, US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Suzuki, N. 2008a. Developing Landscape Habitat Suitability Models for the Oregon slender salamander (*Batrachoseps wrighti*) in the western Oregon Cascades. Appendix 1 of: Clayton, D.R.; Olson, D.H. 2007. Conservation assessment for the Oregon Slender Salamander (*Batrachoseps wrighti*). Version 1.0. USDA Forest Service, Region 6, and Oregon BLM, Special Status Species Program.

Suzuki, N. 2008b. Assessment of risk to conservation of the Oregon slender salamander (*Batrachoseps wrighti*) in the western Oregon Cascade Range. Appendix 2 of: Clayton, D.R.; Olson, D.H. 2007. Conservation assessment for the Oregon Slender Salamander (*Batrachoseps wrighti*). Version 1.0. USDA Forest Service, Region 6, and Oregon BLM, Special Status Species Program.

Vesely, D.; Corkran C.; Hagar, J. 1999. Habitat- selection by Oregon slender salamanders *(Batrachoseps wrighti)* in the western Oregon Cascades. Final Report prepared for the Oregon Department of Fish and Wildlife under Contract 63506138.

Welsh, H.H. Jr., K.L. Pope, and C.A. Wheeler. 2008. Using multiple metrics to assess the effects of forest succession on population status: a comparative study of two terrestrial salamanders in the US Pacific Northwest. Biol. Conserv. 141: 1149-1160.

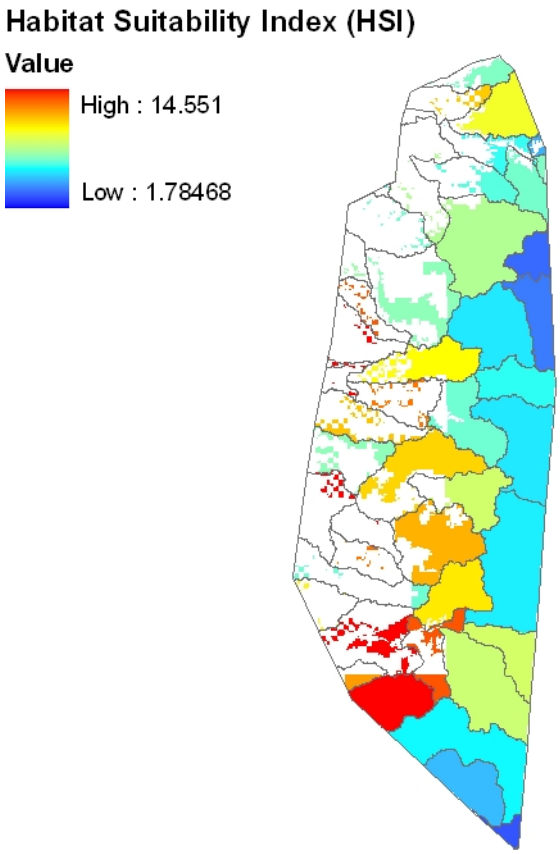


Figure 1. Habitat suitability index scores for federal lands in 5th field watershed within the western portion of the range of the Oregon Slender Salamander in Oregon.

OR / WA BLM GeoBOB v 1.2 OBSERVATIONS & SITE FORM – FAUNA, pg 1.

(*Circle* appropriate option when a list is provided, **Bold** items are required fields, *key to codes on cheat sheet. See data dictionary for Field Name and List of Value definitions.)

OBSERVATIONS

OBS ID: _____ **SPECIES CODE**: _____
SCIENTIFIC NAME: _____ COMMON NAME: _____
UTM: _____ E, _____N ZONE: _____ DATUM: _____
LAT: _____ W, LONG:_____N GPS model & software used: _____
***OBSERVATION TYPE**: _____ **DATE**: _____
DATE ACCURACY: Day, Exact, Hour, Month, Previous Year, Year
RELIABILITY: Excellent, Good, Fair, Poor, Unknown ***LOCATION ACCURACY**: _____
TOTAL QUANTITY: _____ QUANTITY ESTIMATED?**:** Y / N
DISTRIBUTION: Clumpy, Linear, Scattered-Even , Scattered-Patchy
ABUNDANCE: Unknown, Abundant, Common, Uncommon, Rare
OBSERVERS: _____
Notes: _____
_____
_____

