Appendix 1 of

Conservation Assessment for the

Foothill Yellow-legged Frog

in Oregon

(*Rana boylii*)

Version 1.0

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U.S.D.A. Forest Service Region 6 and U.S.D.I. Bureau of Land Management

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Disclaimer

This Conservation Assessment was prepared to compile the published and unpublished information on the foothill yellow-legged frog (Rana boylii). Although the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise and be included. If you have information that will assist in conserving this species or questions concerning this Conservation Assessment, please contact the interagency Conservation Planning Coordinator for Region 6 Forest Service, BLM OR/WA in Portland, Oregon, via the Interagency Special Status and Sensitive Species Program website at http://www.fs.fed.us/r6/sfpnw/issssp/contactus/

Warning

Executive Summary

Species: Foothill yellow-legged frog (*Rana boylii*)

Taxonomic Group: Amphibian

Management Status: U.S.D.A. Forest Service, Region 6 - Sensitive; U.S.D.I. Bureau of Land Management, Oregon – Sensitive; Oregon State Sensitive-Vulnerable; US Fish and Wildlife Service – Species of Concern; NatureServe ranks this species as Globally Vulnerable (at moderate risk of extinction due to a restricted range) (G3), Oregon State imperiled/rare, uncommon, or threatened but not immediately imperiled (S2S3), and List 2 – taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon. Management of the species follows Forest Service 2670 Manual policy and BLM 6840 Manual direction.

Range: The species occurs in Pacific drainages of western Oregon and California, with an isolated population in Baja California, Mexico. In Oregon, it is known from the California border to the East Fork of the Coquille River (Coos County) along the coast, and to the South Santiam River (Linn County) in the Cascade Range, west of the Cascade Range crest. Historic sites dating back to 1896 have a broader distribution (Figure 1).

Specific Habitat: This is a stream-breeding frog, often associated with larger streams with coarse substrates. However, they also have been found in smaller tributaries, and in areas with finer substrates or bedrock. A habitat map has been created for this species (Appendix 1).

Threats: There appear to be three main land-use threats that may impact individuals or populations at occupied sites (site): 1) stream habitat loss or alteration from water impoundments that inundate habitats or alter natural flow regimes, causing fluctuations in water levels and altering water temperatures; 2) introduced species such as smallmouth bass and bullfrogs due to predation and competition; 3) stream habitat loss or alteration from agricultural practices including re-routing stream channels and fluctuations in water levels caused by irrigation. Other activities have unknown impacts, but are perceived as threats: 1) siltation of streams from forest or road management, grazing, mining and water impoundments; 2) applications of or run-off from chemicals, such as herbicides, pesticides and fertilizers; 3) recreation, including wave action from jet boat wakes, may degrade banks used by these frogs.

Management Considerations: Considerations for maintaining local populations include maintaining stream habitat conditions, especially suitable flow regimes. Reducing the impacts of water-releases from dams, grazing, mining, recreation, agro-chemicals, introduced predators and competitors, road and forest management are all important considerations. The timing of activities to avoid the breeding season is also a consideration for this species' management.

Inventory, Monitoring, and Research Opportunities: Information gaps include:

- delineation of the northern Oregon distribution in both the Cascade and Coast Ranges,
- habitat associations,
- distribution of suitable habitat across the species' range,
- understanding threats to the species and distribution of risk factors throughout its range.

APPENDIX 1. HABITAT MODELING AND THREAT ANALYSIS

Introduction

Understanding species-habitat relationships and generation of a habitat map can greatly enhance species conservation efforts for rare or little known species. In particular, a map can help resource managers understand the potential distribution of a species, its likely use of available resources, and potential threats. In addition, a map may help identify areas that may be of key importance for species conservation. For many little-known species, our species knowledge often consists only of a set of scattered survey data and the results of a few studies that provide preliminary information on habitat use. However, this type of information can be useful in extrapolating beyond the locations where species presence is documented (Pearce and Boyce 2006). This is possible through the use of habitat models that formulate relationships between environmental conditions where the species is known to occur and then expand this information across a broader geographic area, beyond where species documentation exists. We used this approach to develop a habitat model and subsequently a habitat suitability map for the foothill yellow-legged frog, *Rana boylii*, in Oregon. Secondly, we addressed disturbances that might pose risk to species persistence at the site scale, and examined associations of these factors with frog occurrence. This threat assessment addressed multiple anthropogenic disturbances that have been identified as having potentially adverse affects on the frogs and that have been posed as explanations for the apparent absence of frogs from modeled suitable habitat. Only threats that could be mapped within the species range were investigated.

Methods

Habitat Modeling

The area selected for habitat modeling was determined by a panel of species experts and based on the species' current and historic distribution in Oregon. It was delineated by grouping 4th - field (i.e., hydrologic unit code) watersheds that encompass the estimated range of the species. This model area boundary enclosed the majority of western Oregon, west of the Cascade crest (Figure 1-1).

The foothill yellow-legged frog is a known stream-associated species (e.g., Hayes et al. 2005). Hence, only the river and stream network within this model area was actually modeled; all other areas within the model area were masked. Linear river and stream GIS data were rasterized using a grid-cell resolution of 100 m (Figure 1-2). The modeled area covered about 16 million acres (~6.5 million ha) and 124,000 miles (~200,000 km) of streams and rivers.

Habitat modeling was conducted by means of an ecological niche factor analysis using BioMapper software-v3.2 (Hirzel et al. 2002). This analysis is well-suited for modeling when only species presence data exists, and absence data are lacking or unreliable. This model compares the environmental conditions that occur where species presence is known, to all sites within the modeled area and computes a habitat suitability index that ranges from 0 to 100. A value close to 0 indicates that conditions at that site are not similar to conditions where the species occurs. Values close to 100 indicate a higher degree of similarity of conditions to where the species occurs. The ecological geometric mean algorithm was used to compute habitat suitability. This algorithm computes habitat suitability based on the density of species presence points within a multi-dimensional ecological “hyperspace” with dimensions that are defined by ecological factors derived from environmental variables. The denser the species points within this hyperspace, the higher the habitat suitability. Additional information about this approach is provided by Hirzel et al. (2002) and Hirzel and Arlettaz (2003).

