Conservation Assessment for the

Foothill Yellow-legged Frog

in Oregon

(*Rana boylii*)

Version 1.0

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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This Conservation Assessment was prepared to compile the published and unpublished information on the foothill yellow-legged frog (Rana boylii).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/

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.

TABLE OF CONTENTS

I. INTRODUCTION

Goal

The primary goal of this Conservation Assessment is to provide the most current information known about this species including life history, habitat, and potential threats, and to describe habitat and site conditions that may be desirable to maintain if management of a particular site or locality for the species is proposed. This species is an endemic vertebrate to Oregon, California, and northern Baja California, with the known range in Oregon restricted to the southwest portion of the state. It is recognized as a potentially vulnerable species by various Federal and State agencies because it is potentially susceptible to land management activities that occur within its range and a number of historic sites appear to be extirpated. The goals and management considerations of this assessment are specific to BLM and Forest Service lands in Oregon. The information presented here was compiled to help manage the species in accordance with Forest Service Region 6 Sensitive Species (SS) policy and Oregon/Washington Bureau of Land Management Special Status Species (SSS) policy. Additional information for Region 6 SS and Oregon BLM SSS is available on the Interagency Special Status Species website (www.fs.fed.us/r6/sfspnw/ISSSSP).

For lands administered by the Oregon/Washington Bureau of Land Management (OR/WA BLM), SSS policy (6840 manual and IM OR-91-57) details the need to manage for species conservation.

For Region 6 of the Forest Service, SS policy requires the agency to maintain viable populations of all native and desired non-native wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands. Management "must not result in a loss of species viability or create significant trends toward federal listing" (FSM 2670.32) for any identified SS.

Scope

While synthesis of biological and ecological information for this species focused on Oregon, relevant range-wide references also were included. We relied on published accounts, reports, locality data from individuals and databases, and expert opinion, each noted as appropriate. Although we did not restrict this compilation to information coming from Federal sources, site data were largely compiled from Federal lands and the scope of the management considerations of this assessment are specific to BLM and Forest Service lands in Oregon. Historic records of observations or museum collections are located on the Lakeview, Medford, Coos Bay, Roseburg and Eugene BLM Districts, and the Rogue River-Siskiyou, Umpqua, and Willamette National Forests. Also, due to the occurrence of modeled optimum habitat (Appendix 1), this species is suspected to occur or to have historically occurred on the Salem BLM District and Siuslaw National Forest.

Management Status

State and Federal agencies classify the foothill yellow-legged frog as a potentially vulnerable species due to its restricted distribution and vulnerability to a variety of anthropogenic disturbances. It is listed by the: USDA Forest Service, Region 6 and Region 5, as Sensitive; USDI Bureau of Land Management, Oregon, as Sensitive; Oregon State as Sensitive-Vulnerable; US Fish and Wildlife Service as a Species of Concern; NatureServe as Globally Vulnerable (G3, at moderate risk of extinction due to a restricted range), Oregon State imperiled/rare (S2S3, uncommon or threatened but not immediately imperiled), 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.

II. CLASSIFICATION AND DESCRIPTION

Systematics

The foothill yellow-legged frog (*Rana boylii* Baird, 1854; Fitch 1938) is among the first-described ranids endemic to western North America (formerly *R. boylei*). Zweifel (1955) recognized it as a distinct species in 1955. The "boylii" group of western ranids seems to have diverged from other ranids about 8 million years ago (Macey et al. 2001). Based on morphological analyses, *R. boylii* was thought to be most closely related to *R. muscosa*, the mountain yellow-legged frog (Zweifel 1955). However, a recent phylogenetic analysis allied it most closely to *R. pretiosa*, the Oregon spotted frog (Macey et al. 2001). Several studies have detected intraspecific genetic variation (Case 1978, Lind 2004, Devers 2007).

Species Description

This is a small ranid frog, with a snout-vent length (svl) ranging 14-83 mm, from metamorph to adult. Females are larger than males (males may grow to 65 mm svl, Borisenko and Hayes 1999). Key characteristics include a rough, grainy skin texture that is a bit toad-like, small eardrums and indistinct dorsolateral. Adults are gray or brown dorsally, sometimes speckled, and ventral surfaces of hind limbs are cream to yellow. The throat may have gray mottling. Hind toes are fully webbed.

Egg masses are found in stream and river margins, are round and attached to substrate (often the downstream-sides of rocks), and are about the size of an orange or grapefruit (<150 mm diameter, individual egg size range 1.9-2.4 mm diameter, Hayes et al. 2005). Egg masses become covered with silt, and can be cryptic. Tadpoles have eyes situated dorsally and a flattened body. They are black, brown, gray, olive or beige with gold flecking dorsally. The tail fin is colorless or with dark specks. The mouth is oriented downward, is large, and has more tooth rows than in other ranids: 6-7 anterior; 5-6 posterior (Zweifel 1955, Nussbaum et al. 1983, Corkran and Thoms 2006). Tadpoles can be 8-70 mm total length. Metamorphs are 14-28 mm svl (Fellers 2005, Hayes et al. 2005).

III. BIOLOGY AND ECOLOGY

Life History

This is a stream/river frog. Eggs are deposited in streams in slow-moving water or backwater locations. Eggs take 5-37 days to hatch and larvae take 3-4 months to metamorphose (Fellers 2005). Based on data from California, males breed at 1 year old, at about 40 mm snout-to-vent length (svl); females breed at >2 years old (Zweifel 1955). The life span of this frog is not well known, however, marked frogs in Oregon were estimated to be 4 years old and skeletochronology revealed 6-year-old females, with one estimated to be 8 years (C. Rombough, pers. commun.). Van Wagner (1996) recaptured a female that was at least 3 years old. Other native western ranids may live 10-12 years. Overwintering appears to occur within streams/rivers and along stream/river edges under various loose substrates (e.g., woody debris, rocks, etc.) and in seeps along the stream margin (Rombough 2006).

Movements

Home ranges and dispersal patterns of the foothill yellow-legged frog are poorly understood. Frogs have been found 50 m (Nussbaum et al. 1983) to 70-80 m (C. Rombough, pers. commun.) from water. Along streams, Van Wagner (1996) reported seasonal movements of about 450 m for this species in California, and an 800 m movement distance is known from Oregon (C. Rombough, pers. commun.). Movements of marked animals were not noted to occur November through March in Oregon (C. Rombough, pers. commun.). Radio telemetry tracking of post-breeding adult females in California documented dispersal distances from 0 to 7,043 m (R. Bourque, pers. commun.) where, over the course of 60 days, one female traveled upstream along the main channel of a perennial stream, then up intermittent and dry tributary channels, then over a ridge eventually working her way downstream to perennial waters in an adjacent watershed (R. Bourque, pers. commun.). Other ranids have capabilities of dispersing kilometers overland; however, according to Nussbaum et al. (1983) this species is likely restricted to movements along streams or stream-riparian corridors. Their likely restriction to riparian corridors needs further study because of the low detectability of frogs in uplands. Dever's (2007) genetic study suggested that a distance of 10 km may effectively isolate frog populations along a river system (i.e., frogs this distance apart on a river are not part of a single interbreeding population). These findings were in the absence of apparent physical barriers or disturbances that may pose threats and fragment populations.

Breeding Biology

Breeding occurs in spring, March-June, often at locations that appear to be used year-after-year. In California, breeding sites were in "wide shallow areas of streams with low water velocity", and 7 of 11 (63%) oviposition sites sampled were used for three consecutive years (Lind 2004). In Oregon, oviposition was reported in off-channel pools and troughs (Rombough and Hayes 2005). Breeding seems to occur when high water flows subside in late spring. Across its entire range, duration of breeding at a site has been reported to range from 2 weeks to 3 months (Fellers 2005). Males call during breeding, frequently from underwater but occasionally from the water surface (M. Hayes, pers. commun.). Their call has been described as a "quiet, throaty, short, lowpitched trill" (Corkran and Thoms 2006) and as "a series [5 to 7 notes] of distinct, rubbery clucks" (Rombough and Hayes 2005). Several males may call from the same general vicinity within the stream. The pairing process is not described, but presumably females are attracted to male calls. Once paired, females use their hind feet to prepare an oviposition site on a rock, scraping away algae and sediment (Wheeler et al. 2003, Rombough and Hayes 2005). Egg masses are laid along the low-velocity margins of streams, usually in water less than 0.5 m deep. Females deposit from 300 to 2,000 eggs. In one observation egg deposition took 1.5 minutes (Rombough and Hayes 2005) and in another observation it took 8 minutes (Wheeler et al. 2003). Egg masses are located at breeding sites and eggs are usually attached to the downstream-side of rocks, but sometimes other solid, stationary substrates.

Range, Distribution, and Abundance

The species range extends from Oregon to California, with one isolated population in Baja California, Mexico (Fellers 2005, Hayes et al. 2005). In Oregon, the current range of the species includes the southern Coast Range and southwestern Cascade Range (Figures 1 and 2). In our data compilation, records occurred from 0 m to 830 m elevation. This range includes Coos, Curry, Douglas, Jackson, Josephine, Klamath, Lane and Linn counties in Oregon. Historic sites also occurred in Marion and Benton counties, but these appear to be extirpated. Borisenko and Hayes (1999) surveyed the 90 historic locations in Oregon with adequate locality information to permit locating sites for resurvey. They found only 39 of 90 (43%) historic sites to be occupied, with the Rogue River watershed having the most occupied sites among the 9 occupied watersheds sampled (Chetco, Coquille, Elk, Pistol, Rogue, Smith, Umpqua, Willamette, Winchuck); the species was not detected in 6 additional watersheds during their survey (Brush, Coos, Hooskanadan, Klamath, Myers, Tuttle). For this Conservation Assessment, we conducted a geographic evaluation of these data to determine occupancy of 5th field watersheds within the species' estimated current range in Oregon: frogs occurred in 51 of 86 watersheds.

To date in Oregon, 699 data records have been compiled, dating back to 1896. Of these, the large majority (n = 645, 92%) have been documented between 1990 and 2006; for the purpose of this Conservation Assessment, these observations are treated as recent. These observations represent two types of data. First, some of these data include point sightings of individuals or groups of individuals. Secondly, some of these records are a single point representative of a larger area, study site, or stream reach in which this species was detected. It is important to note that not all of these "recent" observations were verifiable; voucher specimens or photographs documenting accurate species identification were not available for all records. At this time, the subset of verified recent records has not been determined, and this is an information need. Nevertheless, to the extent practical, some amount of verification was done (see Appendix 1) and we used the remaining data to gauge likely species distribution in Oregon. In order to consolidate these records into a more appropriate format for analyzing distribution and abundance, both record types were buffered by 500 m and those within this distance of another record were combined into one point locality, and here, these consolidated points are treated as individual (separate) sites. The 500-m buffer distance was chosen because it may represent the distance a frog may disperse (Van Wagner 1996; M. Hayes, pers. commun.). Using this process, 699 observation records were consolidated into 229 sites. Of the 645 recent observations (1990-2006), 177 sites were mapped (Figure 1). Gaps in both distribution and knowledge may be apparent by inspecting the site distribution map (Figure 1). Lack of observations on this map likely reflects both a lack of surveys in addition to a patchy occurrence of this animal across its range.

Minimum convex polygons were used to represent the range of this species across drainage areas in Oregon (Figure 1). Based on the site data described above, the historic range of this species in Oregon covered a landscape area of about 4.2 million ha (about 10.3 million acres) included all or portions of Marion, Benton, Linn, Lane, Douglas, Coos, Curry, Josephine, Jackson and Klamath Counties. From our recent data compilation and considering the failure to find the species in some of its historic haunts (Borisenko and Hayes 1998), we estimated about a 41% range contraction from the east-southeast and north-northwest that now excludes Marion, Benton and Klamath Counties (Figure 1).

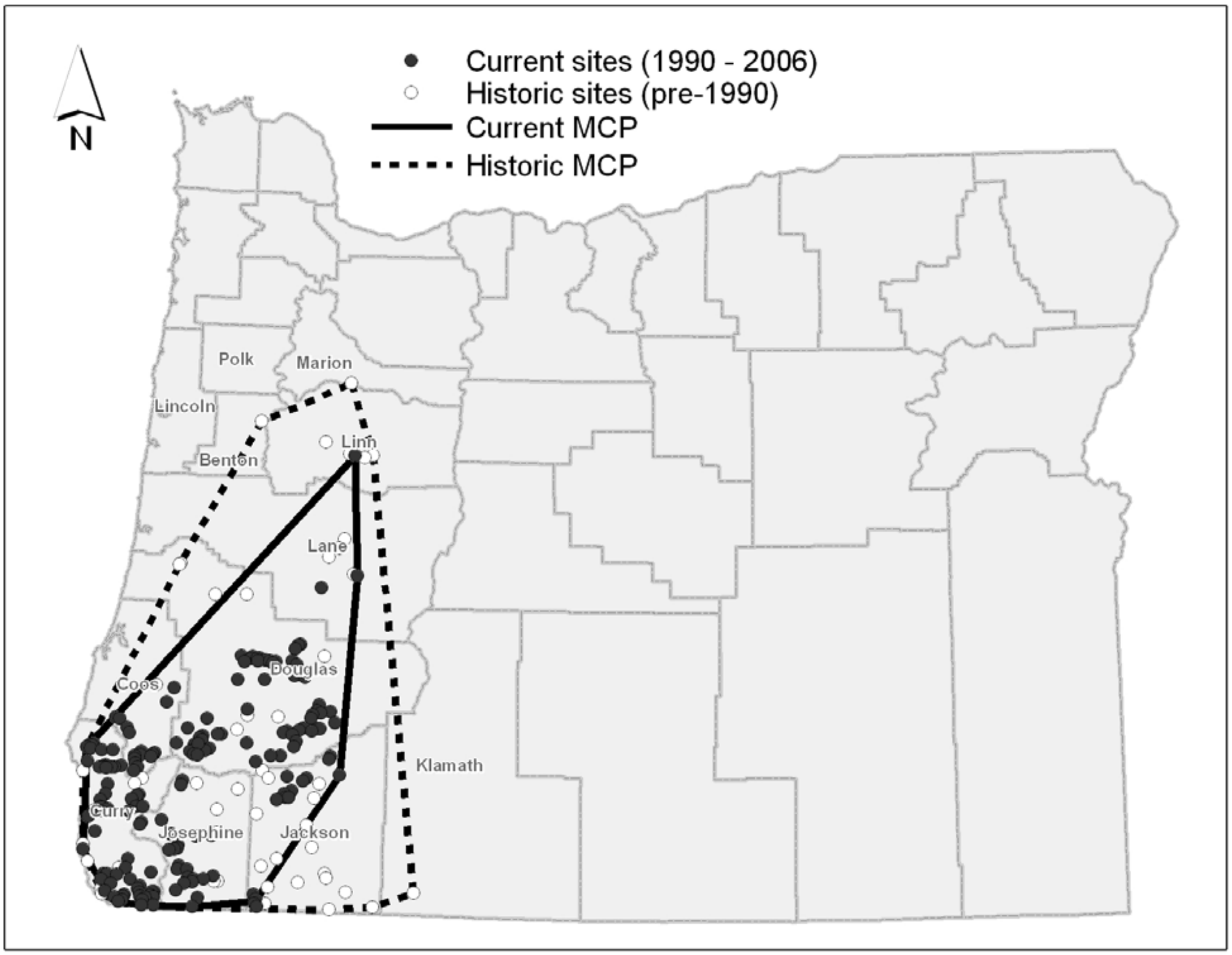

Figure 1. Estimated historic (dashed line) and current range (solid line; represented by minimum convex polygons, MCP), and distribution of historic (open circles, n=52) and current (black circles, n=179) *Rana boylii* sites (as defined in text) in Oregon.

The current frog's distribution appears to be in the central portions of Linn and Lane Counties, the southern half of Coos County and within all or significant portions of Curry, Douglas, Josephine, Jackson and Klamath Counties. Based on historically occupied points alone, and not a minimum convex polygon, the range contraction likely would be estimated to be higher, perhaps as much as a 50% reduction (M. Hayes, pers. commun.). However, it should be noted that a more realistic range estimate procedure for this stream-living frog would involve determination of the linear stream distances of likely occupied habitat within this larger area, and not landscape areas; this has not yet been conducted.