DETAIL OBS

QUANTITY: _____ GENDER: Female, Male, Neuter, Hermaph, Unknown *AGE: _____
*ACTIVITY: _____ CONDITION: Dead, Excellent, Fair, Good, Injured, Live, Poor, Sick, Unknown
REPRO-STATUS: Non-repro, Repro, Unknown, N/A
NOTES: _____
_____

HABITAT/ENVIRONMENTAL OBS

SLOPE (%): _____ SLOPE – MIN. (%): _____ SLOPE – MAX. (%): _____ SLOPE SOURCE: _____
ASPECT (deg): _____ ASPECT – MIN. (deg): _____ ASPECT - MAX. (deg): _____ ASPECT SOURCE: _____
ELEV. (ft): _____ ELEV. – MIN. (ft): _____ ELEV. - MAX. (ft): _____ ELEV. SOURCE: _____
Source: C = Calculated, M = Measured, E = Estimated, G = Used GPS (elevation only)
*LANDFORM:_____ STAND AGE:_____
STAND STRUCTURE: Multiple Canopies, Single Canopy, Two Canopies, Unspecified
SERAL STAGE: Pioneer, Early (20-39yrs), Mid (40-79yrs), Late (80-200yrs), Climax
PERCENT COVER: 1) OVERSTORY: _____, OVERSTORY MIN.: _____, OVERSTORY MAX: _____ 2) UNDERSTORY: _____, UNDERSTORY MIN.: _____, UNDERSTORY MAX: _____
~FIRE PRESENCE: Absent, Burned, Complete Burned, High Scorched, Mod. Scorched, Part Scorched, V. High Scorch
TOPO. POSITION (rel. to overall slope): Bottom, Lower, Mid, Ridge, Upper. *SUBSTRATE: _____
SOIL TEXTURE: Clay, Clay Loam, Loam, Sand, Silt, Silt Loam, Sandy Loam, Other
AIR TEMPERATURE (F): _____ RELATIVE HUMIDITY (%): _____ SOIL TEMP. (F): _____
SOIL MOISTURE: Dry, Moist, Wet LIGHT INDEX: Full Shade, Full Sun, Part Shade
PRECIP.: Dry, Fog, Misty Rain, Rain, Sleet/Hail, Snow WIND: Calm, Light, Moderate, Windy, Gusty
NOTES: _____
_____
_____

ADDITIONAL OBSERVATION LOCATIONS

If more than one observation is found in the survey area and that is within the survey site, record the location, Obs ID, and notes here. If specifics about the additional observations need to be recorded (feature, detail observation, or collection information) complete a separate Obs form.

Latitude/UTM E	Longitude/UTM N	Obs ID	Notes

PLEASE ATTACH MAPS of Observation or Site when helpful.

THREATS

***THREAT TYPE(S):**

_____

NOTES:_____

OR / WA BLM GeoBOB v 1.2 OBSERVATIONS & SITE FORM – FAUNA, pg 2.
(*key to codes on cheat sheet, *Circle* appropriate option when a list is provided, **Bold** items are required fields)

ASSOCIATED OBS

Create a list below of non-target species found in the same geographic location as the observation. If needed, indicate percent cover, abundance and/or quantity for each species.

Species Code	Scientific Name	% Cover	Abundance	Quantity

COLLECTIONS

COLLECTION ID: _____
COLLECTION TYPE: Voucher, Museum, Commercial, Photo, ID Tag, None, Other
DATE: _____ **COLLECTOR**: _____
REPOSITORY: _____ IDENTIFIER: _____
Photo ID: _____
VERIFIER: _____ Verification Date: _____
VERIFIED SPECIES CODE: _____
COLLECTION NOTES: _____
_____
_____
_____

FAUNA SITES

SITE ID: _____ SITE NAME: _____
SITE ALT. ID: _____ **SITE SPECIES CODE**: _____
ADMIN UNIT_____ SUB-ADMIN UNIT_____ ***LOCATION ACCURACY**: _____
SITE STATUS: (locally): Extinct, Extirpated (sp. & habitat), Occupied, Undetected, Unknown, Unoccupied
TOTAL QUANTITY: _____ QUANT. ESTIMATED?: Y / N AREA OCCUPIED (ac): _____
VISIT PURPOSE: Incidental, Inventory, Treatment (specify in notes), Monitoring – Annual/ Fed. Listed, Monitoring – Grazing, Monitoring – Long-Term, Monitoring – Unspecified, Monitoring – Fire, Research, Revisit, Resurvey, Unspecified
DATE: _____ **DATE ACCURACY**: Day, Exact, Hour, Month, Previous Year, Year

REVISIT NEEDED: Y / N REVISIT SCHEDULED DATE: _____

OBSERVERS: _____

NOTES: _____
_____
___
_____
____

PLEASE ATTACH MAPS of Observation or Sit

Appendix 2. Olson, D. 2008b. Field validation of Oregon slender salamander habitat model: Minutes from conference call on December 8, 2008. [This file documents decisions on survey protocol and site selection procedures].