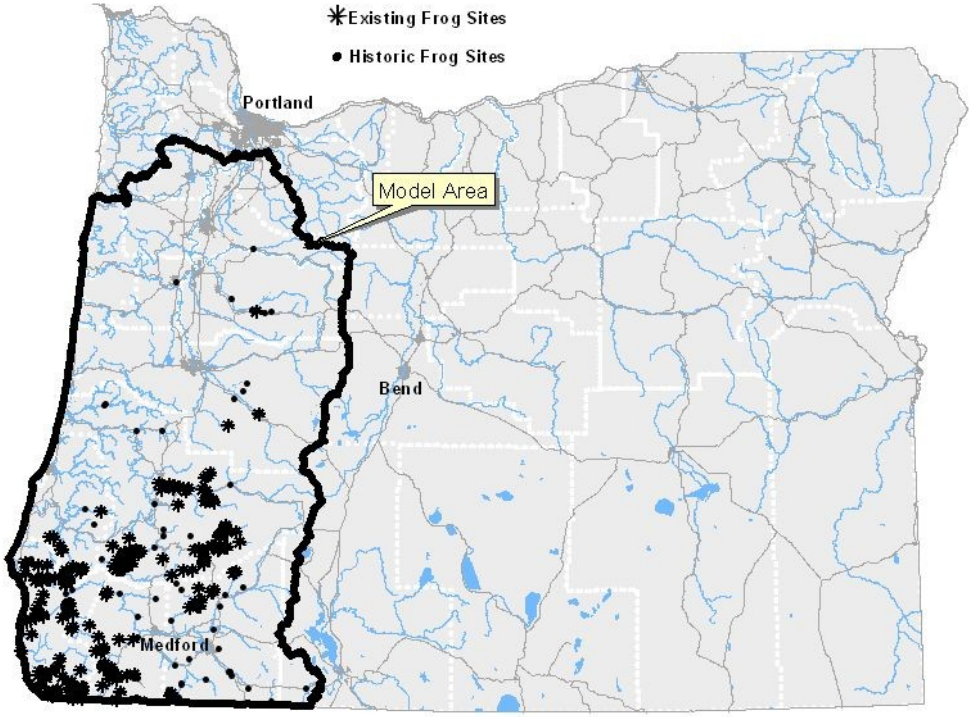
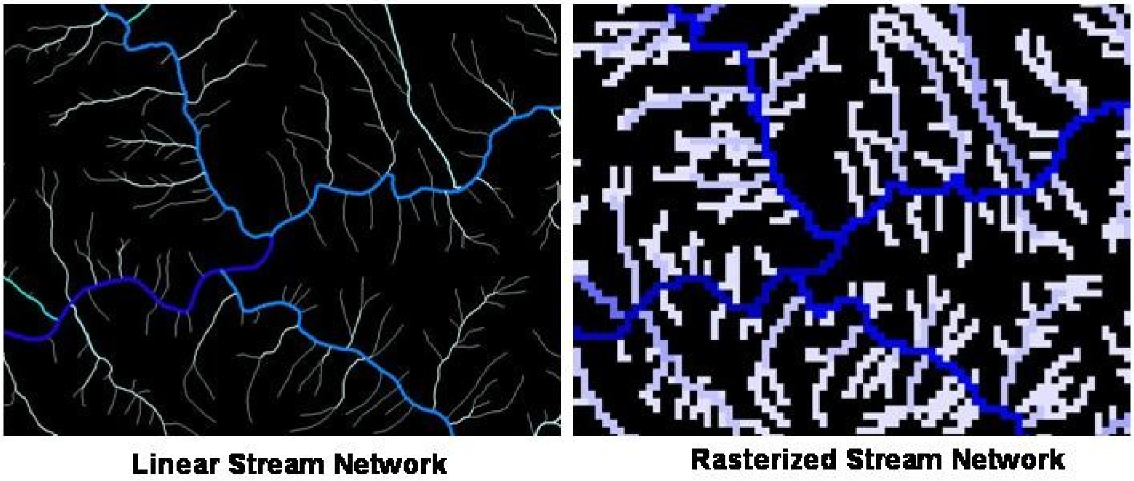


Figure 1-1. Area of western Oregon selected for habitat modeling.


Linear Stream Network

Rasterized Stream Network

Figure 1-2. Linear streams and rivers within the modeled area were rasterized to 100 m for modeling purposes. The black background represents the area masked from modeling.

Because many environmental variables are usually correlated in some manner, they are first standardized to equalize their contribution to the model. This is commonly done by a principal component analysis. BioMapper uses a similar process called an ecological niche factor analysis (ENFA) that takes a set of environmental variables thought to be important to the species, and summarizes them into a few uncorrelated ecological factors. These ecological factors form the dimensions of the ecological hyperspace described above. MacArthur's broken-stick distribution (Jackson 1993) was used to determine the number of dimensions for habitat modeling, as described in Hirzel et al. (2002).

The first ecological factor (Factor 1) computed by ENFA is called the "marginality factor". Its habitat variable coefficient values indicate the differences between where the frog has been found to the average conditions within the analysis area. Positive values indicate that the frog prefers areas with higher than average values, whereas negative values indicate the frog has been found in areas with lower than average values for that habitat attribute. The larger the absolute value, the larger the difference. The remaining factors (Factors 2-8) are called "specialization factors" that explain how selective the species is by comparing the variance of the species distribution to the variance found within the analysis area. Only the absolute value of the habitat variable coefficient indicates the strength of the relationship. Marginality values usually range from 0 to 1, but can be larger than 1 (Hirzel et al. 2002): the higher the value, the greater the difference between species habitat and available sites within the analysis area. The overall value of the marginality factor for the analysis area was 1.053.

Frog presence data used in the model were taken from frog observations compiled for this federal Conservation Assessment. These data were collected from a variety of sources over many years. A total of 699 individual sites, representing thousands of frogs, dating back to 1896 were compiled covering both historic and current observations of this species. Data sources included museums, survey observation and incidental observations. Given the diverse nature and quality of the data sources, an effort was taken ensure that presence data used for modeling was as accurate (both in species identification and spatially) as possible. To this end, data sources were contacted (if possible) and interviewed as to the spatial accuracy and level of assurance of the species identification. There were a few instances (e.g., photo vouchers taken) where juvenile Cascade frogs (*Rana cascadae*) or female tailed frogs (*Ascaphus trueii*) were misidentified as *Rana boylii* (especially in some of the higher elevation sites). These data were not used. In other cases where GPS were not used to record the observation, and the point was subsequently input into GIS based on rough coordinates, the point was moved to coincide with the stream or river in which it was observed. Most sites occurred on federal land, indicating a likely bias in survey effort over the years. A subset of these data were extracted for modeling purposes covering the period from 1990 to 2006, which roughly coincides with the dates of habitat variables used in our modeling. Some presence data were geographically clustered, especially in areas where more intensive surveys were conducted. Because habitat modeling may be susceptible to spatial autocorrelation, a 1-km^2 grid was superimposed on the data set, and only one presence data point per square km was retained for modeling. If several points occurred within a square km, the point nearest the center of the square kilometer was retained and the rest were discarded. A total of 237 sites remained for modeling after the temporal and spatial data screenings.