Patterns of abundance in Oregon were noted during the surveys of historic locations by Borisenko and Hayes (1999). Of 39 occupied sites, 7 (18%) sites had >10 frogs and 19 (49%) had <5 frogs. Also, 19 sites (49%) had at least three life history stages (e.g., eggs, larvae, juveniles or adults), suggesting successful recruitment of a breeding population.

Fellers (2005) surveyed 804 sites in 40 California counties that appeared to have suitable habitat for this species, and detected them at 213 (26.5%). Only 30 of 213 (14%) occupied sites had populations with more than 20 adults. The sites with the largest populations occurred in the northwest coastal zone where 6 sites had >100 frogs and another 9 sites had >50 frogs. Fellers (2005) considered the California portion of the Pacific Northwest as the “stronghold” for foothill yellow-legged frogs.

Population Trends

Little is known about population trends for this species in Oregon. However, a negative population trend is strongly implicated by the retrospective survey of Borisenko and Hayes (1999) revisiting historic Oregon sites. Less than half the sites were occupied. In particular, they failed to detect the species in many northern and southeastern locations of their historic range in Oregon, suggesting these range margins are particularly vulnerable to losses. Unoccupied basins were both the smallest and largest drainages sampled. For example, they did not detect frogs in four drainages (Brush, Hooskanadan, Myer, and Tuttle Creeks) with the smallest drainage areas. They speculated a combination of suboptimal habitat conditions and low resiliency to disturbances, natural or anthropogenic, may be occurring in the smaller drainages (i.e., after a disturbance, recolonization from within the drainage was unlikely due to local extirpation and recolonization from neighboring drainages was unlikely due to dispersal limitations). Sedimentation embedding coarse substrates was implicated in some locations. Additionally, there was a fairly inverse occupancy pattern with bullfrogs, exotic fishes and livestock grazing, suggesting an interaction between the native foothill yellow-legged frog and these introduced species may negatively affect the native frogs. In the larger basins sampled, there was a reduced occupancy downstream of large impoundments (e.g., Willamette, Rogue and Klamath basins), suggesting a negative impoundment effect. Threats are discussed further below.

Similarly in California, Hayes and Jennings (1986) reported disappearances of this frog, and Lind’s (2005) study suggested widespread losses in both Oregon and California. Lind (2005) compiled unique localities in Oregon (n = 90) and California (n = 1,049), and using a stratified random selection process, chose a subset of 372 California sites and all the Oregon sites for status assessment. To evaluate persistence of frogs at historic sites, she eliminated sites from her sample that were detected after 1975, and used resurveys to sites conducted in the 1980s and 1990s to determine current status. Of the 394 historic sites remaining in her sample, she found frogs were absent from 201 (51%).

Habitat

This species is known from just above sea level to 830 m (2,723 ft) elevation in Oregon. It occurs primarily in larger order (Strahler) streams and rivers (4^{th} through 6^{th} order), but is documented from 1^{st} to 8^{th} orders. Bury and Sisk (1997) found this species in intermittent to larger, low-gradient perennial streams (1st to 7th stream order) in the forested landscape of the foothills of the Oregon Coast Range and Cascade Range. They can occur in backwater habitat, such as slow water areas created by instream wood, as well as low-flow and fast-flow glide/riffle/rapid habitats, and along shallow-sloping stream banks. They have been described as occurring in "shallow stream margins, which often occur adjacent to low gradient riffles in alluvial stream reaches" (Fuller and Lind 1991). It is important to note that breeding habitat may be different from habitat used during other times of the year or for other life history functions, but these various habitat associations have not been distinguished for this species in Oregon. Rather, habitat conditions at sites occupied by frogs have been reported, and sometimes habitats occupied by adults versus other life history stages. Breeding is documented in larger streams, but not in smaller tributaries, for example, which may be used as foraging or dispersal habitat. Adult frogs are not usually found in stream sections with moderately high or high overhanging vegetation or shade (see habitat descriptions and models by Borisenko and Hayes 1999). Similarly, Bury and Sisk (1997) surmised *R. boylii* required direct sunlight for basking.

Stream substrates at occupied sites are coarse (>2 mm, Borisenko and Hayes 1999), and may include larger cobbles, gravel bars and bedrock. While frogs are often seen on top of substrates, tadpoles swim in their interstitial spaces. Egg masses were found attached to pebbles or cobbles, within a larger area including gravels and boulders, in glide habitats and stream margins along riffles and run habitats (Fuller and Lind 1991).

Stream temperatures identified from the literature range from 8-20ºC (46-68ºF) during breeding, and 26ºC (79ºF) is considered lethal to embryos (Zweifel 1955; M. Jennings and M. Hayes, unpubl. data). Based on a few recent site data, which had accompanying water temperature data that were compiled for this Conservation Assessment, egg masses were found in water temperatures from 15-16ºC (59-60ºF) and frogs (tadpoles to adults) were found in water temperatures ranging from 12-27ºC (53-80ºF).

In a California study, Hayes and Jennings (1988) reported this species to occur in "shallow, partly shaded stream sites with riffles and at least a cobble-sized substrate." Of 29 streams analyzed, 19 were perennial channels and 10 were spatially intermittent.

We conducted a habitat analysis using current known sites and available landscape data in Geographic Information Systems (GIS; Appendix 1). We found eight ecological factors (Table 1-4) 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. A habitat suitability map was created from these 8 ecological factors and the habitat model they produced (Appendix 1, Figure 1-4). The area of highest suitability (termed optimal) appeared to be within the Umpqua River basin (includes the Umpqua, North and South Umpqua 4^{th} -field watersheds), but also in portions of the Chetco, Coos, Coquille, Illinois, Rogue, Siuslaw, Sixes, Smith (North Fork) and Willamette

River systems (Appendix1, Figure 1-4). Again, it is important to note that we did not consider frog occupancy as an indicator of their type of use of habitats, whether for breeding or other life history functions, and it is likely that these modeled habitats reflect a mix of uses.

Lind (2005) also conducted analyses using GIS parameters of *R. boylii* occupancy using data from both Oregon and California, using a combination of geographic, climatic and anthropogenic factors. Of the non-anthropogenic factors assessed, increased precipitation and elevation were associated with frog presence.

Ecological Considerations

Predator-prey relationships are incompletely known. Across the life stages of this frog, it is eaten by garter snakes (*Thamnophis atratus*, *T. sirtalis*, *T. elegans*). In particular, the Oregon garter snake (*T. atratus*) may rely on juvenile *Rana boylii* for a high proportion of their diet (Fitch 1936, Lind 2004). Frog larvae may be preyed upon by American dipper and insect larvae including dragonfly and diving beetle larvae. Rough-skinned newts eat frog eggs. Non-native bullfrogs and non-native fishes, such as smallmouth bass (C. Rombough, pers. commun.), may prey on foothill yellow-legged frog larvae, juveniles or adults. The recently identified amphibian chytrid fungus disease *Batrachochytrium dendrobatidis* has been detected in *R. boylii* in California, and was associated with reduced growth but not significant mortality (Davidson et al. 2007).

In turn, adult frogs and metamorphs feed on terrestrial and aquatic invertebrates (Van Wagner 1996) including snails (Fitch 1936). Very generally, tadpoles eat algae, diatoms and detritus (Fellers 2005), although the dynamics of these predatory interactions may be complex, involving processes such as facilitation (Kupferberg 1997a). Bullfrogs are competitors of foothill yellow-legged frogs when they are larvae, with algae being the limiting food resource (Kupferberg 1997b).

Biological Considerations

Ranid frog skin has antibacterial and antifungal properties. The foothill yellow-legged frog has antimicrobial properties that are specifically potent against the human pathogens *Candida albicans*, *Escherichia coli*, and *Staphylococcus aureus* (Conlon et al. 2003). Davidson et al. (2007) reported that *R. boylii* skin peptides inhibited growth of the amphibian chytrid fungus *Batrachochytrium dendrobatidis*.

IV. CONSERVATION

Land-use Allocations

Relationship of the species' distribution to lands managed under the federal Northwest Forest Plan is a key consideration for conservation. Of the 177 current sites at the 500-m spatial scale, 113 (64%) occur on federal lands. Of these, 79 (70% of federal sites) occur within the Late-successional Reserve (LSR) land-use allocation and 34 (30%) sites occur within the Matrix or Adaptive Management Area (AMA) land-use allocations, where timber management is a priority. However, all 113 sites are protected by the Riparian Reserve land-use allocation, which runs along streams and rivers in all allocations. The species also occurs in 17 of 34 federally designated Key Watersheds that occur within the current range; Key Watersheds form a system of large refugia identified in the Northwest Forest Plan as important for maintaining and recovering habitat for at-risk fish species and providing high quality water (USDA/USDI 1994).

Threats

Known and suspected threats to this species across its entire range are numerous. Three major threats in Oregon appear to be: (1) stream habitat loss or alteration from water impoundments that inundate former habitats or alter natural flow regimes, causing fluctuations in water levels and altering water temperatures; (2) introduced exotic species such as smallmouth bass and bullfrogs due to predation and competition; and (3) stream habitat loss or alteration from agricultural practices that include re-routing stream channels and fluctuations in water levels caused by irrigation. Other potential threats with uncertain impacts include: (1) chemicals such as applications of herbicides and pesticides as well as drift from aerial applications of agro-chemicals, fire retardants, and toxic metals resulting from current or historic from mining activities; (2) habitat loss or degradation including stream sediment inputs from roads, timber harvest, mining, agriculture, and cattle grazing; (3) recreational activities affecting river shorelines, including boating such as jet boats; (4) invasive species such as the New Zealand mudsnail (*Potamopyrgus antipodarum*); (5) mining, including placer mining and suction dredging, which may physically disrupt streambeds and directly kill or injure stream-dwelling animals; and (6) diseases such as the fungi *Batrachochytrium dendrobatidis* and *Saprolegnia* (reviewed in Fellers 2005, *B. dendrobatidis* effects examined in Davidson et al. 2007).

Disturbances such as mass wasting events (i.e., landslides), flood events, and wildfire may also adversely affect this frog. Additionally, loss of connectivity among habitat patches is a concern from several of these disturbances due to the likely limited mobility of these animals among watersheds and consequent population isolation.

Threats occur across multiple land ownerships. However, many key threats are unrelated to actions occurring on Forest Service or BLM lands relevant to this Conservation Assessment. Hence, Forest Service and BLM land managers may be unable to effectively mitigate for some adverse effects. Nevertheless, all potential or suspected threats are included here to provide a more comprehensive review of the species' risk factors.

We used a modeling approach to provide a preliminary assessment of the association of nine possible threats with the presence of frogs in Oregon (Appendix 1); development of a more refined assessment might be considered as an element in the development of a Conservation Strategy for this species. Landscape coverages of potential anthropogenic stressors (Table 1-2) were obtained in a GIS and compared between two areas: (1) areas with suitable habitat and current frog presence, and (2) areas with suitable habitat but apparently lacking frog presence (e.g., no documentation of current presence). Eight of the 9 factors examined appeared to contribute to affecting frog distributions (Table 1-2). The amount of agriculture and distance from agricultural lands showed the greatest effects, with actual frog sites having much lower amounts of agriculture within a 5-km radius of the site and greater distance to agricultural lands.

Sites with frogs had higher distances from dams, cities and large bodies of impounded water. Distance to hydropower dams also was significantly different between frog sites and sites without known frogs, with frog sites being more distant from dams. Frog sites had slightly lower road densities than areas without frogs. There was not a significant difference in the proximity of clearcut/regeneration type timber harvesting between sites with frogs and without frogs. This last finding might be explained by the application of riparian reserves along perennial streams with fish, and the species' occurrence in streams within non-conifer dominated landscapes.

Lind (2005) also examined associations of GIS parameters related to anthropogenic threat factors with *R. boylii* presence and absence at selected historic sites in Oregon and California. She found frog presence was associated with areas having less agriculture and urban development, and in areas downwind of less urban development. She found trends supporting a negative effect of dam presence and number of dams upstream on frog presence, with larger dams having a stronger negative effect on frogs than smaller dams.

The contributing factors to site-level losses likely vary with local contexts, and single-to-multiple risk factors may need consideration within particular stream systems. Borisenko and Hayes (1999) provided a synopsis of potential threats at historic locations of this frog in 15 Oregon watersheds they surveyed in 1997-1998:

- <u>Brush Creek</u>: No exotic species; no large impoundments; low embeddedness; low human disturbance; roads and recreation reported [0 of 1 historic site occupied during survey].
- <u>Chetco River</u>: No exotic species; no large impoundments; variable embeddedness; timber harvest and recreation reported [4 of 5 sites occupied].
- <u>Coos River</u>: No exotic species; no large impoundments; grazing and siltation reported [0 of 1 site occupied].
- <u>Coquille River</u>: bullfrogs; brown bullhead; embeddedness; chlorine from sewage plant [1 of 3 sites occupied]
- <u>Elk River</u>: No exotic species; no large impoundments; low to intermediate embeddedness [3 of 3 sites occupied].
- <u>Hooskanadan Creek</u>: No exotic species; no large impoundments; timber harvest, grazing, intermediate (40%) embeddedness [0 of 1 site occupied].
- <u>Klamath River</u>: Bullfrogs; impoundments; 1 site inundated; 2 sites isolated; 1-m water level flux within 5-hr during survey in August; poor water quality –orthophosphate, foam mats, speckled dace with fungus [0 of 3 sites occupied in Oregon].
- <u>Pistol River</u>: No exotic species; no large impoundments; grazing; 70% embeddedness [1 of 1 site occupied].
- <u>Smith River</u>: No exotic species; low embeddedness [1 of 1 site occupied in Oregon].
- <u>Myers Creek</u>: No exotic species; no large impoundments; timber harvest and high embeddedness [0 of 1 site occupied].
- <u>Rogue River</u>: Bullfrogs; impoundments; jet boats; agricultural water intakes and gravel diversions; suction dredge mining; grazing; devegetated banks; variable conditions in sub-basins (e.g., Applegate has impoundment, Illinois does not but has water diversions in the upper portions of the watershed); pike minnow [19 of 29 sites occupied].
- <u>Tuttle</u>: No exotic species; no large impoundments; channelization; development; timber harvest; intermediate embeddedness [0 of 1 site occupied].

- Umpqua River: smallmouth bass [5 of 12 sites occupied].
- Willamette River: impoundments; smallmouth bass; specked dace; isolated historic sites; inundated sites; embeddedness; water quality issues [1 of 14 sites occupied].
- Winchuck: No exotic species; no large impoundments; low to intermediate embeddedness [4 of 4 sites occupied].

Water Impoundments

Water impoundments appear to be a major threat to the foothill yellow-legged frog in Oregon and California. Downstream of water impoundments, water release, water diversion, substrate size alteration and sedimentation can affect habitats occupied by foothill yellow-legged frog (e.g., Kupferberg 1996). Fluctuating water levels during breeding and loss of breeding habitat are specific issues. Upstream from dams, habitat can be inundated. Dams may also fragment populations, interrupting connectivity along the stream channel. Lind et al. (1996) reported upstream dam water releases dislodged egg masses from substrates and flushed them downstream. Also, habitat alteration from such peak flows degraded frog breeding habitat, for example by altering substrate size distributions. Conversely, desiccation of egg masses that became stranded out of water due to fluctuations in flow releases from an upstream dam also was observed (see Ashton et al. 1997). Borisenko and Hayes (1999) reported 18% of historic sites in Oregon were isolated (14 of 90 sites) or inundated (6 of 90 sites) by dams > 50 ha. Furthermore, 15 (17%) more sites were downstream of large impoundments, and only 2 of these were occupied during their resurvey, in comparison to 37 of 75 above-reservoir or no-reservoir sites being occupied. They reported impoundments to be a particular issue on the Klamath, Rogue and Willamette Rivers. Numerous water impoundments occur with the species' range in Oregon (Figure 2). In our cursory assessment of potential landscape-level threats to frogs in Oregon, proximity to hydropower, streamnet and large (>50 ha) dams were negatively associated with frog occurrence (Appendix 1, Table 1-5). Lind's threat models (2005) reported trends for negative effects of dams on frog presence using data from Oregon and California.