Field validation of Oregon slender salamander habitat model
Conference call on December 8th, 10am
Dede Olson, 3 December 2008
Minutes are Highlighted in Yellow: NEXT meeting is January 14th at 10am.

Goal of Meeting: Refine design to field validate the habitat model

- where to sample
- how to sample
- when to sample
- what additional attributes to sample
- who will sample
- who to analyze

Current proposal for discussion:

Where to sample -

80 sampling sites on federal lands across western portion of range (Figure 1)

- 20 sampling sites from each of the 4 habitat suitability categories
- Random site selection, no additional strata included
- "Strip search" design to ensure sampling across full range of the animal was abandoned as problematic and complex if we also stratify by habitat category, and with 80 random points we seem to get a good distribution
- 50 sites per category have been randomly drawn in case there are problems getting to these first 20 sites (Figure available upon request). However, we should try not to bias our sample, for example we should try to get to sites with late snow melt and not quit our samples early because we could get 20 sites in a narrow time window.

Eliminate northernmost and southernmost ends of distribution from area to sample

-from last year's surveys, southernmost areas appear to have a very patchy distribution of the animal…with potentially reduced detection, it may be less suitable to include in model validation exercise. Cut off is subjective.

Linn-Lane County boundary was used as cut-off for sampling points shown below.

-there is uncertainty whether or not the northernmost part of this range has an occupancy pattern that is similar to the central portion. For consistency, sampling in the mid portion of the range might be advised. Cut off is subjective.

Multnomah-Clackamas boundary was used as a cut off for sampling points shown below.

We are going forward with this plan. Joe/Mike/Rob/Kelli agreed with the north and south cutoffs.

How to sample –

We have considered using the same sampling approach as last year. In that, a "site" would be one ~~or more~~ 10-acre forest stand~~s in close proximity~~ that matches the general characteristics of the habitat suitability category it should match (for example, category 4 is good habitat and would not be a clearcut), and a sample would be ~~a~~ Two 1 person-hr searches per stand. The 1 hour would be conducted as 3 20-min searches. Two 20-min searches would be located in large down wood aggregates, if available, and one 20-min search would be more opportunistic of other down wood pieces and other forest-floor cover. Joe called this a "walk around" search, and if it were to be conducted first, it could serve as a site reconnaissance and help find the locations of the later 2 20-min searches of down wood aggregates. Questions have been posed about how effective this sampling approach is, how many 1-hr searches are needed, etc.
To begin to get some insight at how detectable animals are using this method, I have looked at our findings from last year at a known site of salamander occurrence. My field crew surveyed this known site using the 1 person-hr (3 20-min searches) approach, with a total of 18 hours of searching done at the site (6 hrs in the moderate thinning treatment unit, 6 hrs in the high density treatment unit, and 6 hrs in the control unit). We did 6 surveys per unit in order for us to have enough data to look at treatment effects later, once thinning was done.

Oregon slender salamanders were detected in:

89% of the 1-hr searches (N = 18)
62% of the 20-min searches conducted in down wood aggregates (N = 34)
39% of the 20-min searches conducted opportunistically (N = 18)
55% of the 20-min searches conducted any which way (N = 52)

I did a quick analysis of detection probability, following the simplest formula in MacKenzie et al. (2006).

Caveats: I assumed detection and occupancy were equal in the different parts of this site, so the data could be put together. Probability of detection results below would be applicable to this site with my survey crew, and if used for other sites and other crews, you would assume all things were equal.