Our modeling effort focused on the use of biotic and abiotic habitat variables that would produce an estimate of potentially suitable habitat regardless of human influence factors, such as urbanized or agriculturally developed areas. Although it was realized that human interactions are likely important to current distributions of the frog, we attempted to estimate the potential historic distribution, pre-dating intensive human settlement. It is possible that human-caused factors could potentially cloud important relationships between frog presence and the basic habitat variables that would have shaped its niche before Euro-American settlement. Consequently, we addressed human-caused factors secondarily, after ecological habitat modeling, to determine if there were any significant differences between where the frogs are known to occur today, as opposed to where the habitat model predicted they might have occurred.

The habitat variables were selected using species expert knowledge, and assembled from national or region-wide data sources (Table 1-1). We used 13 habitat attributes for this modeling effort – seven climate variables showing different measures of temperature, precipitation and solar radiation; three vegetative variables for measures of tree cover; two topographic variables for measures of slope (stream) gradient and elevation; and one lotic variable for stream order. Prior to running the ENFA, each habitat variable was standardized and normalized using the Box-Cox algorithm (Sokal and Rohlf 1998). Table 1-1 lists and describes each habitat variable used for modeling and the source of the data.

We evaluated our model using the k-fold cross validation procedure described by Hirzel et al. (2006). In brief, this procedure randomly divides the data set of frog presence (n=237) into k-independent partitions. One of these partitions is set aside and the rest are used to calibrate the model. The partition that was set aside is then used to test the model's predictions. This procedure is repeated k-times, each time leaving out a different randomly selected partition. Once completed, the median and 90%-confidence interval for the k-evaluations is then graphed to help interpret the predictive capabilities of the model.

One measure of a model's predictability is based on the Spearman rank correlation (Boyce et al. 2002, Pearce and Boyce 2006). Spearman rank correlations range from -1 to 1. A positive value near 1 indicates a model that is predicting species presence accurately, values close to zero mean that the model is not different from a random chance model, negative values indicate an incorrect model, which predicts poor quality areas where species occur most often. Hirzel et al. (2006) developed Boyce indices in their latest version of BioMapper (v3.2). They advocated two indices; one in which the habitat suitability is divided into 10 classes of equal intervals (e.g., 0-10, 11-20…etc.) called the Boyce index B10, and the other which is based on a continuous "moving window" of habitat suitability scores with a width of 10 that calculates a moving average. The continuous Boyce index Bcont(0.1) was shown to be a slightly more accurate and reliable measure of the model's predictive capability (Hirzel et al. 2006).

Another measure of model accuracy inherent to BioMapper is derived from the Absolute Validation Index (AVI) and Contrast Validation Index (CVI). The Absolute Validation Index (AVI) is the percentage of species presence sites for which the model calculated habitat suitability values >50 (assumed as suitable habitat for the species). The Contrast Validation

Index (CVI) is the difference between AVI and the percentage of the entire analysis area for which the model calculated habitat suitability >50. A CVI of 0 indicates that the model did not predict suitable habitat any better than one could do by guessing randomly (Hirzel and Arlettaz 2003). CVI can never be greater than AVI and the closer its value to AVI, the better the model.

Table 1-1. Habitat variables used in modeling. Each variable is incorporated into ecological factors during the ecological niche factor analysis (ENFA) process.

Type	Variable	Description	Range of values
climate	annualrad	18-yr average daily total shortwave radiation from 1980-1997 (Thornton et al. 1997). Data is from the DaymetUS website - http://www.daymet.org/	Continuous integer values from 4 to 16 MJ-m²/day
	precipfreq	18-yr average annual frequency of precipitation from 1980-1997 (Thornton et al. 1997). Data is from the DaymetUS website - http://www.daymet.org/	Continuous integer values from 19 to 46% of year
	preciptotal	18-yr average annual total precipitation from 1980-1997 (Thornton et al. 1997). Data is from the DaymetUS website - http://www.daymet.org/	Continuous integer values from 51 to 347 cm/day
	summermax	18-yr average daily maximum air temperature between Jun-Aug 1980-1997 (Thornton et al. 1997). DaymetUS website - http://www.daymet.org/	Continuous integer values from 32 to 84ºF
	summermin	18-yr average daily minimum air temperature between Jun-Aug 1980-1997 (Thornton et al. 1997). DaymetUS website - http://www.daymet.org/	Continuous integer values from 28 to 51ºF
	summerrad	18-yr average daily total shortwave radiation between Jun-Aug 1980-1997 (Thornton et al. 1997). DaymetUS website - http://www.daymet.org/	Continuous integer values from 0 to 24 MJ-m²/day
	wintermin	18-yr average daily minimum air temperature between Dec-Feb 1980-1997 (Thornton et al. 1997). DaymetUS website - http://www.daymet.org/	Continuous integer values from 12 to 39ºF
vegetative	brdlfcov	Percent cover by broadleaf trees. Data is remote sensed Landsat TM data from the Interagency Vegetation Mapping Project (IVMP) http://web.or.blm.gov/gis/projects/ivmp.asp	Continuous integer values from 0 to 100%
	conifcov	Percent cover by conifer trees. Data is remote sensed Landsat TM data from the Interagency Vegetation Mapping Project (IVMP) http://web.or.blm.gov/gis/projects/ivmp.asp	Continuous integer values from 0 to 100%
	totalcov	Percent total tree cover. Data is remote sensed Landsat TM data from the Interagency Vegetation Mapping Project (IVMP) http://web.or.blm.gov/gis/projects/ivmp.asp	Continuous integer values from 0 to 100%
topographic	elevation	Elevation from USGS digital elevation models from the USGS National Elevation Dataset website - http://ned.usgs.gov//	Continuous integer values from 0 to 2,952 meters
	slope	Stream or river gradient as derived from USGS digital elevation models from the USGS National Elevation Dataset website - http://ned.usgs.gov//	Continuous integer values from 0 to 48 degrees
lotic	strahler	Stream order using the Strahler system (Strahler 1957). Base watercourse data from the PNW Hydrography Framework Clearinghouse (USDI 2005) http://hydro.reo.gov/	Continuous integer values from 1 to 9

Threat Assessment

Our threat assessment investigated disturbances within the species range that may pose risk to its persistence and explain the current pattern of occurrence in Oregon. We assessed potential threats in two spatial contexts; 1) an area representing the core area where 95% of the current documented frog sites occur; and 2) the area of modeled suitable habitat outside of this core area, where there is an apparent lack of frog presence (Figure 1-3). Delineation of these areas was performed non-subjectively using 95%-kernels of the presence data set to delineate the core area where frogs are known to still occur and the 95%-kernel of all suitable (HS>40) modeled habitat.