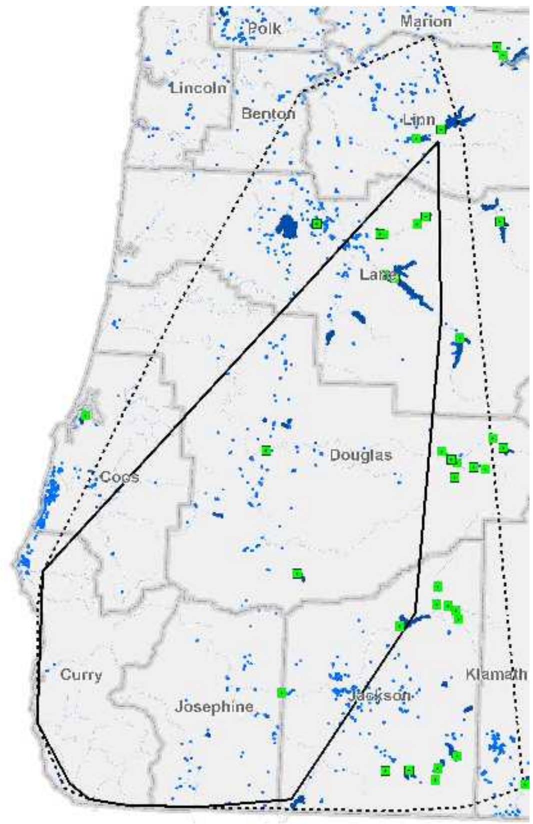

Figure 2. Map of water impoundments in relationship to the historic (dashed line) and current (solid line) MCPs. Darker shade of blue indicates large (>50ha) impoundments and green points indicate hydropower dams.

Introduced Species

In Oregon, smallmouth bass and bullfrog occurrences in streams with foothill yellow-legged frogs are a major threat. Borisenko and Hayes (1999) found exotic bullfrogs and fishes occurred

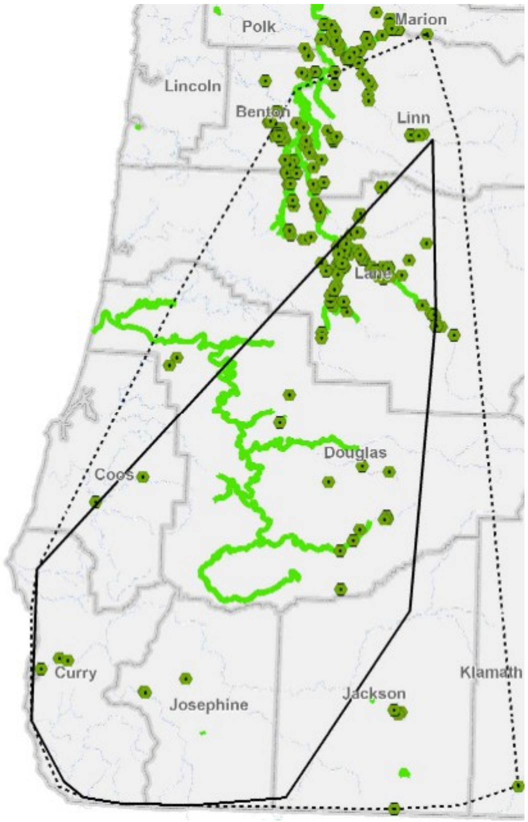

Figure 3. Map of bass (green line) and bullfrog (green point) distributions in relationship to the historic (dashed line) and current (solid line) MCPs.

significantly more often at historic yellow-legged frog sites that lacked yellow-legged frogs during their resurveys. Bullfrogs were noted on the Coquille and Rogue Rivers while smallmouth bass were reported on the Umpqua and Willamette Rivers. Rombough (2006) found smallmouth bass were the best predictor of yellow-legged frog occurrences in Cow Creek, Oregon, having an inverse relation to the yellow-legged frogs. He also found bullfrogs were negatively correlated with yellow-legged frog distributions. Smallmouth bass and bullfrogs may be predators and competitors. Over 20 years ago, Hayes and Jennings (1985) identified fish and bullfrogs as potential causes of amphibian declines in the American West. Figure 3 shows the currently compiled status of bass and bullfrog distributions data to date.

In California, Kupferberg (1997) found foothill yellow-legged frogs to have decreased abundance in stream reaches occupied by bullfrogs. She found bullfrog tadpoles out-competed tadpoles of the yellow-legged frogs. Also, Lind et al. (2003) found male foothill yellow-legged frogs in amplexus with female bullfrogs in two locations in California, implying that reproductive effort on the part of the native frogs may be wasted.

New Zealand mudsnails, quagga mussels (*Dreissena* species), and reed canary grass (*Phalaris arundinacea*) are emerging concerns for Oregon waterways, but their influences on this frog are not known. New Zealand mudsnails are currently documented in the Lower Umpqua, Lower Rogue, Coos, Sixes, Siletz and Yaquina River sub-basins. They have the ability to reproduce quickly, grow rapidly (Hall et al. 2006) and mass in high densities (e.g., to 299,000 individuals per m^2 in the Greater Yellowstone Ecosystem; Kerans et al. 2005), and potentially may alter macroinvertebrate community composition (Kerans et al. 2005) and food web function (Hall et al. 2006). Disinfection procedures for field gear to reduce risk of transmission of New Zealand mudsnails between water bodies are under development and at this time include drying gear for 48 hours in sunlight, freezing gear to -3ºC (27 ºF) for 1 hour, heating to 46ºC (120ºF) for 5 minutes, or decontamination with quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride; diecyl dimethyl ammonium chloride).

Agriculture and Cattle Grazing

Agriculture (Figure 4) can have multiple effects on streams, some of which can be a major threat to foothill yellow-legged frogs. The effects of agriculture on frogs are little known, but suspected threats include alteration of stream channels (e.g., rerouting streams to create agricultural lands, irrigation canals… etc.), damming and irrigation that causes fluctuations in stream water levels or the use of flood irrigation during the breeding season, chemical applications, including both pesticides and herbicides, which may be aerially transmitted to frog habitats, or may be transmitted via runoff. These effects are discussed further below. Livestock grazing may result in bank erosion, degrading shorelines and increasing stream sedimentation. These effects could directly impact instream habitats for frogs. Borisenko and Hayes (1999) found locations with frogs had significantly less grazing than locations without frogs. They reported grazing or agricultural concerns for the Coos, Hooskanadan, Pistol and Rogue Rivers. Proximity to agriculture was negatively associated with frog occurrences in Oregon (Appendix 1, Table 1-5); however the reason for this association is only conjecture at this time. Similarly, Lind (2005) found foothill yellow-legged frog presence was associated with less agriculture in the nearby vicinity, using data from Oregon and California in her analyses. Additionally, whether grazing and other agricultural factors may be largely a historic threat to frogs in our region due to riparian mitigations now in effect remains uncertain.

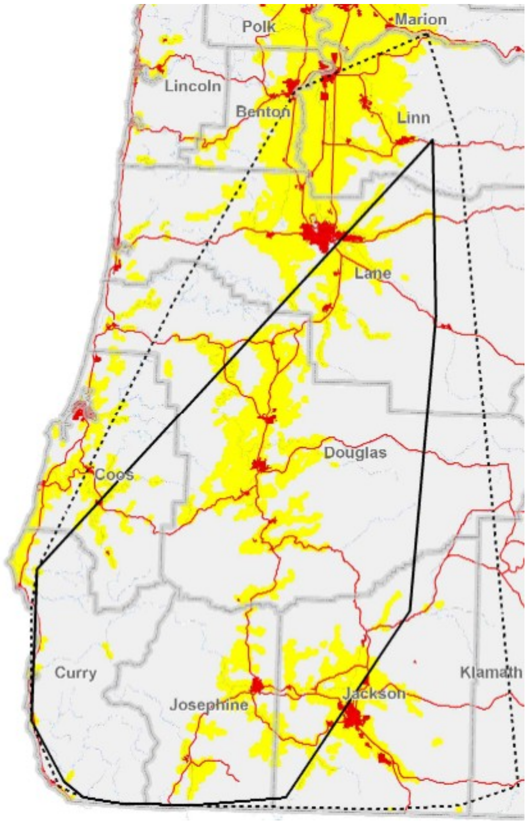

Figure 4. Map of agricultural lands (yellow) in relationship to the historic (dashed line) and current (solid line) MCPs. Major cities and highways shown in red.

Timber Harvest

Timber harvest is a complex disturbance that may be or may have been a potential threat to this frog, yet the effects of specific activities are largely unknown, and some harvest practices may even benefit these stream frogs. Conceptually, the following interactions of timber harvest activities and foothill yellow-legged frogs may be possible. First, as important background information, within the range of the foothill yellow-legged frog, the landscape is fragmented by past timber harvest practices (Figure 5), and is a patchwork of stands of different ages, from early seral to mature forests. Sites with frogs are nested within this patchy landscape. Potential effects of forestry need to be separated into larger scale influences and site-specific influences. At larger scales, when considering all land ownerships, forestry practices may contribute to elevated stream water temperatures and sedimentation of downstream reaches; these changes may have adverse effects on frogs. Loss of standing green trees reduces the future potential for down wood recruitment in streams, which function to provide complex instream habitats including slow water areas that may be preferred by frogs for breeding. As new trees regenerate in harvested stands, their smaller sizes likely do not provide the same functions (i.e., as large down wood) and larger wood may not be available for several decades to centuries. However, foothill yellow-legged frogs have been found in stream reaches with limited down wood, so the importance of large wood is uncertain across the range of the animal. At a site scale, frogs appear to prefer open habitat, perhaps for basking, and observations have been made that they do not seem to occur in areas with overhanging vegetation or shade. Hence at a site scale, loss of streamside canopy closure due to timber harvest may not have an adverse effect or may have a positive effect. If frogs venture upslope, timber harvest may more directly affect their upland retreats. The complex interactions of forestry practices with different types of frog habitats warrant further examination.

Hence, while it warrants further study, it bears acknowledgement at this time to recognize that not all timber harvest practices are equal. Some harvest practices include the use of riparian reserves, which may have a reduced landscape-scale impact on foothill yellow-legged frogs and their habitats. Frogs may persist at sites, or recolonization may be accelerated with upstream retention of standing trees that reduce sedimentation risk, ameliorate microclimate alteration, and offer recruitment of future down wood. While it is possible that reduced canopy closure at frog stream sites may benefit frogs, if frogs disperse into upland forests, retention of upslope canopy can retain upland moisture conditions, reduce ground disturbance and may benefit frogs. Green tree retention may retain connectivity among suitable habitat patches, either via providing continuous habitat or by providing "stepping stones" of habitat patches through which animals may traverse to larger habitat blocks. Unfortunately, at this time we do not know to what extent, if any, these frogs use forested uplands. Privately owned timberlands and federal forests may apply different types of riparian management and protection, complicating the understanding of the effects of timber harvest on this species.

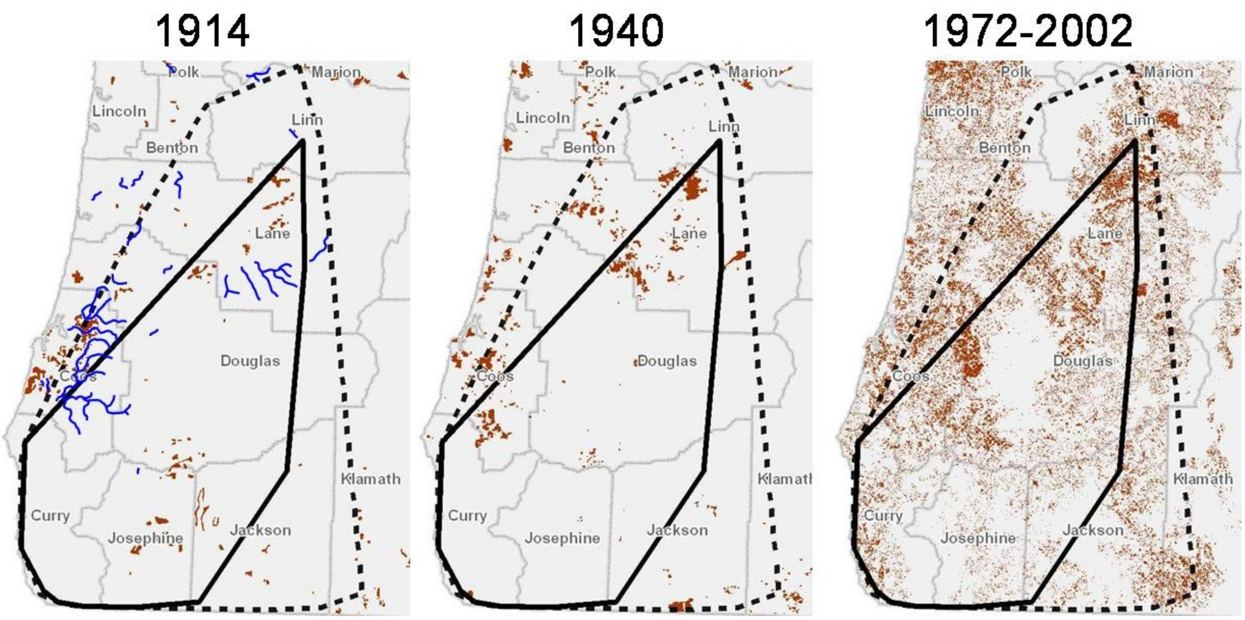

Figure 5. Three different snapshots in time of clearcut timber harvest history (brown = clearcuts) in relation to the estimated historic (dashed line) and current (solid line) minimum convex polygons (MCP) of the foothills yellow-legged frog in Oregon. Splash dams are shown as "blue" lines in the 1914 picture.

Historic logging practices called "splash-damming" in the early 1900s (Figure 6), likely had severe impacts on some frog habitats and perhaps their populations. Federal intervention ended this practice in 1957 because of impacts to fisheries. Proximity to splash dams was not associated with frog occurrences in our threat assessment (Appendix 1, Table 1-5), implying no lingering signature of this past impact on current frog distributions in Oregon.

No real estimates exist of how much area within the species' range has been impacted by timber harvest activities, but 55% (n = 99) of current frog localities are on land allocations in which timber harvest activities may occur (nonfederal lands, federal Matrix and Adaptive Management Area; although it should be noted that timber harvest also occurs in Late-Successional Reserves). Hayes and Borisenko (1999) reported timber harvest to occur in the Chetco, Hooskanadan, Myers, and Tuttle River systems that they had surveyed for frogs.

Interestingly, proximity to areas with timber harvest was not associated with frog occurrences (or lack of detections) in our initial model of potential threats to this frog in Oregon (Appendix 1, Table 1-5).

Chemical Applications

Chemical applications are another potential threat. Chemicals such as herbicides, pesticides, fungicides, fertilizers and fire retardants may have a direct impact on these frogs, but there is no evidence of these effects on this species in Oregon at this time. These animals' skin is moist and permeable for gas exchange, and can readily uptake lethal chemical doses. In California, Davidson et al. (2002) modeled the population status of foothill yellow-legged frogs relative to landscape attributes associated with agro-chemicals, with two attributes showing significant associations. First, agricultural use within a 5-km radius of a known site was associated with decreasing frog population numbers. Second, populations declined with greater area of upwind agriculture. Sparling and Fellers (2007) examined the effects of the pesticides chlorpyrifos, diazinon, and malathion and their oxon derivatives on *R. boylii* in California, and concluded that environmental concentrations of these chemicals can be harmful to these frogs, with concentrations in run-off being potentially toxic. Davidson et al. (2007) examined the effects of the pesticide carbaryl on *Rana boylii* froglets, and found no direct effect on frog survival. However, Hayes et al. (2006) found mixtures of pesticides to have much greater effects on frogs than single pesticides, and suggested that studies examining single pesticides may underestimate pesticide impacts on amphibians. To date, a study of the effects of multiple pesticides in combination on *R. boylii* has not been published. Davidson and Knapp (2007) reported that windborne pesticides contribute to declines of a related species, the mountain yellow-legged frog (*Rana muscosa*) in California.

Borisenko and Hayes (1999) cited poor water quality, including ammonia and pH levels, as being associated with some reservoirs, and speculated there could be adverse effects on frogs. In particular, water quality in the Klamath River may be an issue for frogs (Borisenko and Hayes 1999; M. Hayes, pers. commun.). They also noted the chlorine inputs from a sewage plant into the Coquille River were a specific concern. There is a suggestion that in 1966, a hydrogen sulfide buildup associated with the Fall Creek dam construction, and its subsequent release into Fall Creek (tributary to the Middle Fork of the Willamette River), may have caused significant aquatic organism mortality, although frog deaths were not reported (R. Davis, pers. commun.). In Oregon, we can only speculate that chemicals may be a problem. We also found proximity to agricultural areas (Figure 5) was negatively associated with frog presence (Appendix 1), but whether or not this has a relationship to chemical applications is unknown. While aerial spraying of chemicals may affect frogs, riparian and aquatic restrictions of chemical applications reduce risk of potential harm to this stream-associated species.