$p^* = 1 - (1-p)^k$
where p^* is probability of detection with k surveys
k = no. surveys, p = probability of detection

1. When p = 0.89 (probability of detection with a 1-hr search at my site)
    a. With 2 surveys, $p^* = 0.988$ [with 2 hrs of searching, there is a 98.8% chance of finding a salamander at this site]
    b. With 3 surveys, $p^* = 0.945$
    c. With 4 surveys, $p^* = 0.999$
2. When p = 0.62 (probability of detection with a 20-min search of a wood aggregate at my site)
    a. 2 surveys, $p^* = 0.86$ [with 2 20-min searches, there is an 86% chance of detecting a salamander at this site]
    b. 3 surveys, $p^* = 0.945$
    c. 4 surveys, $p^* = 0.98$

3. Let's take a hypothetical case where p is much lower. Let's say p = 0.25.
    a. 2 surveys, p* = 0.44
    b. 3 surveys, p* = 0.58
    c. 4 surveys, p* = 0.68
    d. 5 surveys, p* = 0.76
    e. 6 surveys, p* = 0.82

    So, if you had a 25% of detecting an animal with a 20 min search, you would have an 82% chance of detecting an animal with 2 hrs of searching.

For discussion – what level of effort is desired?

We decided to conduct two 1-hr searches of each sampling point/site, which is a 10-acre area. This level of sampling would find at least one animal, hence determine occupancy, at a site with higher probability of detection. There is a 16% chance of not finding an animal at sites with less than 62% probability of detection.

When to sample – March-June 2009, as conditions warrant….

We will have the field crews regularly check-in with Dede, reporting what sites have been surveyed, in order to reduce a geographic or habitat class sampling bias and also to talk about if conditions are ok to sample. More than 80 total sites will be sampled if possible, but we will need to be careful not to cluster these by geography, elevation, class, etc. Having Tiffany and Loretta do a sampling day together at the beginning of the season will help to reduce variation in field crew methods.

Additional attributes – we should include main parameters of model to analyze what we have really done, rather than relying on GIS data. These include elevation, stand age, stand height, tree diameter, tree basal area, hardwood canopy cover and basal area (bigleaf maple), and Pacific silver fir basal area. I would like the survey crews to be trained similarly in how to collect data. I think temperature and precipitation would need to come from the GIS layers. Also, down wood surveys … yes, and how?

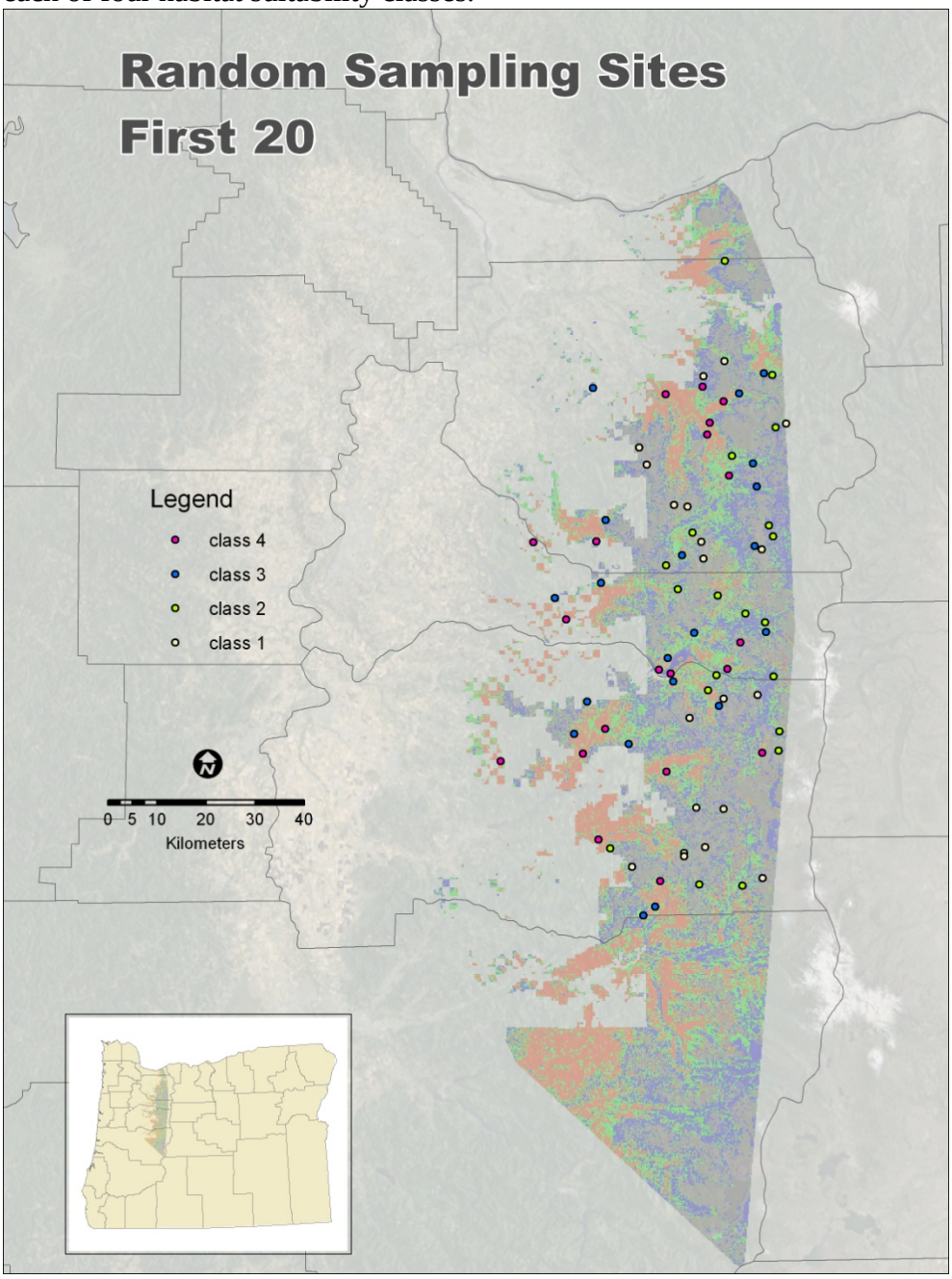
Dede is drafting a data form to have habitat attributes in a multiple choice format of categorical variables. Loretta is asking Paul Anderson for suggestions, because his field crews do these types of measurements. Dede is asking Jim Alegria (did he retire?) and Kim Mellon about this, and about down wood protocols. We could try to match FIA procedures, for example. For Down Wood, we are thinking of transect samples. Mike stressed importance of these data reflecting the area sampled for salamanders. We will talk more about this in January. Dede will send suggested approaches beforehand.