Across both areas, ten GIS coverages (Table 1-2) representing potential landscape-scale threats to the frog were created using historic and/or existing maps and data sources. The IVMP maps used for tree canopy closures (Table 1-1) were also the source for agricultural lands as of 1996. Historic forest type maps from Elliot (1914) and Harrington (2003) along with change detection data for Oregon and Washington covering the period from 1972-2002 (Healy et al. 2002) were used to represent clearcut timber harvesting and stand-replacing wildfire. Water impoundment data were provided by Streamnet data and then cross-referenced with hydrography coverages for waterbodies (USDI 2005) to accurately map large impoundments (>50ha surface area) and hydropower dams. Historic splash-dam locations were mapped from a figure in Sedell and Luchessa (1988). City locations came from the Oregon State geospatial data website (http://www.gis.state.or.us/data/alphalist.html) and road density was derived in GIS using the Interagency Monitoring Oregon road coverage. See Table 1-2 for data sources.

Table 1-2. Landscape-scale variables often thought of as threats to *Rana boylii*. These variables were used in the Mann-Whitney test of the Borisenko and Hayes (1999) data.

Variable	Description	Range of values
1	Agricultural lands within a 5km radius - mapped in GIS using roving window on agricultural areas mapped by IVMP	Continuous integer values from 0 to 92%
2	Distance from agriculture (km) - distance analysis mapped in GIS using agricultural lands mapped by IVMP	Continuous integer values from 0 to 72 km
3	Distance from all streamnet dams (km) - distance analysis mapped in GIS using data from http://www.streamnet.org	Continuous integer values from 0 to 38 km
4	Distance from cities (km) - distance analysis mapped in GIS using cities point locations from http://www.gis.state.or.us/data/alphalist.html	Continuous integer values from 0 to 35 km
5	Distance from historic splash dam (km) - distance analysis mapped in GIS using hand digitized data from Sedell and Luchessa (1988)	Continuous integer values from 0 to 151 km
6	Distance from hydropower dam (km) - distance analysis mapped in GIS using data from http://www.streamnet.org and http://hydro.reo.gov/	Continuous integer values from 0 to 99 km
7	Distance from large (>50ha) dams (km) - distance analysis mapped in GIS using data from http://www.streamnet.org and http://hydro.reo.gov/	Continuous integer values from 0 to 79 km
8	Road density (mi/mi^2) - road density analysis in GIS using road data from http://www.reo.gov/monitoring/10yr-report/maps-maps.html	Continuous integer values from 0 to 15 mi/mi^2
9	Cumulative clearcuts within a 5km radius (%) - mapped in GIS using roving window on data from Elliot (1914), Harrington (2003) and Heally et al (2002).	Continuous integer values from 0 to 94%
10	Cumulative stand-replacing fires within a 5km radius (%) - mapped in GIS using roving window on data from Elliot (1914), Harrington (2003) and Heally et al (2002).	Continuous integer values from 0 to 100%

We compared (Mann Whitney test) the values of these landscape-scale threat variables between historic sites where frogs were and were not detected during a recent re-survey in 1997-1998 (Borisenko and Hayes 1999). Borisenko and Hayes conducted a Mann-Whitney test on site-specific variables such as stream substrates; no analysis was performed on landscape-scale variables. To avoid spatial autocorrelation in our analysis, we selected a subset of data by using only one site per 6th-field watershed (HUC 6: hydrologic unit code designation for regional sub-watersheds ranging about 4,000-12,000 ha). If more than one site occurred within a 6th-field watershed, then only one site was randomly selected, regardless of whether it represented presence or absence (i.e., not detected during the 1997-1998 survey). From the total set of 91 sites, 70 were retained for this analysis (Figure 1-3).

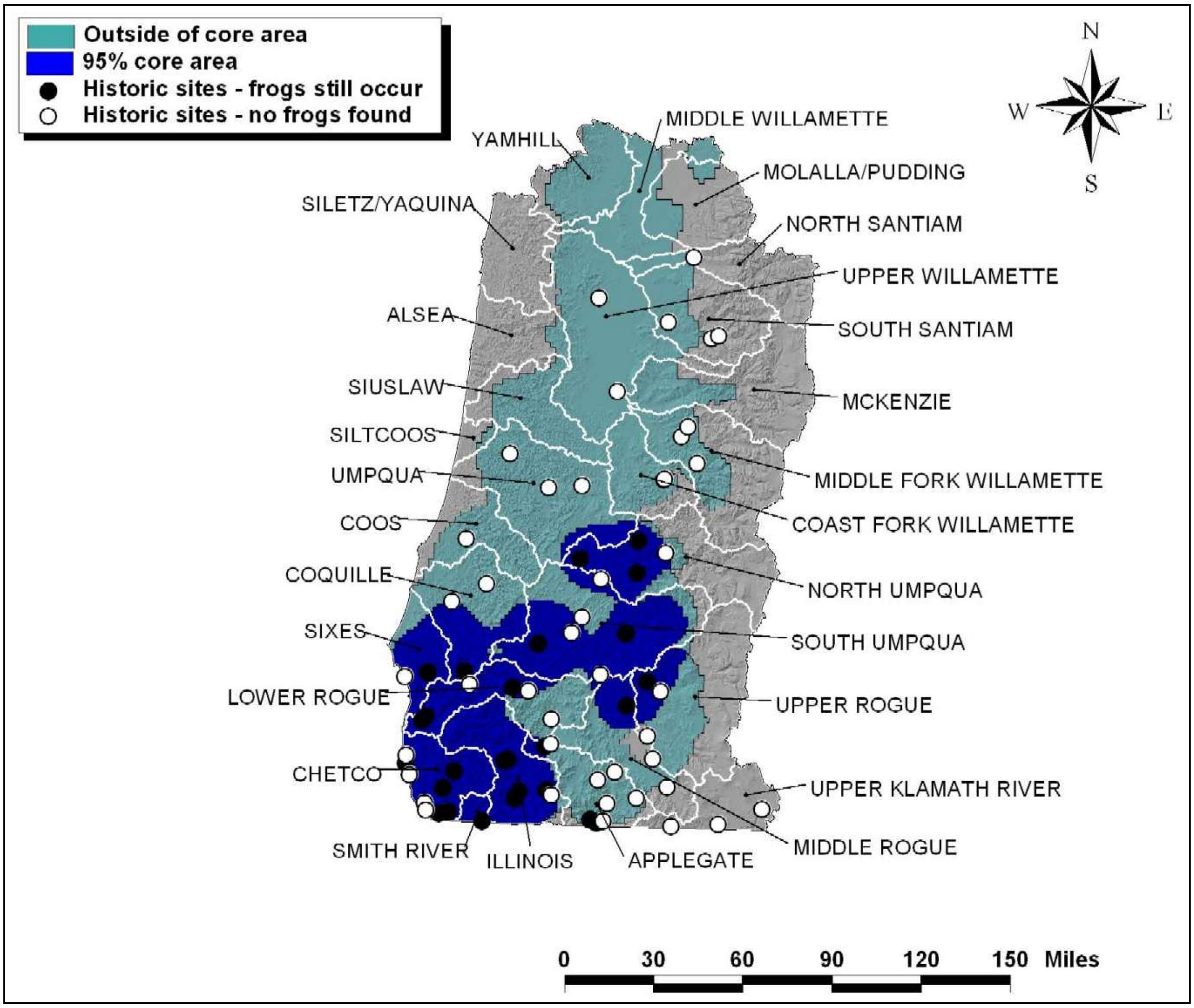


Figure 1-3. Map of estimated "core area" of frog presence and distribution of suitable habitats, showing Borisenko and Hayes (1999) data used for the Mann-Whitney test comparison of threat factors between sites with and without frogs.