Roads and Urbanization

Roads and urbanization are logical potential threat to this frog. The human population continues to increase in western Oregon. This results in continued expansion of urban and agricultural areas (Figure 5) and construction of new roads (Figure 6). Currently, there are approximately 74,000 km (46,000 miles) of highways and roads that have been constructed, primarily for transportation and timber management, within the current range of the species (Figure 6). While road impacts are uncertain for this frog, road construction crossing streams may adversely affect frogs due to sedimentation during road building, maintenance or failures. Sediments can embed stream substrates and removes interstitial spaces used by these frogs. The use of culverts that do not easily pass frogs also impacts population connectivity. Road-kill is not well-documented for this species.

Proximity to cities and increasing road density were negatively associated with frog occurrence in our initial threat assessment for Oregon (Appendix 1, Table 1-5). Lind (2006) similarly found *R. boylii* presence was associated with less urban development nearby, using data from both Oregon and California.

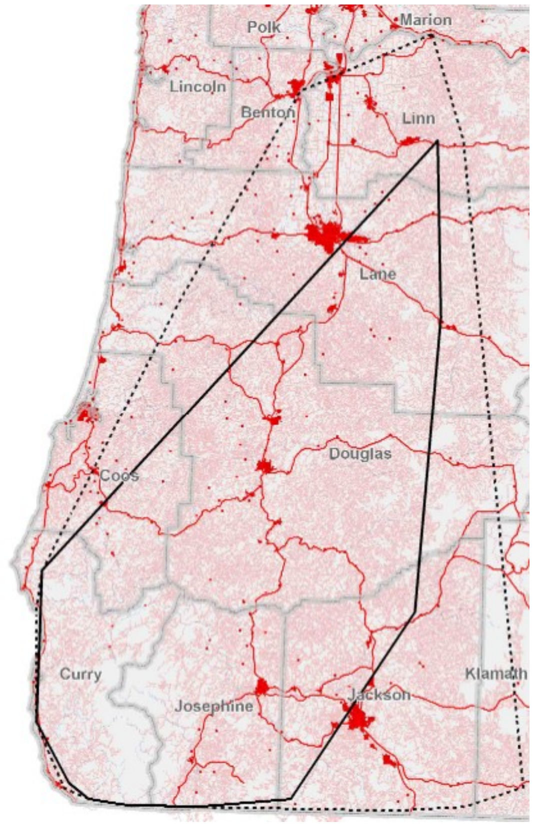

Figure 6. Map of roads (pink) in relationship to the historic (dashed line) and current (solid line) MCPs.

Another transportation system warrants mention. Train tracks may follow riparian corridors through the high topography of the southwest Oregon landscape. In 2004, a diesel oil spill from a train into Cow Creek, Oregon, is known near a historically abundant location of *Rana boylii*. Effects on the frog were not monitored. In 1993, another diesel oil spill (6,100 gallons) from a train is documented into Yoncalla Creek, Oregon. Following the spill "several dieseled dead and moribund foothill yellow-legged frogs were collected from this site…and it is likely that we saw only a fraction of animals actually affected" (M. Hayes, pers. commun.). Frogs were reported at the creek in 1995 (Oregon Dept. Fish. & Wildl.).

Mining

Mining is another potential threat. In southwestern Oregon, suction-dredging/placer-mining is an extensive historic in-stream activity, allowed by the 1872 Mining Act. In Josephine County, Oregon, there are 1600 mining permits on USDA Forest Service land (D. Clayton, pers. commun.). Yet the actual extent of mining across the *R. boylii* range in Oregon is unknown, and much may be uncontrolled. Gravel extractions are another type of mining to be considered. Stream substrates are removed, processed and relocated during the mining procedures, and all life history stages of foothill yellow-legged frogs would be at risk of direct mortality if such mining occurred at occupied sites. The tailings of abandoned mines may have contaminants, such as mercury used to historically extract gold as would settling ponds. The magnitude of these activities relative to its impact to frogs and their habitat warrants further study.

Disease

Disease is emerging as a potential threat to all ranid frogs, including *R. boylii*. Current research on global amphibian declines is focusing on these effects. While disease has not been implicated as a serious issue for this frog in Oregon, chytrid fungus (Chytridiomycosis: *Batrachochytrium dendrobatidis*, or "*Bd*"), an aquatic pathogen, has been detected in this frog in California and is thought to be the cause of local extirpations of montane frogs in the Washington Cascade Range and the California Sierra Nevada Range. Davidson et al. (2007) examined the effects of *Bd* on survival and growth of *Rana boylii* froglets and found no effect on survival but, growth was reduced by one half, regardless of whether *Bd* was alone or in the presence of the carbamate insecticide carbaryl. Skin peptides of this frog strongly inhibit *Bd* growth.

A fungus consistent with *Saprolegnia* infection has been noted in egg masses of the foothill yellow-legged frog in the main stem Trinity River, California (Ashton et al., unpublished data).

While at this time it is not reported to occur in *R. boylii*, two additional diseases are of concern. Known from related species are the bacterial disease "red leg" (*Aeromonas hydrophila*) (e.g., *Rana muscosa*, Bradford 1991) and iridoviruses (*Ranavirus* species), which are a complex of viruses found in frogs and fish (Mao et al. 1999).

Disease warrants mention here to alert biologists to be aware of and report observations of ill or dead animals. Individuals or tissues collected can be analyzed at regional or national laboratories. *Saprolegnia* or *Bd* fungi may be spread to other water bodies from boots or nets, waterfowl, translocated fishes, or movement of water (e.g., during fires). Disinfection guidelines to reduce risk of transmission of *Bd* among water bodies by field gear are under development and at this time include bleaching equipment between uses in different aquatic locations (20% bleach solution, 30 seconds, e.g., 22 ounces of liquid Clorox per gallon water; 7% bleach solution, 10 minutes, e.g., 9 ounces of liquid Clorox per gallon water). However, it should be noted that bleaching is not effective against some invasive aquatic organisms of concern in Oregon, such as the New Zealand mudsnail that similarly might be spread among water bodies inadvertently by human activities (see above). Decontamination with quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride; diecyl dimethyl ammonium chloride) likely disinfects against both mudsnails and *Bd*. Drying gear for 3 hours in sunlight and heating gear to 60ºC (140ºF) for 5 minutes may also reduce risk of *Bd* transmission.

Recreation

There are a few potential threats related to recreation. Jet boats create waves that could potentially result in dislodgement and loss of egg masses, stranding of tadpoles, disruption of adult basking behavior, and erosion of shorelines (Borisenko and Hayes 1999). Borisenko and Hayes (1999) reported jet boats passing every 5 minutes with wakes up to a meter high breaking on shore in the lower Rogue River, and no frogs in that area. They also reported recreation concerns for the Chetco River. Vehicles driven along stream gravel bars and recreationists fishing, swimming, walking or camping along shores may adversely affect frogs, including disruption of frog basking opportunities (Borisenko and Hayes 1999).

Global Climate Change and Ultraviolet Radiation

Global climate change and ultraviolet radiation are potential threats to be considered for this frog, but there is no evidence suggesting these are major issues in Oregon. Davidson, Shaffer, and Jennings (2002) examined the spatial patterns of declining frogs in California and hypotheses of spatial patterns of ultraviolet radiation effects and climate change. For foothill yellow-legged frogs, they found a north-to-south gradient of increasing frog losses, consistent with climate change hypotheses (more losses at drier sites to the south), but increasing frog declines at lower elevations, which was at odds with the UV-B hypothesis. Their multivariate analysis did not support climate change affecting this species. Lind (2006) considered climate change as a potential threat to *R. boylii*, due to precipitation being associated with frog presence.

Fire

The effects of fire on these frogs are unknown. Pilliod et al. (2003) cited both positive and negative effects of fire and fire suppression activities on western amphibians. Low-intensity fires likely have no adverse effect on this species. It is also possible that historic fires may have reduced streamside vegetation providing sunny areas for frog basking, a potential benefit to frogs. Fire suppression may increase riparian shading, a potentially adverse effect for these animals. The effects of a more intense level of fire disturbance due to fire suppression and fuel loading is of concern in that stand-replacement wildfire represents a more catastrophic disturbance to flora and fauna, and potentially aquatic habitats. Figure 7 shows the distribution of stand-replacement fires within the species' range in three timeframes.

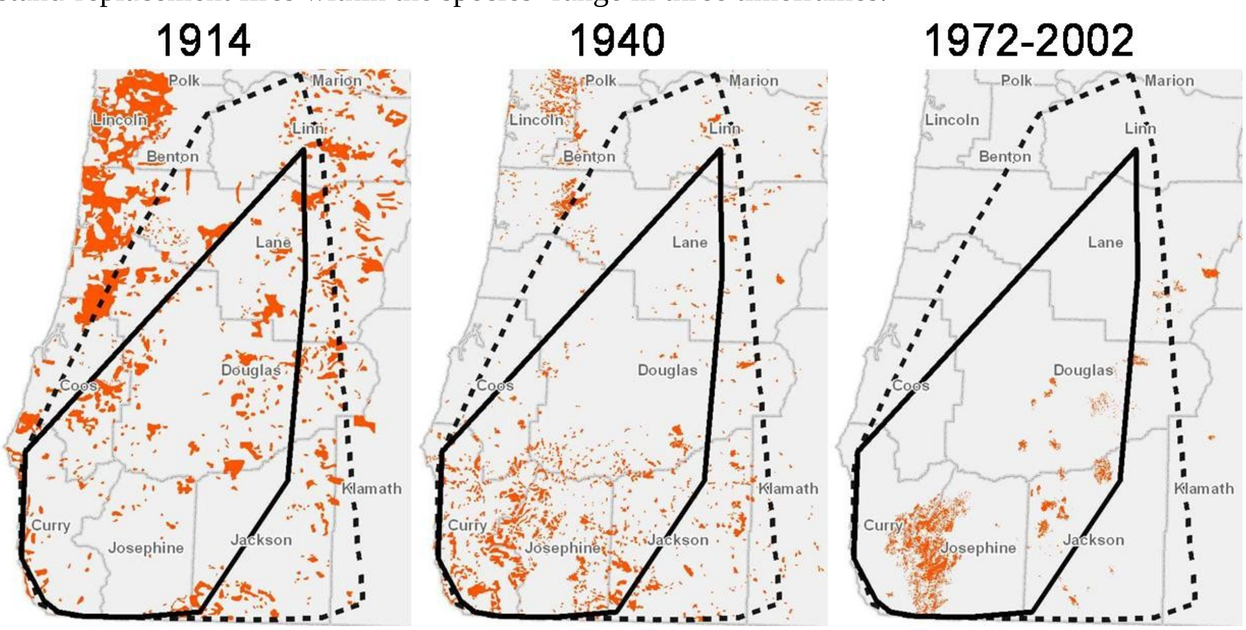

Figure 7. Three different snapshots in time of stand-replacing wildfire (orange) history in relation to the estimated historic (dashed line) and current (solid line) MCPs of the foothill yellow-legged frog in Oregon. The fires mapped in the 1914 and 1940 map likely occurred over a period of 2-3 decades for each time period.

Aerially applied fire retardant and suppressant chemicals may have adverse effects on amphibians (reviewed in Pilliod et al. 2003), although this has not been examined specifically for *R. boylii*. In particular, an ingredient of fire retardants, yellow prussiate of soda (sodium ferrocyanide), has been found to be toxic to anurans.

In particular, relative to foothill yellow-legged frog habitat, intense fires remove overstory canopy that serves to moderate surface microclimates from extremes (e.g., high temperatures), and reduces standing green trees that may supply streams with future down wood. Increased landslide potential post-fire is a concern for sedimentation of stream habitats. The large spatial scale of recent more severe fires may be more extensive than the historic fire regime. In our initial threat assessment (Appendix 1, Table 1-5), proximity to stand-replacement fires was not associated with lack of frog occurrences in Oregon.

Landslides and Floods

Landslides are a potential threat because they can cause stream sedimentation, embedding substrates and eliminating refugia for larval and adult frogs as well as the availability of coarse substrates for oviposition. Prey species in substrate interstices also would be impacted. Occupancy patterns across the landscape relative to landslide-prone geologies would be of interest to study. Landslides may occur more frequently in areas with timber harvest and roads. Federal riparian reserves are designed to buffer high-gradient slopes along streams that may be prone to slope failures. It is of note to mention that periodic mass wasting events provide inputs of sediments and down wood to streams, and are thought to recharge stream sediment and wood loads which are flushed out through time. Retention of stream habitat complexity may rely on cyclic episodes of slope failures.

If timed post-breeding, annual freshet events can dislodge frog egg masses from substrates in the same way that is known for dam-release of water. It is possible that this species has a natural boom and bust recruitment cycle, such that some years' losses of egg masses from ill-timed peak flows results in complete loss of the 0+ year cohort. Boom years of high survival could offset such bust years. Frog longevity and prolonged breeding seasons extending weeks to months could be adaptations to offset an unpredictable timing of peak flows. However, late-season breeding might be disadvantageous if larvae and then metamorphs cannot achieve sufficient sizes to survive winter or do not quickly outgrow predator gape limits.

Isolation and Fragmentation

Several known or potential threats could disrupt the connectivity of frog populations. Longitudinally along stream networks, impoundments or exotic predator-occupied streams could isolate subpopulations of frogs. Threats that affect stream habitat conditions could similarly fragment existing distributions. These might include effects of agriculture, grazing, roads, mining and timber harvest activities. The mobility of this frog along streams is not well known, but some support is available suggesting they can move 400-800 m. Distances larger than this might be necessary to isolate subpopulations. The impacts of fragmented habitat on this species are only speculative at this time, but may include a disruption of population dynamics. For example, isolation of smaller populations that require a “rescue effect” of immigrants from neighboring sites to persist could be prone to extinction. Certainly loss of connectivity may be a contributing factor to the apparently reduced distributions in Oregon.

Fish Habitat Restoration

Under limited circumstances, fish habitat restoration is suspected to adversely affect individuals or localized groups of *Rana boylii* (Fuller and Lind 1992). In particular, altered hydrological regimes from inputs of large down wood can reduce the suitability of localized stream areas for frog breeding. Although the activity may be intended to restore prior conditions to streams and potentially improve frog habitat conditions, if frogs have reduced distributions from a variety of other factors, this well-intentioned restoration might have a negative consequence for an isolated remnant population reliant on a particular reach as a source area for population recruitment. It is unknown whether such an isolated remnant population would be sufficiently resilient to persist over time with such a disturbance. It is possible that a longer term positive response could result from such restoration.

Conservation Status

This species is of concern due to its limited distribution in southwestern Oregon and apparent losses. This species seems to be vulnerable to a cadre of threats affecting stream habitats, and could have relatively narrow habitat requirements which would reduce its resiliency to habitat alterations. In addition, during recent surveys in Oregon, when the animal is found, numerous individuals are infrequently seen; sometimes only a few animals are found with considerable survey effort. While its cryptic nature likely reduces its detectability and clouds our understanding of abundance patterns, this animal does not seem to occur in high numbers within suitable habitat and optimal habitat may be patchy across the landscape. Isolation of sub-populations is an emerging concern.

Known Management Approaches

In Oregon, the combined federal interagency Special Status and Sensitive Species Programs is the only management program that has addressed this species. This species was not determined to be a close associate of old-growth forest conditions (Thomas et al. 1993) and hence was not addressed by the Northwest Forest Plan (USDA and USDI 1993, 1994). However, this species likely benefited incidentally by habitat protections offered by the Northwest Forest Plan, including federal Riparian Reserves and other reserved land allocations (see above). Mandated riparian buffers along streams in state and private forested lands also likely benefit this species.

Management Considerations

The conservation goal for foothill yellow-legged frogs is to contribute to a reasonable likelihood of long-term persistence within the range of the species, including the maintenance of well-distributed populations, and to avoid a trend toward federal listing under the Endangered Species Act.

Specific Objectives

- Assess and prioritize areas of the species range on federal lands relative to species management needs.
- As projects are proposed on federal lands, identify high-priority sites to be managed for species persistence (FS) or for species conservation (BLM), in accordance with Agency policy. Consider using field surveys as a tool to help determine presence, abundance, and areas for management.
- At stream/river sites managed for species persistence, maintain the integrity of microhabitat and microclimate conditions for all life stages by managing water flows, water quality, sedimentation, species assemblages, and a more open canopy.