Who to sample – Tiffany and Dede's group

Who to analyze – for discussion, Nobi is gone, could try to contract this with him though.

Dede will contact Nobi. Also, will ask about value of purposive survey data for habitat model validation…and how to collect those data.

Figure 1. Eighty sampling sites for BAWR habitat model validation, with 20 sites selected from each of four habitat suitability classes.



Appendix 3. Olson, D.H. 2009. ISSSSP Interim Report: Field validation of the Oregon slender salamander, *Batrachosepts wrighti*, habitat model. 8 October 2009.

ISSSSP Interim Report
8 October 2009

PROJECT TITLE: Field validation of the Oregon slender salamander, *Batrachoseps wrighti*, habitat model

PROJECT LEAD(S): **Dr. Deanna H. Olson**, USDA Forest Service, PNW Research Station, Corvallis, OR; ph 541-750-7373, fax 541-750-7329, dedeolson@fs.fed.us

PROJECT OBJECTIVES: Conduct field validation of the habitat model for Oregon slender salamanders by surveying at modeled habitats with high suitability and low suitability scores in the western portion of the species range in Oregon.

BACKROUND: The Oregon slender salamander is an Oregon endemic species, restricted to the Oregon Cascade Range. This is terrestrial salamander which does not require streams or ponds for any part of its life history, and is a forest-dependent species with strong ties to down wood (e.g., Blaustein et al. 1995). It is a federal agency species of concern due to its restricted range and potential threats of multiple disturbances including forest management practices (Clayton and Olson 2007). Although several studies have found that the species was associated with down wood and older forest conditions (e.g., Bury and Corn 1988, Gilbert and Allwine 1991, Vesely et al. 1999, Suzuki 2008a), there remains uncertainty regarding its habitat associations.
The ISSSSP Conservation Assessment for this species (Clayton and Olson 2007) states an information need for this species includes a better understanding of the distribution of habitat across the species range. While a habitat model has been developed for the species, and this has been mapped for the western portion of its range (Suzuki 2008a) (Figure 1, from Suzuki 2008b), the model has not been field validated. We propose to field validate this model by conducting surveys of modeled habitats with high and low suitability index scores within the western portion of the range in Oregon. The benefits of this work will be threefold: 1) improved understanding of species-habitat requirements which may be affected by federal agency land management decisions; 2) habitat model assessment; and 3) validation of current version of habitat map for Oregon. Such a map could streamline field unit project environmental assessments and will help prioritize areas for potential field surveys.