Subsequent to the Mann-Whitney test, a simple comparison of average landscape conditions (with 95% confidence intervals) was performed for all frog presence sites used in habitat modeling (n=237) and 1000 bootstrapped replicates (with replacement) of an equivalent density (n=383) of randomly generated sites with suitable habitat outside of the core area (n=383). While this analysis may be statistically questionable because it has elements of pseudoreplication (the sampled areas are not identical), we felt that it could reveal interesting hypotheses regarding potential threats to the frog that could be pursued in future research or monitoring. Figure 1-4 shows only one of these replicates.

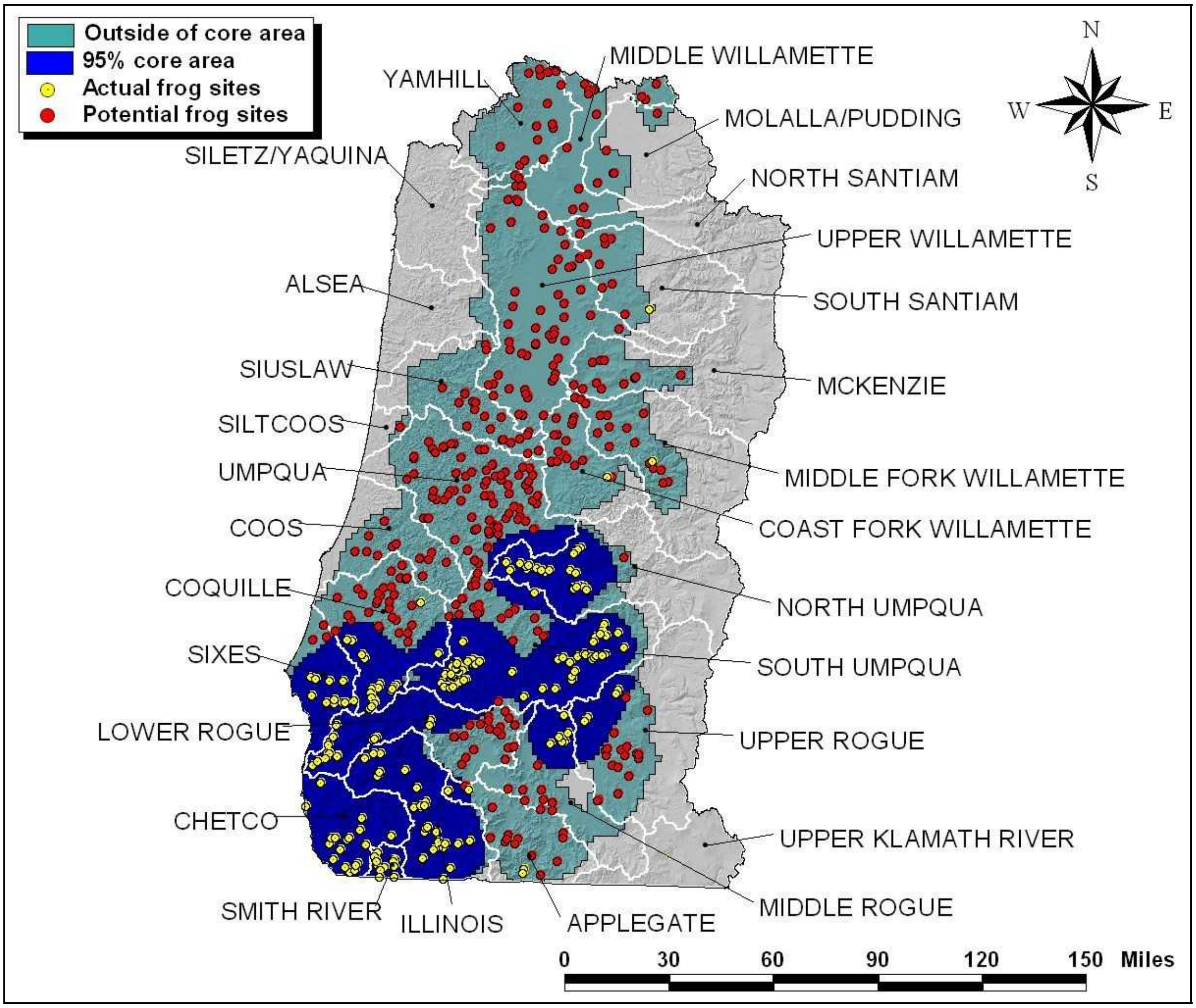


Figure 1-4. Map of estimated "core area" of frog presence and distribution of suitable habitats, showing all current frog presence sites used for modeling (yellow dots) and one replicate of randomly generated "potential sites" (red dots) used for a means comparison.

Results

Habitat Modeling

In our habitat modeling approach using ENFA, 13 environmental variables (Table 1-1) were converted into eight ecological factors (Table 1-4) that explained 89% of the species presence information. Stream order and minimum temperatures were important habitat attributes explaining species presence, followed by precipitation frequency, stream gradient and elevation, which also top the list of many of the specialization factors (Tables 1-4).

Our cross-validation Boyce indices were as follows: B10 = 0.912 ± 0.075 and Bcont(0.1) = 0.895 ± 0.068. These values indicate that our habitat model had a high predictive capability (Figure 1-5). The AVI for our model was 0.522 (SD=0.153) and the CVI was 0.486 (SD=0.148), showing a small difference (0.036) between the two. This small difference is another indicator that our model predicted foothill yellow-legged frog presence fairly accurately.