Although recommendations can be developed for the entire range of the species, the variety of site conditions, historical and ongoing site-specific impacts, and population-specific issues warrant consideration of each site with regard to the extent of both habitat protection and possible restoration measures. General threats known for historically occupied watersheds are listed above, and should be considered during development of site-level and basin-level management approaches.

Borisenko and Hayes (1999) suggested 4 key guidelines for management of foothill yellow-legged frogs in Oregon:

1. <u>Minimize fine sediment loading into streams</u> - This is a concern relative to grazing, water impoundments, timber harvest, mining, and road building and maintenance.
2. <u>Minimize alterations of stream-edge habitats</u> - This is a concern relative to grazing, water impoundments, timber harvest, mining, road building and maintenance, and recreation.
3. <u>Minimize exotic species distributions</u> - At this time, in Oregon, this concern appears to be specific to bullfrogs and centrachid fishes such as smallmouth bass.
4. <u>Minimize degradation of water quality</u> - This concern relates to chemical applications, water impoundments, forest management, and road maintenance.

Two additional guidelines may be considered:

5. <u>Minimize fluctuations of flow regimes and avoid manipulating flow regimes</u> – Altered and fluctuating flows are a concern specific to water impoundments, and likely have the greatest effect on frogs during breeding and larval development, spring to summer.

6. <u>Minimize fragmentation and isolation of populations</u> - Aquatic connectivity can help retain the resiliency of populations to the variety of potential threats they may encounter.

Many Best Management Practices (BMPs) and Standards and Guidelines (S&Gs) utilized by the Forest Service and BLM already address the 6 broad concerns identified above. Those BMPs and S&Gs were designed to provide protection for multiple aquatic and riparian species.

Additional Considerations

Per project, the proposed activity can be assessed to identify the potential hazards specific to the site. For instance, will the activity create or increase stream sedimentation, produce microclimate shifts, or affect any of the six management guidelines listed above? The site or project area can be evaluated across several spatial scales. Proximity of sites to large reserved land allocations and maintaining connectivity to such areas is a prime consideration. Conversely, consider proximity to lands unlikely to serve as suitable habitat and their possible edge effects. Consider delineating the spatial extent of the occupied site and determine its relationship to other sites in the watershed.

Consider the spatial and temporal scales of the activity. A minimal or short-term risk may be inappropriate at a small, isolated population, whereas it may be acceptable in a well-connected, larger, stable population. Similarly, small-scale impacts such as incidental mortality caused by heavy equipment operations in habitat restoration may have a more adverse impact in small isolated populations as opposed to one in a larger, well-connected population. In many cases, the short-term impacts of restoration activities will have to be weighed against the long-term benefits they can produce. Thus, both current and predicted future conditions of the site and its habitat can be considered during risk assessment procedures.

If the risk, hazards, or exposure to actions are unknown or cannot be assessed, conservative measures, such as seasonal restrictions of habitat disturbing activities are recommended. Take the seasonal activity patterns of this species into consideration. Disturbance of animals and their habitats during breeding or larval development could result in direct mortality of individuals. A seasonal restriction during this critical season could reduce direct mortality. The exact dates of a seasonal restriction may vary, based on local conditions.

When possible, monitoring the effects of the activity may provide important information for future project planning efforts. When dead frogs are found, try to determine the cause of the mortality. If disease is implicated, employ disinfection protocols to reduce spread to other areas. Implement routine use of disinfection protocols when field gear such as waders and nets are used in multiple stream sites.

V. INVENTORY, MONITORING, AND RESEARCH OPPORTUNITIES

Data and Information Gaps

Additional data are needed to refine distribution and management effects on this species. Both monitoring and research studies may contribute to knowledge gaps. Appendix 3 lists all information gaps determined by an interagency work group assessing this species. At this time, ongoing projects are addressing several of these topics, with some progress revealed in this Conservation Assessment and below. In particular, information was lacking in these priority areas, determined by the working group in 2006:

FIRST PRIORITY

Suitable Habitat

- *Habitat map for Oregon*: Progress has been made on this task in 2007, see Appendix 1.
- *Need a more defined definition of habitat and habitat associations*: Progress has been made on this task in 2007, see Appendix 1; however, field validation of this habitat model has not occurred and is needed.

Distribution, Surveys & Survey Efforts Gaps

- *A full geographic inventory is needed in the northern extent of the range*: How far north does the species occur in the Coast Range and the Cascades? There are a couple of historic sites just east of the Siuslaw NF in the Smith River in the Coast Range that could indicate areas for further surveys. In the northern Oregon Cascade Range foothills west of the crest, the Pudding and Middle Mollala Rivers warrant survey considerations due to likely suitable habitat (C. Rombough, pers. commun.). Does this species occur in the Willamete basin? Surveys are funded to address some of these information gaps in 2007, with the BLM and Forest Service conducting inventories in the Coast and Cascade Ranges (D. Olson, pers. commun.) and Oregon Department of Fish and Wildlife contracting surveys in the Cascade Range (C. Rombough, pers. commun.).
- *Compile site and survey data from various sources*: This gap was identified as a priority for the Conservation Assessment Team, and resulted in the sites compiled for this document; this task has been completed.

SECOND PRIORITY

Life History Gaps

- *Movement: how far do they move in the aquatic zone and do they move into the upland? Do they go into riparian and upland areas?* The work group held a one-day meeting with RABO researchers in Corvallis Oregon in 2006. At that meeting, the researchers were asked what they could tell the team about aquatic and terrestrial movements. That information gathered from the meeting is presented in the Biology and Ecology section of the Conservation Assessment.
- *Habitat use by juvenile frogs*: Habitats important for non-adult post-metamorphic life stages are largely unknown. This could be a subject for further investigation.

Site Issues/Threats Gaps

- *Map each threat occurrence (fish distribution, bull frogs, dams, culverts, suction dredging/placer mining, fragmented ownership patterns, etc.).* This task was initiated by the Conservation Assessment Team (R. Davis, pers. commun.), and figures herein are the progress made to date. Location data on mining, culverts and invasive species distributions have not been well compiled. As additional information is gathered, these maps may be updated.

- *Where do we have local, presumably stable populations? Can we assess what makes the site likely to be stable (and apply that to other sites) i.e., if bullfrogs co-exist at stable site, then maybe bullfrogs are not the threat.* The work group asked researchers this question; this is unknown and still considered an important gap.

<u>Population Monitoring and Trends Gaps</u>

- *Need to find out what monitoring has been done*: As part of this Conservation Assessment we investigated monitoring efforts, but found no efforts in place specific to this frog. However, this is a topic under consideration by the USGS Amphibian Research and Monitoring Initiative for BLM lands in southwestern Oregon. Also, the NWFP Aquatic and Riparian Effectiveness Monitoring Program (AREMP) surveys stream and river systems. We determined that AREMP has detected this species, but an assessment as to the efficacy of this monitoring approach for these frogs was not conducted.

Inventory

Survey approaches may vary with objective and available resources. Several protocols can be considered for the foothill yellow-legged frog to detect presence and estimate relative abundance. In considering protocols for use, site selection and survey approach procedures need to be determined. Examples follow.

Seltenrich and Pool (2002) used a habitat-based site selection, such that a priori habitat reconnaissance determined moderate- and high-value habitats to be surveyed, with representative sub-sampling if a complete census was not practical. A follow-up survey was proposed if frogs are seen elsewhere. They suggested a 2-person Visual Encounter Survey (VES, Heyer et al. 1994, Olson et al. 1997) approach where a lead person scans ahead for frogs which may be spooked from surface habitats and a second person looks more closely at substrates to detect egg masses and tadpoles.

Rombough (2006) surveyed a 32-km stream length. His approach similarly involved a 2-person team, but these surveyors searched the two banks, overturning cover objects during their VES.

Borisenko and Hayes (1999) surveyed historic locations by locating the historic site at the mid-point of a stream reach for survey. A 2-person crew searched the reach (VES) for 2 hrs (hence a time-constrained survey, TCS), primarily in an upstream direction. If the stream was not wade-able, the crew remained on one side, but otherwise were deployed on each side.

While walking the stream might be the preferred approach, a streamlined method for extensive stream systems could include a two-step approach. First, reconnaissance of the targeted stream reach could be conducted to identify suitable habitats (e.g., by kayak to look for areas without silty substrates and overhanging vegetation; C. Rombough, pers. commun.). Then, suitable areas are revisited for a more intensive 2-person survey. A kayak could cover 20 stream miles in a day, whereas stream walking could be conducted at a rate of 2-5 miles per day, depending upon whether animals were measured and marked, or if only their locations were recorded (C. Rombough, pers. commun.).

Bury and Sisk (1997) used a habitat-based scheme and stratified habitats into headwater and large water types. They first mapped stream reaches, then conducted frog surveys. They used VES, TCS, and area-constrained searches (ACS), with a 3-person crew: 2 searchers and 1 data recorder. TCS was used in larger streams, with one surveyor on each side of the stream conducting VES. In headwaters, in a 100-m reach, three 5-m bands, regularly spaced, were identified for an ACS.

Surveys conducted for the federal Northwest Forest Plan Aquatic and Riparian Effectiveness Monitoring Program (AREMP) have detected this frog. This is an extensive survey effort of about 250 watersheds over a 5-year period. They used a random stratified site selection, with VES, TCS and electrofishing approaches. Survey protocols and AREMP information is available at: http://www.reo.gov/monitoring/report_show.php?show=watershed

Welsh et al. (1997) provides another habitat-based approach for streams with systematic subsampling in belts for amphibians.

Fellers and Freel (1995) provided a standard protocol for western aquatic amphibians, and more comprehensively discussed a host of survey considerations. Their basic VES approach was to scan ahead with binoculars for basking frogs, walk the water or bank and search for all life history stages, and dip net to capture tadpoles and frogs. They provide specific tips for foothill yellow-legged frogs.

Bury and Corn (1991) provided one of the first sampling protocols for stream amphibians. The above-cited approaches are refinements of this early approach, and are likely more appropriate for detection and monitoring of foothill yellow-legged frogs.

The timing of surveys needs considerations. Finding eggs in the spring can be very time consuming, while late summer is a good time to more readily find transforming larvae and juveniles. However, if egg or larval mortality is high, the later surveys may not detect frog presence.

Collection of accurate locations is a survey priority. Using a Global Positioning System, coordinates of reaches surveyed should be recorded. It is critical to document reaches surveyed without detections of the frog and enter the survey data into the appropriate corporate database (GeoBOB/NRIS), in addition to reaches with detections.

Detectability is an issue with most amphibian survey methods. Are the animals detected if present? Repeat observations can be easily built into a survey protocol for inventories. A second site visit in a subsequent year detected frogs at sites where they were not detected in their first survey (M. Hayes, pers. commun.), hence detectability is not assured by the single pass by a 2-person crew.

Other types of inventory or research methods may be needed for studies that address such questions as species-habitat associations, long-term effects of disturbances, movement or occupancy patterns. This type of work will have additional inference to the sampled population if random site selection is used. Nonrandom site selection results in case studies with implications only to the sampled sites; biased samples and results may occur. Mark-recapture methods may be effective approaches for long-term site or population studies (Heyer et al.1994).

Monitoring

Knowledge of land management activities at sensitive species' sites can enable monitoring and adaptive management relative to species management objectives. If impacts to sites occur, annual accomplishment reporting could be considered, and electronic data entry in GeoBOB/NRIS provides a standard format for documentation. Complete all applicable GeoBOB/NRIS data fields (e.g., site management status, non-standard conservation action; threat type; and threat description). With later monitoring, impacts to habitats or species can be assessed.

Ongoing monitoring of current-populations and the implementation and effectiveness monitoring of currently-imposed protective measures are needed. What are the recognized hazards, exposure to hazards, and risks to animals or habitats at each locality and for each population? How is management addressing each identified scenario of hazards, exposures, and risks per site or population? How can hazards be reduced over the long term in highly sensitive areas? Rather than always focusing on site-specific management, can the results of compiled risk analysis be used to generate long-term area management goals?

Research

The data gaps discussed above each relate to needed research on this animal. In particular, there is little information on how various land and stream management practices may affect microhabitats or populations of these frogs.

The use of the Federal GeoBOB/NRIS databases will allow several questions of the spatial distribution of this species to be addressed for the development of landscape-level design questions and assessment of habitat. If sites surveyed with no detections were also reported in these databases, relationships in frog distributions relative to the spatial distribution of vegetation types, slope, aspect, topography, elevation, riparian areas, land allocation, land ownership, historical disturbances, and current disturbances could be assessed, as well as detectability relative to survey protocols used. A risk assessment is currently being developed between these factors and the long-term persistence of populations to assist in answering such questions as: are there populations or areas where stronger or relaxed protective measures may be warranted, or where adaptive management might be attempted? Development of strategies to address these questions of conservation biology is a critical research need.

VI. ACKNOWLEDGMENTS

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VII. DEFINITIONS

Persistence - The likelihood that a species will continue to exist, or occur, within a geographic area of interest over a defined period of time. This includes the concept that the species is a functioning member of the ecological community of the area.

Site (Occupied) - The location where an individual or population of the target species (taxonomic entity) was located, observed, or presumed to exist and represents individual detections, reproductive sites or local populations. Specific definitions and dimensions may differ depending on the species in question and may be the area (polygon) described by connecting nearby or functionally contiguous detections in the same geographic location. This term also refers to those located in the future. (USDA, USDI 1994)

Oregon and California Natural Heritage Program Definitions

Globally Vulnerable

G3 = Vulnerable, at moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

State imperiled/not immediately imperiled

S2 = Imperiled in the state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation
S3 = Rare, uncommon or threatened, but not immediately imperiled, typically with 21-100 occurrences.

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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 4^{th}-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).

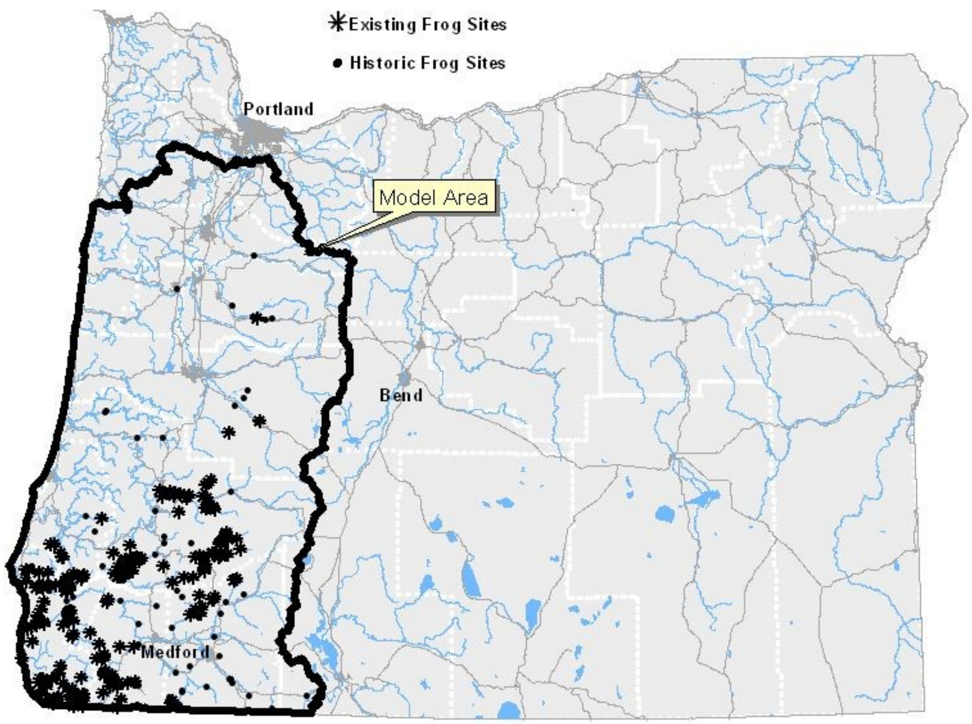

Figure 1-1. Area of western Oregon selected for habitat modeling.