STATEMENT OF WORK:

Project Area and Site Selection: Field surveys were conducted west of the Cascade Range crest on federal lands in the area delineated as potential range in Suzuki 2008a, with the northernmost and southernmost ends of distribution eliminated. At the south end, the Linn-Lane County boundary was used as the cut-off because our 2008 surveys detected very patchy animal occurrences there. There was uncertainty about the occupancy pattern in the northernmost end of the species range, and to hedge this uncertainty, we chose the Multnomah-Clackamas boundary as the cut-off for sampling.

Our target was to randomly select 80 sites for surveys, with 20 sites from each of four habitat suitability score categories from the Suzuki (2008) model (Figure 1). No additional strata were included in the site selection. However, in anticipation that some sites would not be accessible, more than 80 random sites were drawn initially in order to have a sufficient pool of random sites from the beginning. A "site" was a 10-acre forest stand that matched the general characteristics of the habitat suitability category (for example, category 4 is good habitat and would not be a clearcut). We divided the work into two for 40 survey sites to be covered by Tiffany Young from the Willamette National Forest, and 40 sites to be covered by Loretta Ellenberg of PNW.

Surveys: The survey consisted of a 2 person-hour search of habitat per site. Two sets of three 20-minute surveys summing to a 2 person-hour search were conducted within a 10-acre forest area in the spring wet-season after snowmelt when site temperatures were above freezing. Four 20-min surveys were "plot surveys", where a more intensive 20-minute time-constrained search was conducted at a targeted location of down wood. An additional two 20-minute searches were conducted throughout the area in an opportunistic fashion, focusing on substrates, litter, moss, and other down wood features likely to harbor salamanders. Search methods included looking within and under surface cover items likely to harbor salamanders. Hand garden claws may have been used to gently separate layers of down wood, moss or litter during the search, and these will be replaced after searching. Habitat and down wood data were collected at each survey site.

Analyses: The null hypothesis that there is no relationship between modeled habitat suitability scores of sampled sites and salamander relative abundance, length/weight ratios, and size structure of populations will be examined. These three metrics are proposed to more fully test the interaction plethodontid species may have with habitat conditions (Welsh et al. 2008). Statistical consultation will be conducted to explore final avenues of analysis. The odds of correct classification using the existing habitat suitability model can be determined from the results, and compared with the initial model. If sufficient data are collected, a prospective model can be developed.

PROGRESS TO DATE:

We had considerable late season snow and an extended spring season in 2009, with snow and cold temperatures having bearing on site access and suitability of conditions for salamander surveys at sites. Some higher elevation sites could not be accessed until June or July. Logistics were more of a challenge than expected, including site accessibility from roads, drive times, overnight lodging, and weather conditions. Surveys were conducted from 13 April to 6 July 2009.

Although our target was to survey 80 sites, Tiffany and Loretta surveyed 84 sites (Figure 2). These 84 sites were spread across the four habitat categories with captures and land ownerships as follows:

Category 1:	20 sites sampled, all on USFS lands 2 sites with Oregon slender salamanders (10%) 3 animals total
Category 2:	23 sites sampled, all on USFS lands 7 sites with Oregon slender salamanders (30%) 11 animals total
Category 3:	20 sites sampled, 13 USFS and 7 BLM sites 12 of 20 sites with animals (60%) 6 of 13 USFS sites with animals, 6 of 7 BLM sites with animals 40 animals total
Category 4:	21 sites sampled, 13 USFS sites, 8 BLM sites 12 of 21 sites with animals (57%) 6 of 13 USFS sites with animals, 6 of 8 BLM sites with animals 40 animals total
Summary:	84 sites sampled, 33 with animals (39%) 69 USFS sites sampled, 21 with animals (30%) 15 BLM sites sampled, 12 with animals (80%) 94 animals total

There is a pattern of occupancy and relative abundance across habitat categories, from Category 1 having low occupancy and abundance of animals and Category 3 and 4 sites appearing to have comparable conditions relative to habitat suitability.