Our habitat map shows distinct stream and river reaches that appear to have suitable habitat for the frog. The area of highest suitability (given the term "optimal") appears to be within the Umpqua River basin (includes the Umpqua, North and South Umpqua 4th -field watersheds), but also in portions of the Chetco, Coos, Coquille, Illinois, Rogue, Siuslaw, Sixes, Smith (North Fork) and Willamette river systems (Figure 1-6 and Appendix 2). Suitable habitat extends the full north and south breadth of the model area, but is confined to the foothills and large river canyons of the Cascade Range and interior margins of the Coast Range along the Willamette Valley. Habitat occurs along the coast to the Coos watershed near the area where the coastal dunes and lakes begin, and then begins to trend away from the coastline and recede to the east.

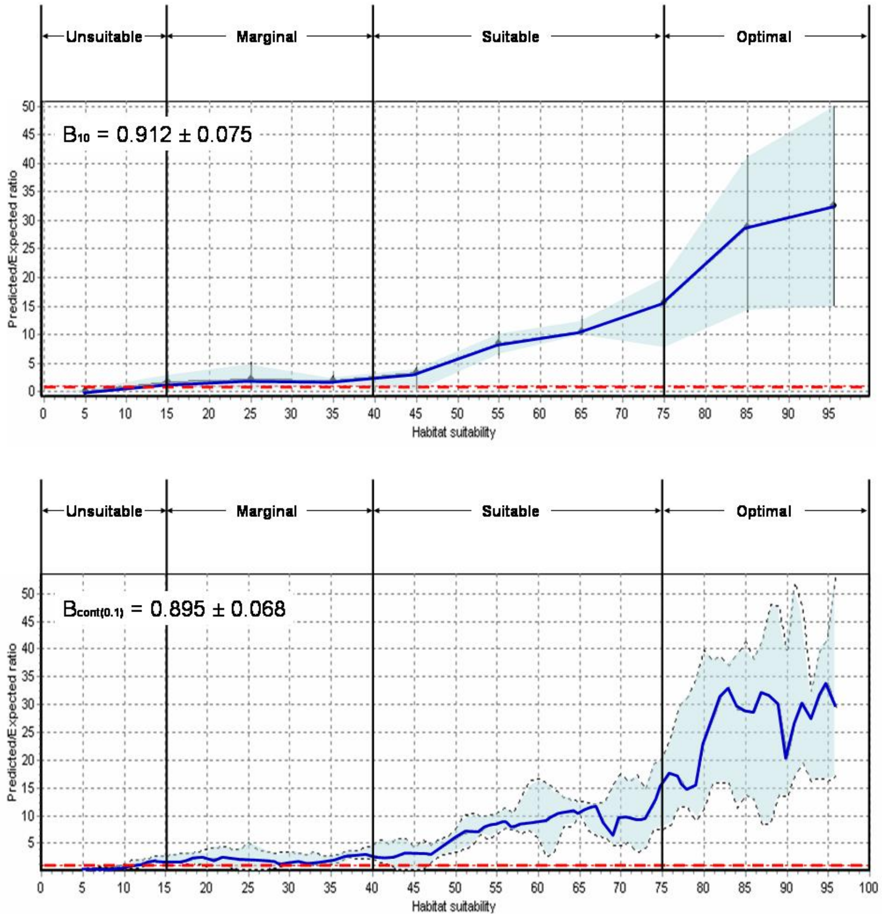


Figure 1-5. Results of the k-fold cross model validation, showing the Boyce Indices (top: B10 index; bottom: continuous Bcont(0.1) index) and how the curve was divided into areas representing unsuitable, marginal, suitable and optimal habitat (Hirzel et al. 2006).

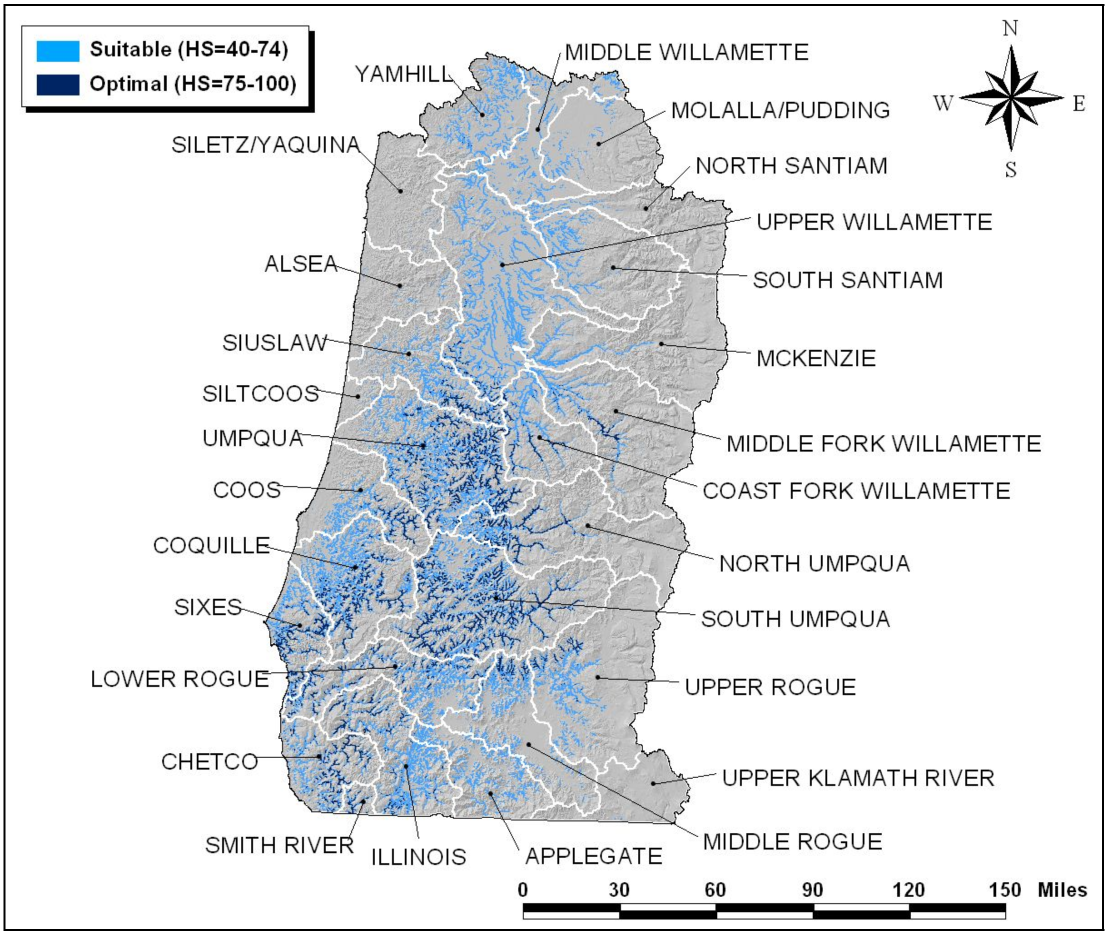


Figure 1-6. Modeled habitat (blue) for the foothill yellow-legged frog in relation to 4th -field watersheds (white boundary lines).