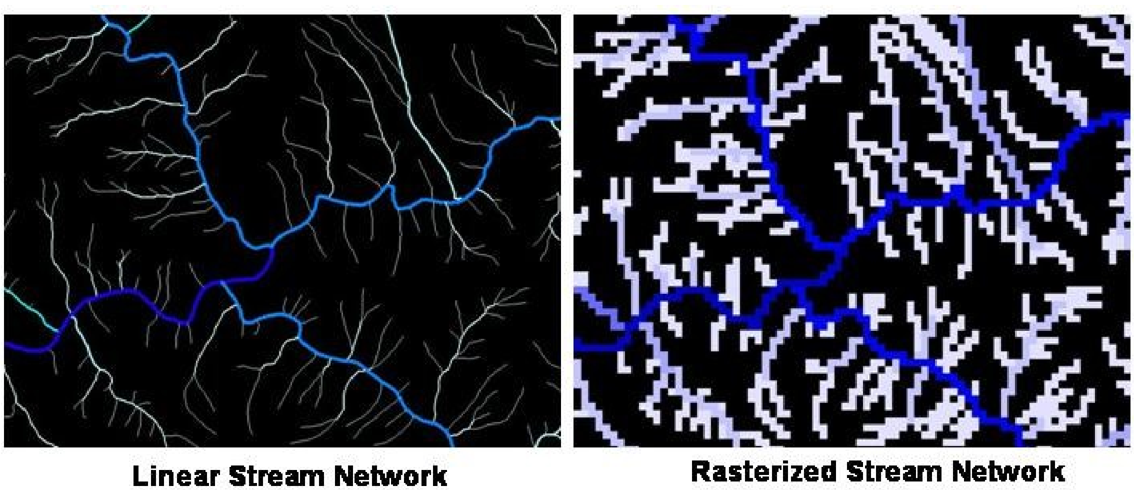

Figure 1-2. Linear streams and rivers within the modeled area were rasterized to 100 m for modeling purposes. The black background represents the area masked from modeling.

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).

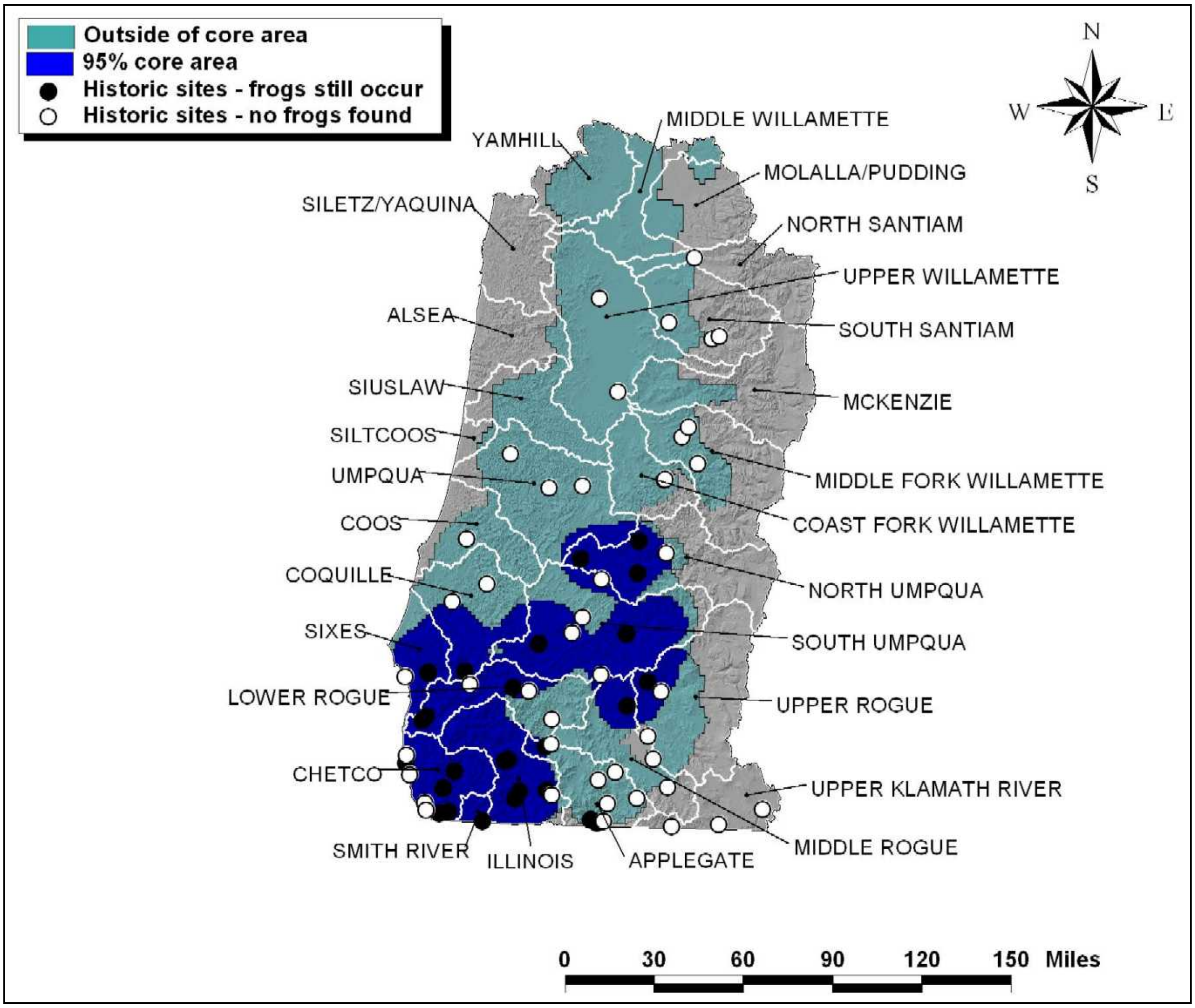

Figure 1-3. Map of estimated "core area" of frog presence and distribution of suitable habitats, showing Borisenko and Hayes (1999) data used for the Mann-Whitney test comparison of threat factors between sites with and without frogs.

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.

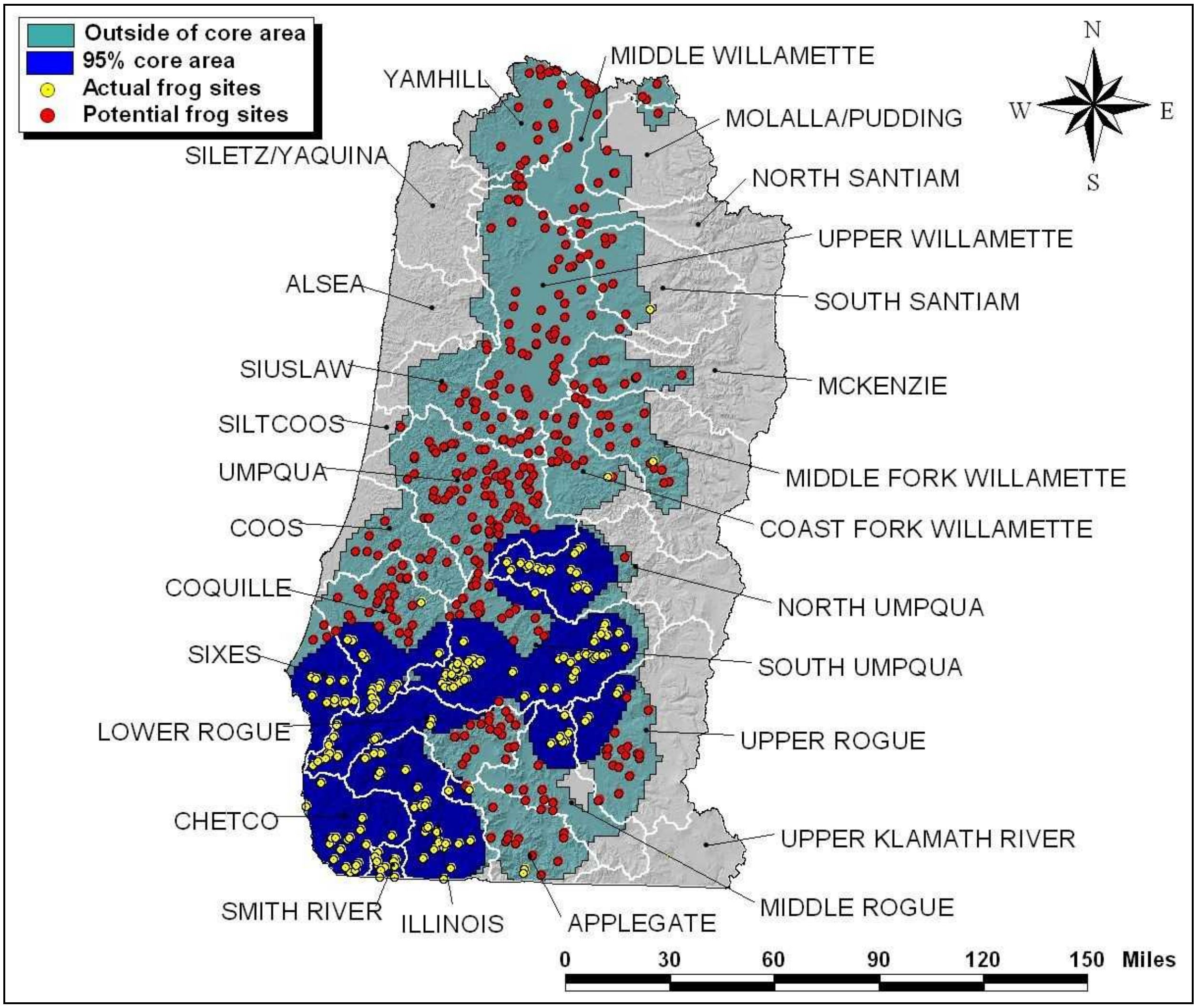

Figure 1-4. Map of estimated "core area" of frog presence and distribution of suitable habitats, showing all current frog presence sites used for modeling (yellow dots) and one replicate of randomly generated "potential sites" (red dots) used for a means comparison.

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.

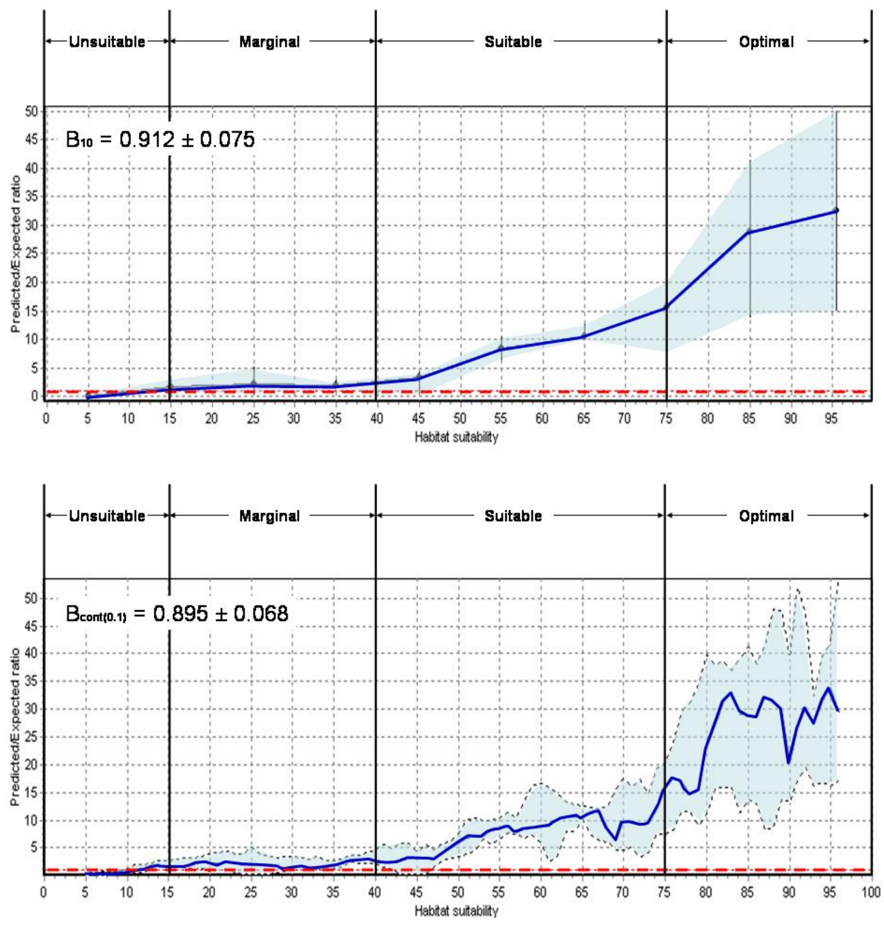

Figure 1-5. Results of the k-fold cross model validation, showing the Boyce Indices (top: B10 index; bottom: continuous Bcont(0.1) index) and how the curve was divided into areas representing unsuitable, marginal, suitable and optimal habitat (Hirzel et al. 2006).

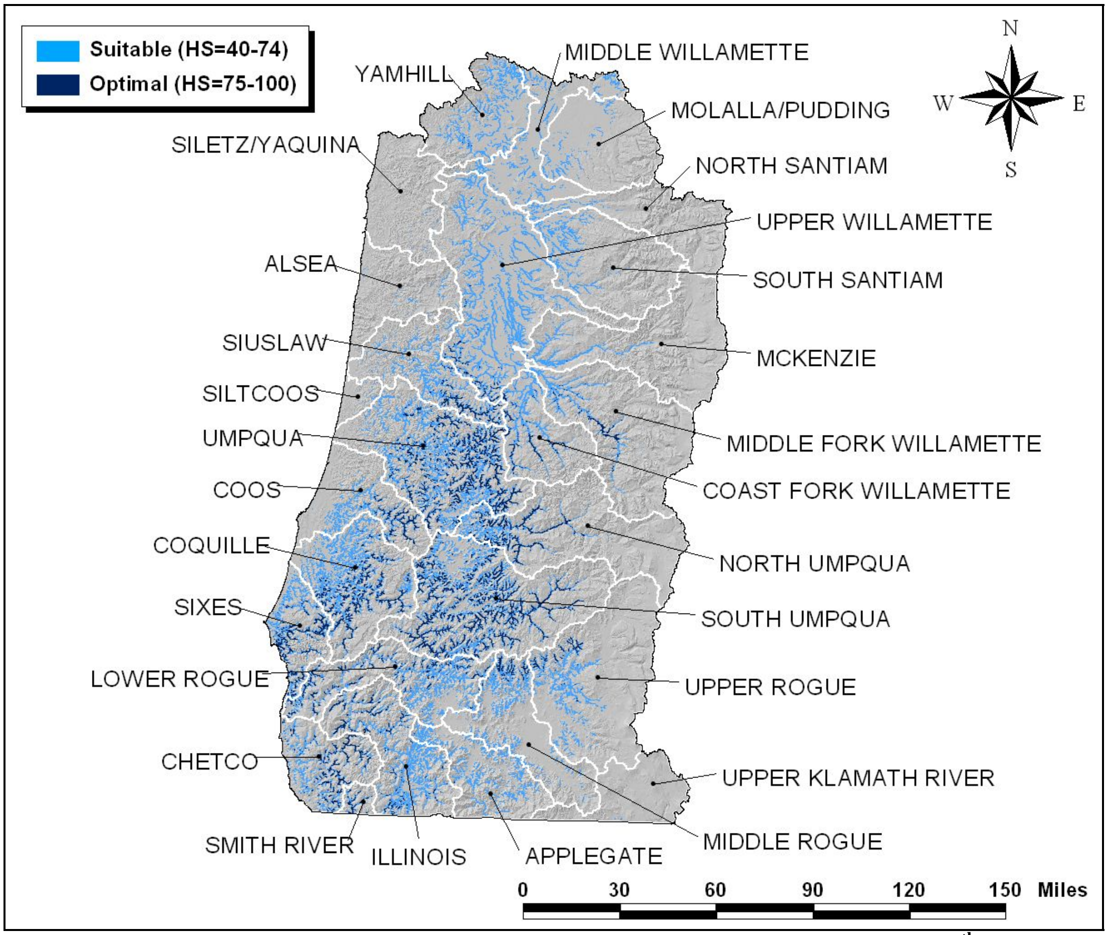

Figure 1-6. Modeled habitat (blue) for the foothill yellow-legged frog in relation to 4th -field watersheds (white boundary lines).