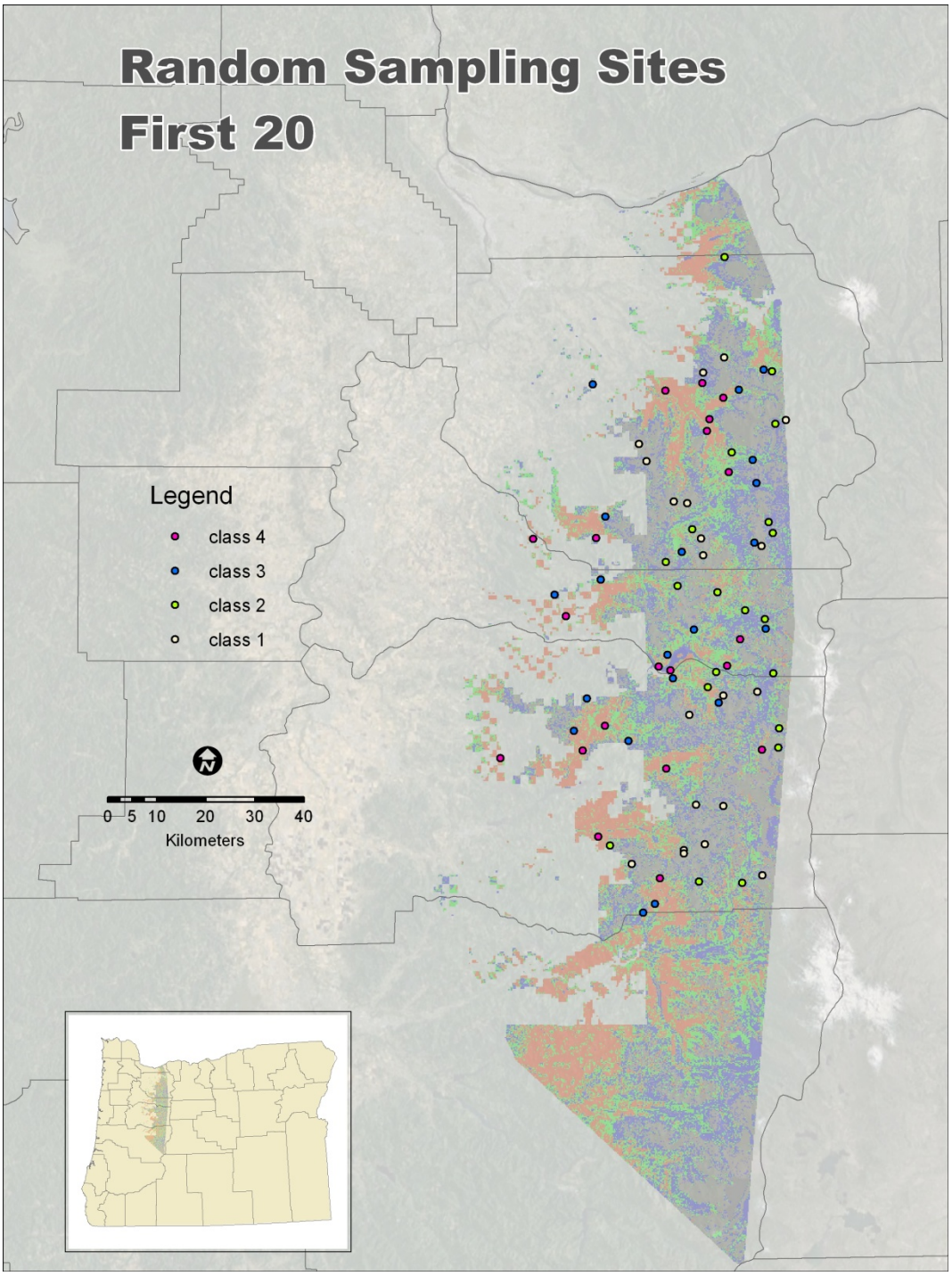
Comments from field crews included: 1) that the modeled habitat categories were a suite of parameters that were not easily ascertained during site visits, to be sure that current conditions met conditions modeled remotely; and hence 2) there was difficulty in assessing how well some selected sites fell into discrete habitat categories. This may help explain why some adjacent categories (i.e., 3 and 4) may be similar.