Table 1-3. Marginality factor habitat variables and coefficient values in order of magnitude with corresponding means and standard deviations for both the species and analysis area (available sites).

Weight	Habitat EGV	Description	Species Sites		Available Sites	
			Mean	SD	Mean	SD
+ 0.74	strahler	stream order	5.3	1.5	2.0	1.5
+ 0.32	summermin	daily min temp Jun-Aug (ºF)	47.8	1.2	46.3	2.4
+ 0.31	wintermin	daily min temp Dec-Feb (ºF)	33.2	2.1	31.2	3.4
− 0.30	precipfreq	precipitation frequency (% of year)	33.8	2.9	36.8	5.1
− 0.23	slope	stream gradient (degrees)	8.7	6.5	12.6	8.2
− 0.21	elevation	meters above sea level (m)	334.9	193.9	533.1	393.5
+ 0.16	summermax	daily max temp Jun-Aug (ºF)	73.4	4.8	71.8	4.8
+ 0.12	brdlfcov	broadlead cover (%)	25.0	22.5	20.1	20.2
+ 0.11	annualrad	annual daily shortwave radiation (MJ-m^2/day)	13.3	0.5	13.2	0.7
− 0.09	conficov	confier cover (%)	44.5	31.7	52.7	35.8
− 0.06	totalcov	total tree cover (%)	67.2	29.6	70.9	32.6
+ 0.05	summerrad	daily shortwave radiation Jun-Aug (MJ-m^2/day)	21.3	0.8	21.2	0.9
− 0.04	preciptotal	annual precipitation total (cm)	163.4	52.6	167.3	48.2

Table 1-4. Results of the ecological niche habitat analysis showing the influence of the 13 habitat variables in descending order of importance. The marginality factor is Factor 1, the specialization factors are Factors 2-8. These eight factors represent the dimensions of the hyperspace representing the niche. The values in the parentheses represent the coefficient values. The amount of specialization accounted for by each factor is given in parentheses in each column heading.

variable	Factor 1 (28%)	Factor 2 (19%)	Factor 3 (13%)	Factor 4 (9%)	Factor 5 (6%)	Factor 6 (6%)	Factor 7 (4%)	Factor 8 (4%)
1	strahler (0.74)	wintermin (0.54)	precipfreq (0.69)	elevation (0.75)	summermax (0.66)	totalcov (0.63)	elevation (0.50)	summermin (0.61)
2	summermin (0.32)	summermin (0.45)	elevation (0.43)	wintermin (0.58)	preciptotal (0.63)	brdlfcov (-0.53)	conifcov (-0.45)	wintermin (-0.40)
3	wintermin (0.31)	strahler (-0.41)	wintermin (0.38)	annualrad (-0.20)	summerrad (0.25)	conifcov (-0.44)	summerrad (0.43)	summerrad (0.35)
4	precipfreq (-0.30)	elevation (0.34)	summermin (0.25)	summerrad (0.14)	annualrad (-0.17)	preciptotal (-0.22)	summermax (-0.36)	preciptotal (0.31)
5	slope (-0.23)	annualrad (0.24)	summermax (-0.24)	slope (0.13)	conifcov (-0.12)	precipfreq (-0.17)	wintermin (0.25)	totalcov (0.30)
6	elevation (-0.21)	preciptotal (-0.23)	preciptotal (-0.19)	precipfreq (0.10)	strahler (-0.12)	annualrad (-0.16)	summermin (0.24)	annualrad (0.26)
7	summermax (0.16)	summerrad (-0.20)	strahler (0.15)	summermax (0.06)	brdlfcov (-0.12)	summermax (-0.15)	precipfreq (0.23)	precipfreq (0.19)
8	brdlfcov (0.12)	conifcov (0.15)	slope (-0.08)	totalcov (0.06)	wintermin (0.11)	wintermin (0.08)	brdlfcov (-0.19)	summermax (-0.17)
9	annualrad (0.11)	totalcov (-0.14)	annualrad (0.05)	conifcov (-0.06)	slope (-0.10)	slope (-0.06)	preciptotal (-0.10)	conifcov (-0.14)
10	conifcov (-0.09)	summermax (0.11)	totalcov (-0.04)	summermin (0.06)	elevation (0.07)	summerrad (-0.06)	slope (-0.09)	brdlfcov (-0.09)
11	totalcov (-0.06)	brdlfcov (0.10)	conifcov (0.03)	strahler (0.04)	totalcov (0.07)	strahler (0.02)	annualrad (-0.07)	slope (0.06)
12	summerrad (0.05)	slope (-0.04)	summerrad (0.02)	preciptotal (0.01)	summermin (-0.05)	elevation (0.01)	totalcov (0.06)	elevation (-0.04)
13	preciptotal(-0.04)	precipfreq (-0.01)	brdlfcov (-0.01)	brdlfcov (0.00)	precipfreq (0.01)	summermin (0.00)	strahler (0.04)	strahler (0.01)

Threat Assessment

Seven of the ten landscape-scale potential threat variables examined were significantly different between sites with and without frogs (Table 1-5, presence/no detection data from recent resurvey by Borisenko and Hayes 1999). Sites with frogs were further from hydropower facilities, cities, agricultural lands and dams in general. They also contained less agricultural land and fewer roads within the landscape immediately surrounding the site. The amount of clearcut timber harvesting or stand-replacing wildfire did not differ between sites with and without frogs.

Table 1-5. Results of Mann-Whitney test of potential landscape-scale threats at survey sites from Borisenko and Hayes (1999). Median values are shown for sites where frogs were documented (presence) and sites where frogs were not found (absence).

Potential Threat Variable	Presence (n = 26)	Absence (n = 44)	U	Alt Hypothesis	p-value*
Distance from hydropower dam (km)	44.5	21.5	851	Absence ≤ Presence	0.0004
Distance from cities (km)	8.5	3.0	817	Absence ≤ Presence	0.0014
Agriculture within a 5km radius (%)	0.0	1.0	763	Absence ≥ Presence	0.0063
Distance from agriculture (km)	7.0	0.0	769	Absence ≤ Presence	0.0064
Road density (mi/mi^2)	4.0	5.0	768	Absence ≥ Presence	0.0081
Distance from all streamnet dams (km)	10.5	4.5	756	Absence ≤ Presence	0.0124
Distance from large (>50ha) dams (km)	24.5	17.5	695	Absence ≤ Presence	0.0673
Distance from historic splash dam (km)	55	31	670	Absence ≤ Presence	0.1179
Clearcuts within a 5km radius (%)	7.0	10.5	668	Absence ≥ Presence	0.1223
Stand-replacing fire within a 5km radius (%)	10.5	10.5	613	Absence ≥ Presence	0.3088

* *normal approximation, corrected for ties*

A look at average conditions for all current sites (n=237) and random sites (1000 replicates of 383 bootstrapped with replication) outside of the core area yet within modeled suitable habitat for the frog suggest that landscape conditions and anthropogenic disturbances differ in these two zones (Figure 1-7).