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-m²/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-m²/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%)
1	strahler (0.74)	wintermin (0.54)	precipfreq (0.69)	elevation (0.75)
2	summermin (0.32)	summermin (0.45)	elevation (0.43)	wintermin (0.58)
3	wintermin (0.31)	strahler (-0.41)	wintermin (0.38)	annualrad (-0.20)
4	precipfreq (-0.30)	elevation (0.34)	summermin (0.25)	summerrad (0.14)
5	slope (-0.23)	annualrad (0.24)	summermax (-0.24)	slope (0.13)
6	elevation (-0.21)	preciptotal (-0.23)	preciptotal (-0.19)	precipfreq (0.10)
7	summermax (0.16)	summerrad (-0.20)	strahler (0.15)	summermax (0.06)
8	brdlfcov (0.12)	conifcov (0.15)	slope (-0.08)	totalcov (0.06)
9	annualrad (0.11)	totalcov (-0.14)	annualrad (0.05)	conifcov (-0.06)
10	conifcov (-0.09)	summermax (0.11)	totalcov (-0.04)	summermin (0.06)
11	totalcov (-0.06)	brdlfcov (0.10)	conifcov (0.03)	strahler (0.04)
12	summerrad (0.05)	slope (-0.04)	summerrad (0.02)	preciptotal (0.01)
13	preciptotal(-0.04)	precipfreq (-0.01)	brdlfcov (-0.01)	brdlfcov (0.00)
variable	**Factor 5 (6%)**	**Factor 6 (6%)**	**Factor 7 (4%)**	**Factor 8 (4%)**
1	summermax (0.66)	totalcov (0.63)	elevation (0.50)	summermin (0.61)
2	preciptotal (0.63)	brdlfcov (-0.53)	conifcov (-0.45)	wintermin (-0.40)
3	summerrad (0.25)	conifcov (-0.44)	summerrad (0.43)	summerrad (0.35)
4	annualrad (-0.17)	preciptotal (-0.22)	summermax (-0.36)	preciptotal (0.31)
5	conifcov (-0.12)	precipfreq (-0.17)	wintermin (0.25)	totalcov (0.30)
6	strahler (-0.12)	annualrad (-0.16)	summermin (0.24)	annualrad (0.26)
7	brdlfcov (-0.12)	summermax (-0.15)	precipfreq (0.23)	precipfreq (0.19)
8	wintermin (0.11)	wintermin (0.08)	brdlfcov (-0.19)	summermax (-0.17)
9	slope (-0.10)	slope (-0.06)	preciptotal (-0.10)	conifcov (-0.14)
10	elevation (0.07)	summerrad (-0.06)	slope (-0.09)	brdlfcov (-0.09)
11	totalcov (0.07)	strahler (0.02)	annualrad (-0.07)	slope (0.06)
12	summermin (-0.05)	elevation (0.01)	totalcov (0.06)	elevation (-0.04)
13	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/mi²)	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).

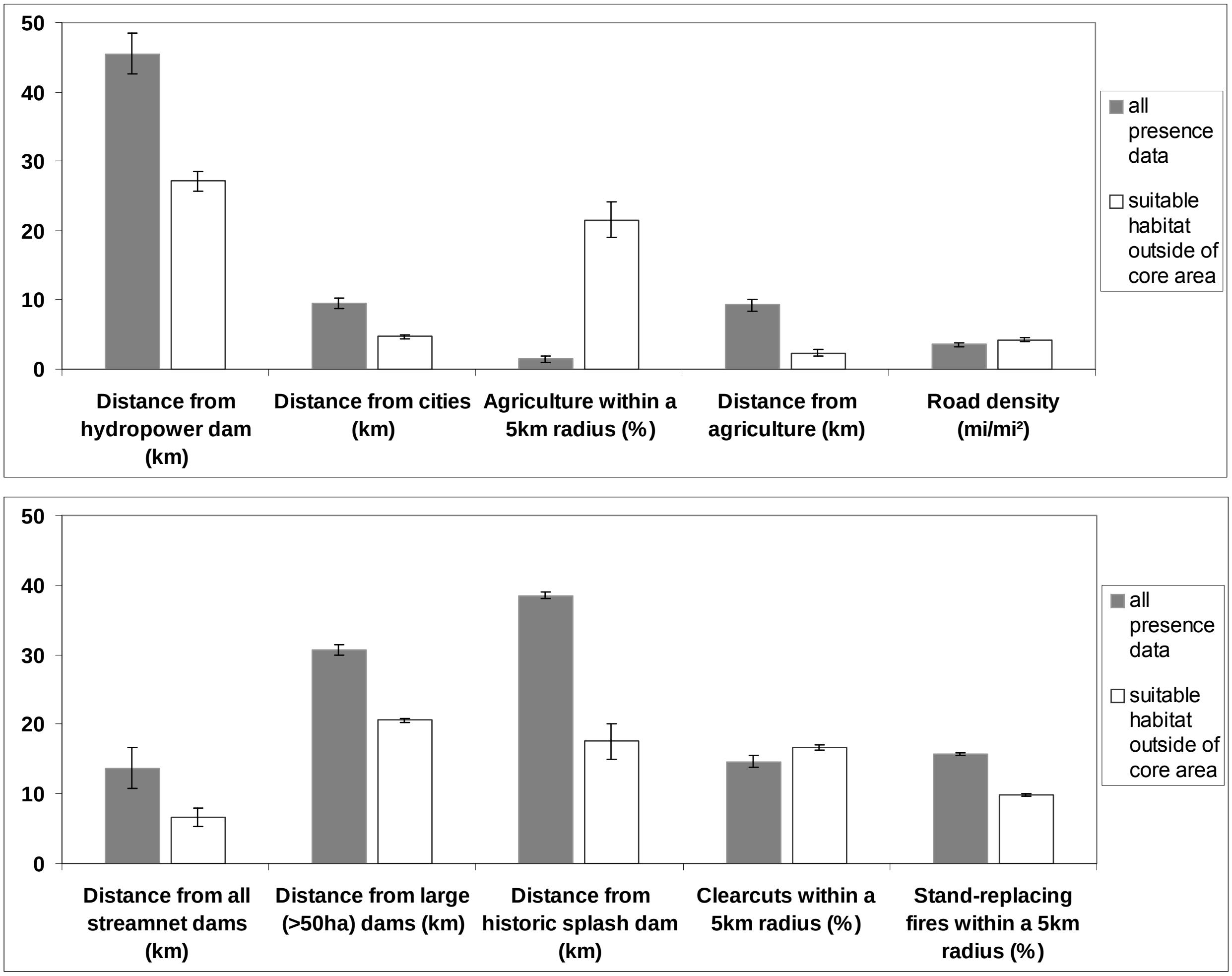

Figure 1-7. Mean values (and 95% confidence intervals) for landscape-scale potential threat variables at sites with current frog presence (n=237) and bootstrapped sample of the area of suitable habitat outside of the core area.

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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APPENDIX 2. WATERSHED SUMMARIES

Table 2-1. Summary table of 4th and 5th -field watersheds that contained modeled suitable habitat or documented sightings.

4th-Field Watershed	5th-Field Watershed	Percent of Rivers & Streams: % Suitable (HS>40)	% Optimal (HS>75)	% Suitable on Fed Land	Frog Presence: Historic	Current
ALSEA	UPPER ALSEA RIVER	1	0	13		
APPLEGATE	LITTLE APPLEGATE RIVER	3	0	44	■	
	UPPER APPLEGATE RIVER	3	0	60		■
	APPLEGATE RIVER/MCKEE BRIDGE	4	0	89	■	
	MIDDLE APPLEGATE RIVER	4	0	39	■	
	LOWER APPLEGATE RIVER	6	0	41		■
	WILLIAMS CREEK	6	0	36		
CHETCO	CAPE FERRELO FRONTAL	3	0	3	■	
	HUNTER CREEK	6	1	3		■
	PISTOL RIVER	8	0	24		■
	CHETCO RIVER	12	3	78		■
	WINCHUCK RIVER	24	5	91		■
COAST FORK WILLAMETTE	ROW RIVER	3	0	9		■
	MOSBY CREEK	6	1	4		
	UPPER COAST FORK WILLAMETTE RIVER	10	2	2		
	LOWER COAST FORK WILLAMETTE RIVER	24	1	0		
COOS	COOS BAY	4	0	5		
	MILLICOMA RIVER	4	0	0		
	SOUTH FORK COOS	7	2	16		
COQUILLE	EAST FORK COQUILLE	6	1	39		■
	COQUILLE SOUTH FK LOWER	8	3	32		■
	LOWER COQUILLE	9	0	3		
	MIDDLE FORK COQUILLE	9	2	19		■
	NORTH FORK COQUILLE	10	0	29		
	MIDDLE MAIN COQUILLE	15	3	4		■
ILLINOIS	SUCKER CREEK	6	0	55		■
	INDIGO CREEK	7	2	100		■
	SILVER CREEK	7	2	95		■
	ILLINOIS RIVER/LAWSON CREEK	8	3	91		■
	BRIGGS CREEK	11	2	97		■
	ILLINOIS RIVER/KLONDIKE CREEK	11	3	100		■
	EAST FORK ILLINOIS RIVER (WEST)	13	0	29		
	ILLINOIS RIVER/JOSEPHINE CREEK	13	0	64		■
	DEER CREEK	14	0	29		
	EAST FORK ILLINOIS RIVER (EAST)	16	0	27		■
	WEST FORK ILLINOIS RIVER	19	1	30		■
LOWER ROGUE	ROGUE RIVER/HORSESHOE BEND	5	1	96		■
	JUMPOFF JOE CREEK	6	0	29	■	
	ROGUE RIVER/ILLAHE CREEK	8	2	90		■
	ROGUE RIVER/STAIR CREEK	8	1	97	■	
	LOWER ROGUE	9	2	34		■
	LOBSTER CREEK	10	3	41		■
	ROGUE RIVER/HELLGATE	10	0	70		
	GRAVE CREEK	13	1	25	■	
MCKENZIE	MCKENZIE RIVER/QUARTZ CREEK	2	0	17		
	MOHAWK RIVER	4	0	2		
	LOWER MCKENZIE RIVER	6	0	1		

Table 2-1. Watershed summary (cont.)

4th-Field Watershed	5th-Field Watershed	Percent of Rivers & Streams: % Suitable (HS>40)	% Optimal (HS>75)	% Suitable on Fed Land	Frog Presence: Historic	Current
MIDDLE FORK WILLAMETTE	HILLS CREEK	1	0	100		
	NORTH FORK OF MIDDLE FORK WILLAMETTE RIVER	1	0	74		
	SALMON CREEK	1	0	66		
	SALT CREEK/WILLAMETTE RIVER	1	0	100		
	LITTLE FALL CREEK	2	0	5		
	FALL CREEK	3	0	14	■	
	HILLS CREEK RESERVOIR	4	1	79		
	MIDDLE FORK WILLAMETTE/LOOKOUT POINT	8	1	40		■
	LOWER MIDDLE FORK OF WILLAMETTE RIVER	15	0	1		
MIDDLE ROGUE	BEAR CREEK	1	0	2	■	
	ROGUE RIVER/GRANTS PASS	1	0	32		
	ROGUE RIVER/GOLD HILL	3	0	29		
	EVANS CREEK	7	1	41		■
MIDDLE WILLAMETTE	ABERNETHY CREEK	6	0	1		
	MILL CREEK/WILLAMETTE RIVER	7	0	0		
	RICKREALL CREEK	7	0	5		
	WILLAMETTE RIVER/CHEHALEM CREEK	13	0	0		
MOLALLA/PUDDING	LOWER MOLALLA RIVER	1	0	5		
	ROCK CREEK/PUDDING RIVER	1	0	0		
	ABIQUA CREEK/PUDDING RIVER	3	0	0		
NORTH SANTIAM	LOWER NORTH SANTIAM RIVER	7	0	0	■	
NORTH UMPQUA	CANTON CREEK	1	0	69		
	MIDDLE NORTH UMPQUA	4	1	79		■
	ROCK CREEK/NORTH UMPQUA RIVER	4	2	29		■
	LITTLE RIVER	6	2	15		■
	LOWER NORTH UMPQUA RIVER	19	4	8		■
SIUSLAW	DEADWOOD CREEK	1	0	13		
	INDIAN CREEK/LAKE CREEK	1	0	21		
	NORTH FORK SIUSLAW RIVER	1	0	49		
	LOWER SIUSLAW RIVER	2	0	13		
	LAKE CREEK	3	0	19		
	WOLF CREEK	8	0	28		
	WILDCAT CREEK	10	0	13		
	UPPER SIUSLAW RIVER	11	2	27		
SIXES	NEW RIVER FRONTAL	9	0	0		
	ELK RIVER	11	3	49		■
	HUMBUG NESIKA FRONTAL	12	4	1	■	
	SIXES RIVER	12	3	18		■
SMITH RIVER	LOWER SMITH RIVER	8	0	100		
	NORTH FORK SMITH RIVER	12	4	98		■
SOUTH SANTIAM	THOMAS CREEK	1	0	0		
	WILEY CREEK	1	0	0		
	SOUTH SANTIAM RIVER/FOSTER RESERVOIR	3	0	0		■
	CRABTREE CREEK	6	0	0		
	HAMILTON CREEK/SOUTH SANTIAM RIVER	7	0	0	■	

Table 2-1. Watershed summary (cont.)

4th-Field Watershed	5th-Field Watershed	Percent of Rivers & Streams			Frog Presence	
		% Suitable (HS>40)	% Optimal (HS>75)	% Suitable on Fed Land	Historic	Current
SOUTH UMPQUA	UPPER SOUTH UMPQUA RIVER	1	0	80		■
	WEST FORK COW CREEK	3	1	38		■
	JACKSON CREEK	4	1	83		■
	MIDDLE SOUTH UMPQUA RIVER (EAST)	6	2	68		■
	UPPER COW CREEK	7	2	38		■
	ELK CREEK/SOUTH UMPQUA	10	3	32		■
	LOWER COW CREEK	10	3	30		■
	MIDDLE COW CREEK	11	3	21		■
	MIDDLE SOUTH UMPQUA RIVER (WEST)	11	3	8		
	MYRTLE CREEK	12	3	16	■	
	OLLALA CREEK/LOOKINGGLASS	12	3	10		■
	LOWER SOUTH UMPQUA RIVER	13	2	0		■
	SOUTH UMPQUA RIVER	13	4	31		■
UMPQUA	LOWER UMPQUA RIVER	1	0	30		
	LOWER SMITH RIVER	3	0	41	■	
	UPPER SMITH RIVER	8	1	50		
	LAKE CREEK	10	1	12		
	MIDDLE UMPQUA RIVER	12	2	27		
	UPPER UMPQUA RIVER	12	2	25		
	ELK CREEK	15	4	11	■	
	CALAPOOYA CREEK	18	6	2		
UPPER KLAMATH RIVER	COTTONWOOD CREEK	0	0	0	■	
	JENNY CREEK	0	0	0		■
	KLAMATH RIVER/IRON GATE	1	0	30		
	MIDDLE UPPER KLAMATH RIVER				■	
UPPER ROGUE	LITTLE BUTTE CREEK	2	0	29		■
	ELK CREEK/ROGUE RIVER	5	1	29		■
	BIG BUTTE CREEK	8	0	23		
	ROGUE RIVER/SHADY COVE	8	0	52	■	
	ROGUE RIVER/LOST CREEK	9	0	32	■	
	TRAIL CREEK	10	1	32		■
UPPER WILLAMETTE	LUCKIAMUTE RIVER	7	0	0		
	CALAPOOIA RIVER	9	0	0		
	MARYS RIVER	9	0	7		
	OAK CREEK	17	0	0		
	LONG TOM RIVER	19	1	3		
	MUDDY CREEK	23	0	0	■	
YAMHILL	MILL CREEK/SOUTH YAMHILL RIVER	3	0	0		
	UPPER SOUTH YAMHILL RIVER	3	0	0		
	WILLAMINA CREEK	3	0	7		
	NORTH YAMHILL RIVER	10	0	0		
	LOWER SOUTH YAMHILL RIVER	12	0	0		
	YAMHILL RIVER	12	0	0		
	SALT CREEK/SOUTH YAMHILL RIVER	17	0	0		