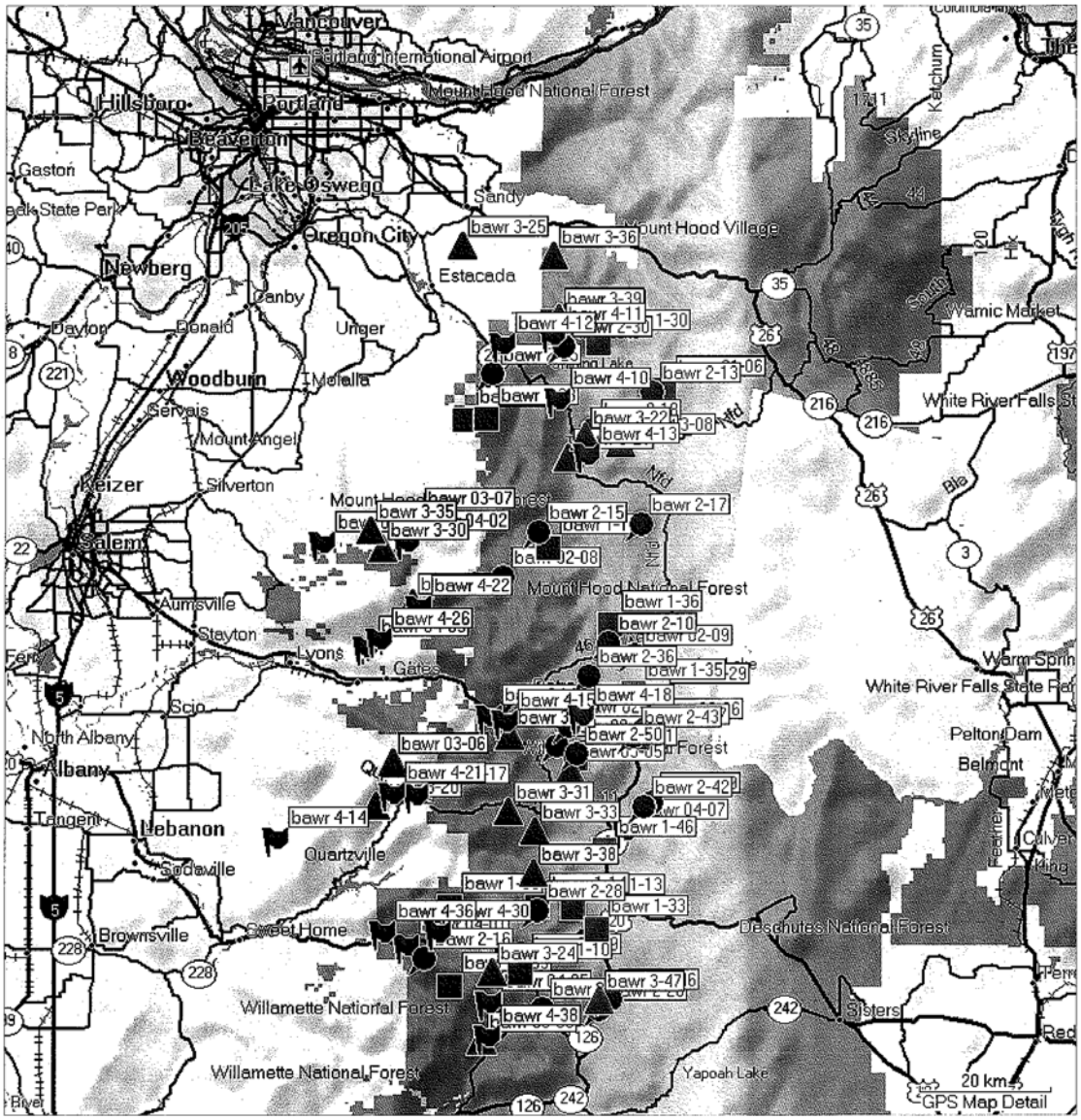
However, it is too soon to say much more, and analyses are pending. We have engaged a statistician to help with analyses in the Fall of 2009. I will be asking for the model validation in addition to a new modeling effort based on field-collected habitat data. This will enable down wood metrics to be included in analyses, which was a challenge to include in the original model (as it was based on GIS coverages that estimated wood poorly).

At this time, we are sharing data with Kelli Van Norman and Tiffany Young for data entry into the federal data systems for the BLM and the USFS.

As early analyses are completed, we may consider convening a subgroup meeting to discuss additional avenues of analysis. This is a very rich dataset to explore additional objectives.

Figure 1: The first 80 sites randomly selected for surveys show the survey area in western Oregon (class = habitat category)





□ - squares - Tier 1
♀ - lollipops - Tier 2
△ - Triangles - Tier 3
⚑ - Flags - Tier 4

© Garmin Ltd. or its Subsidiaries 1995-2007