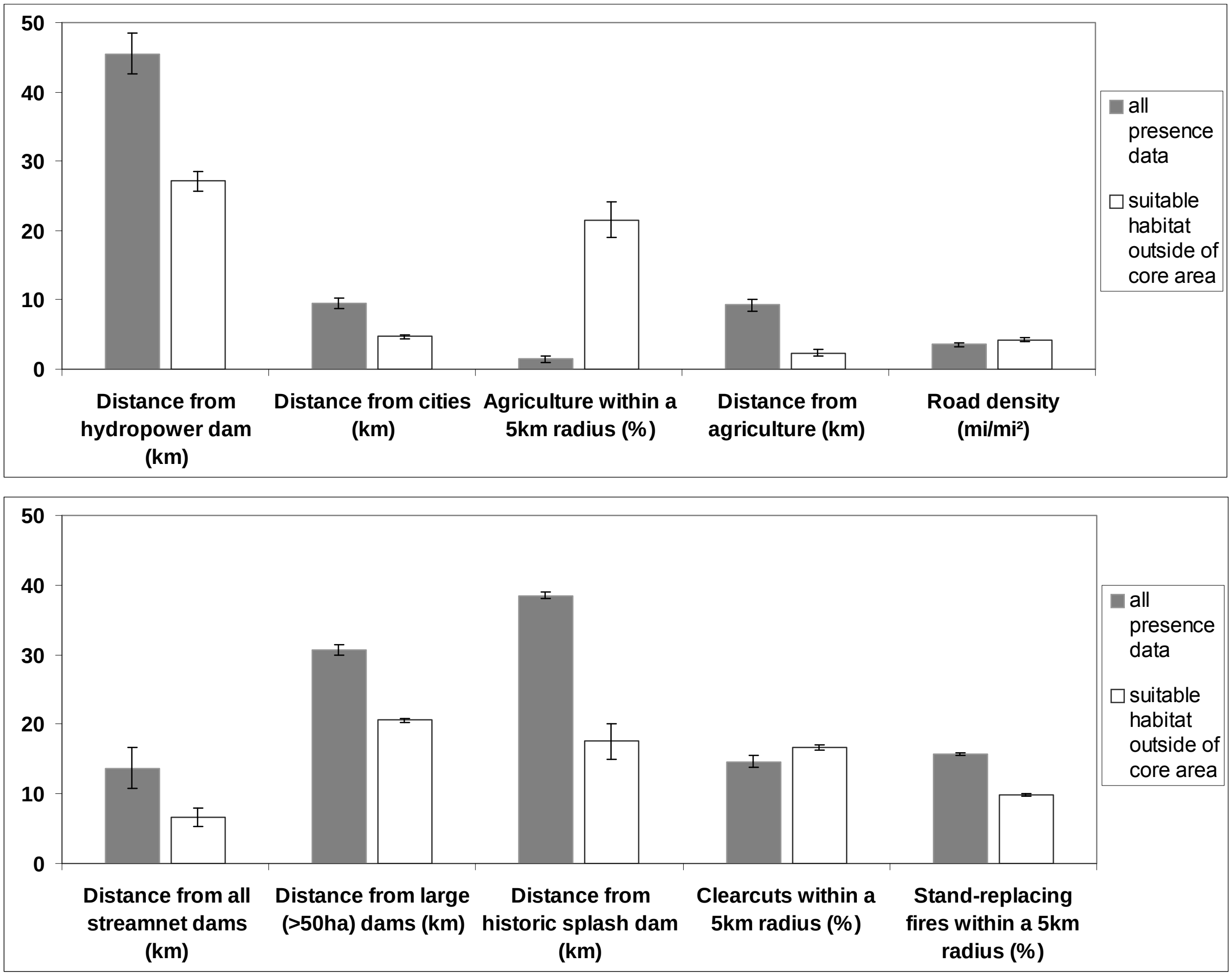


Figure 1-7. Mean values (and 95% confidence intervals) for landscape-scale potential threat variables at sites with current frog presence (n=237) and bootstrapped sample of the area of suitable habitat outside of the core area.

Discussion

Our habitat model mirrors expert opinion in the literature about habitat associations of the foothill yellow-legged frog (e.g., Hayes et al. 2005, Borisenko and Hayes 1999). For western Oregon, our model shows the frog to occur in gentler, lower elevation, higher-order streams, with a moderately open canopy of hardwood and conifer, in areas that experience relatively warmer temperatures and sunnier days.

Our habitat map is the first visual display of potentially suitable habitat for this frog in Oregon. It shows habitat may occur in several drainage basins of southwestern Oregon. This map can help focus survey efforts in areas where frogs have not been surveyed or reported, and may help identify areas of potentially optimal habitat conditions within and among watersheds for future management emphasis.

Our findings relative to potential threat factors affecting frog distributions are consistent with or support assumptions in other studies (Davidson et al. 2002, Borisenko and Hayes 1999, Lind et al. 1996). It should be emphasized that our correlations cannot be extended to definitive explanations of cause and effect relative to frog occurrence. Nevertheless, our results suggest that proximity to hydropower and other dams, agricultural land, cities and road density are negatively associated with foothill yellow-legged frog distributions in Oregon. Disturbances that affected forest canopies and stand structure (e.g., stand-replacing wildfire and clearcuts), however, did not seem to influence the frogs in our cursory analysis of these at the landscape-scale (e.g., within 5 km of localities examined). We were unable to analyze the potential affects of other perceived threats, such as the presence of introduced predatory exotic species (e.g., bass, bullfrogs) because of lack of geographic information on their occurrence. However, there is evidence that invasive species may pose a significant threat to this native frog (Hayes and Jennings 1986, Kupferberg 1997, Kiesecker and Blaustein 1998, Adams 1999). The effects of mining activities in southwestern Oregon is another factor that was not addressed here but may warrant further consideration relative to its effects on this stream frog.

The available data (geographic and written) were useful for modeling habitat for the foothill yellow-legged frog and establishing a baseline map for future use in the conservation of this species. It is expected that our map will evolve as more information is gathered on the species distribution and use of habitat. Our analysis also sheds light on possible threats to the species, as well as habitat relationships. It appears that the range of the frog has shrunk in Oregon. The core area appears to be in the southwestern portion of the State.

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