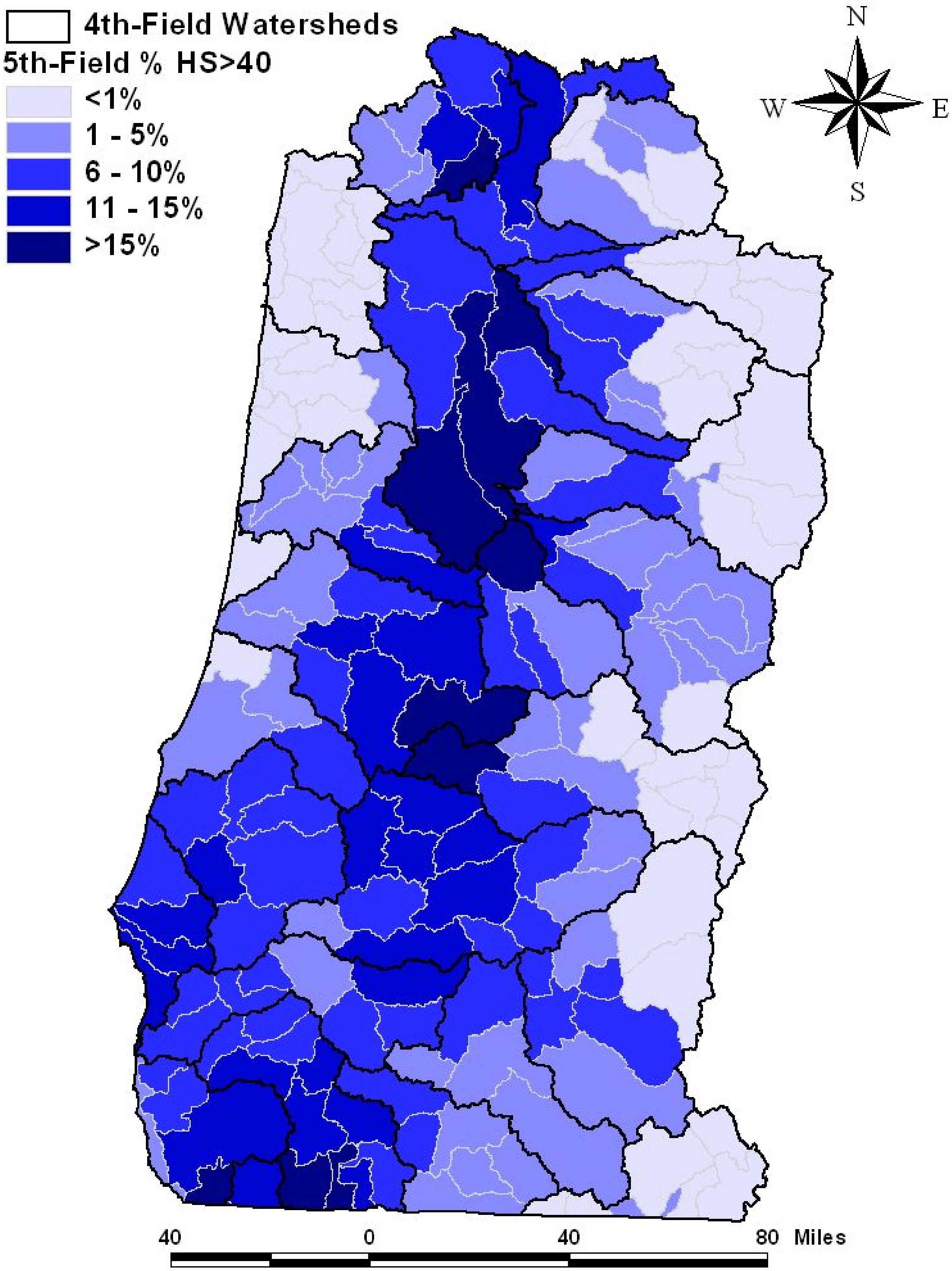

Figure 2-2. A graduated 4th and 5th -field watershed map showing the percentage of the watershed's river and stream network that was modeled as suitable habitat (HS>40) for the foothill yellow-legged frog. Percentages ranged from 0-24%. For watersheds that contained suitable habitat, the mean percentage of a watershed's river and stream network that was modeled as suitable was 10%.

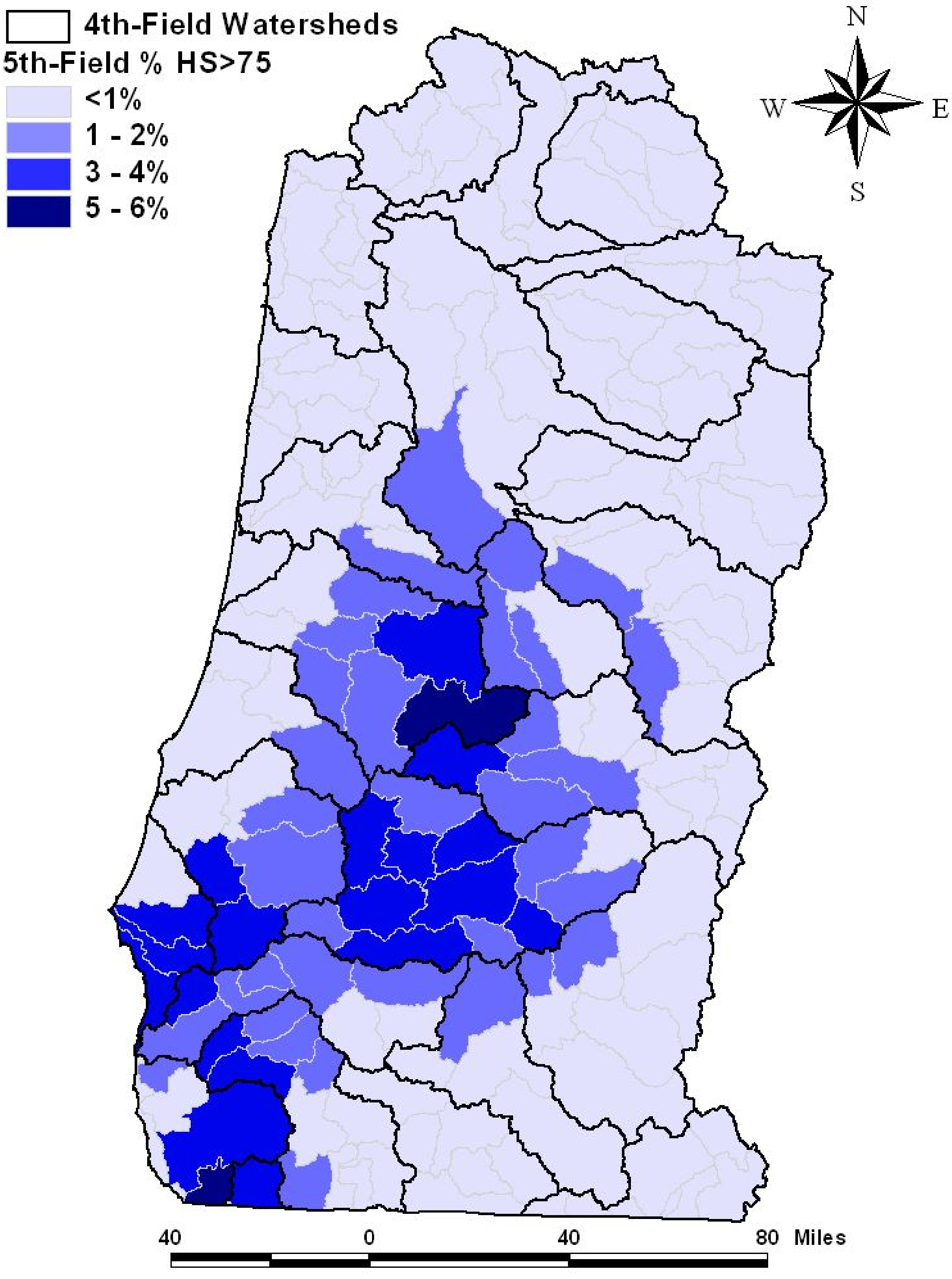

Figure 2-3. A graduated 4th and 5th -field watershed map showing the percentage of the watershed's river and stream network that was modeled as optimal habitat (HS>75) for the foothill yellow-legged frog. Percentages ranged from 0-24%. For watersheds that contained suitable habitat, the mean percentage of a watershed's river and stream network that was modeled as optimal was 2%.

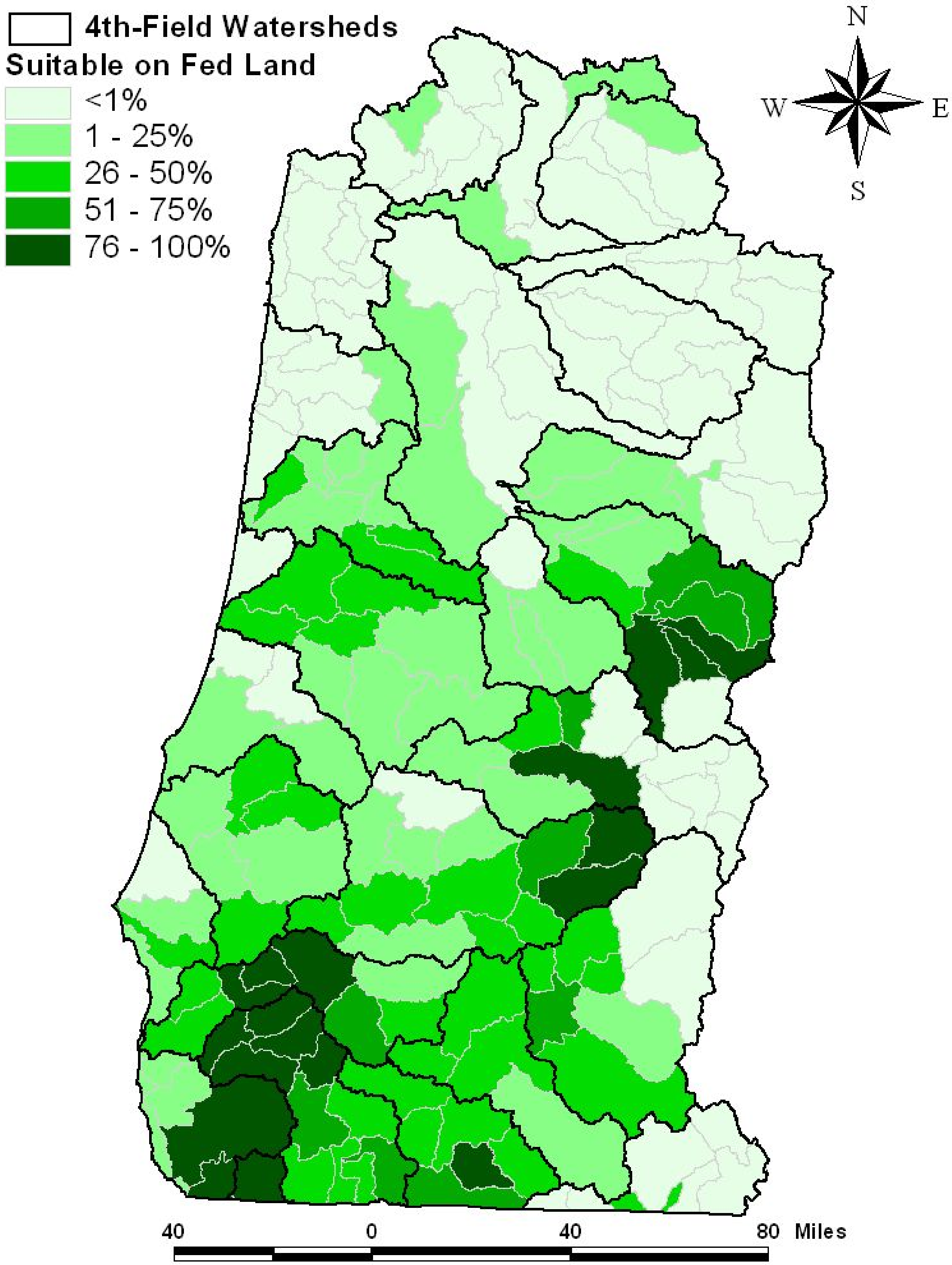

Figure 2-4. A graduated 4th and 5th -field watershed map showing the percentage of the watershed's suitable habitat (HS>40) for the foothill yellow-legged frog, that is on Federal Lands (e.g., USFS and BLM). Percentages ranged from 0-100%.

APPENDIX 3. INFORMATION GAPS

The following is an exhaustive list of perceived information gaps and data needs that were brainstormed by the Foothill yellow-legged frog interagency work group during the early phases of this Conservation Assessment. Some progress has been made on some of these gaps during the development of this Conservation Assessment: see the text of the Assessment for a discussion.

Habitat Gaps

- What is the priority habitat in a linear distribution network? Are tributaries as important as larger streams? There's a difference between where they can occur versus critical habitat (what pieces of the stream network do they need to complete a life cycle: breeding, foraging, summer and winter refugia).
- What is their overwintering habitat?
- Habitat map for Oregon.
- Are the small streams where they are found always associated with large nearby streams? Is the proximity of small to large streams important?
- What are the responses to change in habitat?
- Need a more defined definition of habitat. What are key habitat features and habitat associations?
- Are beaver ponds unsuitable habitat? (because beavers create slow water, but there has been no mention of this species in beaver pond areas)
- Elevational distribution for Oregon?
- Map temperature variations along elevational gradient.
- Map of substrate for Oregon rivers/streams and geomorphology.

Life History Gaps

- What's the maximum and minimum temperatures use in their aquatic form (eggs and tadpoles) and optimum (what should we be managing for?)?
- Movement: how far do they move in the aquatic zone and do they move into the upland? Do they go into riparian and upland areas?
- What constitutes a stream habitat gap (what's a barrier)? What are the connectivity barriers? (identify, map, and analyze connectivity barriers to known sites).
- How much area and how many animals is a sub-population that would persist along a stream network to conduct their life cycle? How much habitat is necessary to support a self-sustaining population? (is it feasible in a checkerboard land ownership to manage for this species).
- Are there sex ratio changes as a result of environmental pressures/habitat changes?
- Fecundity and mortality: is there adequate recruitment of young to replenish self-sustaining populations?

Distribution, Surveys & Survey Efforts Gaps

- A full geographic inventory is needed in the northern extent of the range. How far north does the species occur in the Coast Range and the Cascades? There are a couple historic sites just east of the Siuslaw NF in the Smith River.
- Where are stable populations?
- What survey protocol would you use? Need protocol to determine "no detection."
- Can we piggyback on the fish surveys? They may be collecting info we don't know about.
- What is the genetic variation of species?
- Compile site and survey data from various sources:
- How do we get anecdotal data from fish bios?

Site issues/Threats Gaps

- Map each threat occurrence (e.g., fish distribution, bull frogs, dams, culverts, suction dredging/placer mining, fragmented ownership patterns, etc.).
- Where do we have local, stable populations. Can we assess what makes the site stable and apply that to other sites (e.g., if bullfrogs co-exist at stable site, then maybe bullfrogs are not the threat)?
- Site (risk) assessment: assess each site, determine stability states, threats.
- Is fish/ecosystem restoration work truly beneficial to this species?
- Bullfrogs and introduced fish:
    - Are there circumstances where you can get co-occurrence?
    - Are these a contributing factor in local extirpations?
- Dams and influence of dam management on this species:
    - Which are hydropower versus other (map)? Management creates flow flushes in summer and impacts frog.
    - Flood control (time of year)
    - Size of reservoir
- Sedimentation activities, pesticides, and chemicals:
    - What is their sensitivity to water quality, sedimentation, pollutants?
    - How sensitive are they?
    - At what point do the interstitial spaces become filled, unused?
    - Do fish and BMPs provide sufficient management?
    - Whole role does the duration of the activity play?
- Does the chytrid fungus occur in the Oregon range and habitat? Is it a threat to this species?
- Recreational jet boats:
    - How wakes might impact egg masses, tadpoles, and adult behavior?
- Habitat fragmentation, ownership patterns (BLM):
    - How well can the species move across non-habitat?
    - What constitutes a habitat barrier?
    - How land uses on non-federal may impact federal land capability?
- Suction dredging/placer mining:
    - How much suction dredging and placer mining is occurring now and in the recent past? Placer mining is a permitted activity so we could map active claims.

    - What is the extent of on-site impacts (cobble/gravel movement) and the downstream impacts (sedimentation)? Clean-water Act and ESA do apply in the streams.
- Global climate change/UV radiation
    - How sensitive are they to UV levels?

Population Monitoring and Trends Gaps

- Need to find out what monitoring has been done. Is there a comprehensive status assessment of where we had the species and where they are now in Oregon? Know historic locations and when they were last extant?
    - Is it really extirpated in the northern range in the Willamette Basin?
    - What monitoring plan does USGS have for this species? Does it suffice for this species range in Oregon? Is NWFP AREMP monitoring detecting this species and if so, could their monitoring plan suffice?
- Where are the populations doing well and why?