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Public Comments Processing
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U.S. Fish and Wildlife Service
MS: BPHC
5275 Leesburg Pike
Falls Church, VA 22041–3803

RE: Comments in support of Endangered Species Act Protection for the Green Salamander (*Aneides aeneus*) 80 FR 37568

Figure 1. Green Salamander Photograph © John B. Jensen, Georgia Department of Natural Resources

Please accept these comments from the Center for Biological Diversity in support of Endangered Species Act (ESA) protection for the green salamander (*Aneides aeneus*). We urge the Service to promptly issue a proposed listing rule for this threatened salamander. The survival of this unique amphibian is of scientific, moral, aesthetic, recreational, economic, spiritual, and other value to our members.

Though the green salamander occurs in appropriate habitat in states throughout Appalachia, its multi-state distribution does not ensure that it will not become endangered in the foreseeable future. It is widely but very patchily distributed. Much of the range includes isolated and peripheral populations that are vulnerable to statewide extinction in most of the states within it range (Brodman 2004, p. 2). Range wide it is highly vulnerable to rapid declines from threat factors such as climate change, habitat alteration, collection, and/or disease. Emerging issues pose grave threats to the salamander's future. Recent research has predicted that it will lose from 49 to 93 percent of its total habitat to climate change (Sutton et al. 2014, p. 14; Barrett et al. 2014, p. 287) and 20 percent of its habitat in the Marcellus Shale region to natural gas development through fracking (Brand et al. 2014, p. 239). The life history factors of the green salamander make it very difficult for populations to recover following decline; combined with its very specific habitat requirements, the green salamander is extremely vulnerable to extirpation.

DESCRIPTION

Even in the salamander rich eastern United States, green salamanders play a particularly special role in the natural history of the region. They represent a unique component of the fauna because they are the only member of the climbing family of salamanders that is found east of the continental divide. They are also the only salamander in the east with bright green coloration (Conant and Collins 1998). Their lichen-like blotches, large buggy eyes, long-legs, conspicuously square toes and flattened body make the green salamander noticeably remarkable. Green salamanders grow to be about five inches long.

TAXONOMY

Though the green salamander is currently considered to be a single species, it is highly likely that the species will be split into several smaller taxonomic groups (Brodman 2004, Pauley and Watson 2005). This heightens the conservation priority and risk of extinction for each smaller entity. Morescalchi (1975) and Sessions and Kezer (1987) report that there are three distinct forms of green salamander based on chromosomal studies. Based on nucleotide sequences, Corser (pers. comm. cited in Brodman 2004 and AmphibiaWeb 2015) determined that there are four species-level clades of green salamanders based on nucleotide sequences and ecological and morphological traits.

RANGE

The green salamander is patchily distributed throughout the Appalachian Mountains in appropriate habitat patches.

Figure 4. The historic range of the green salamander (adapted from USGS ARMI).

Figure 2. Green Salamander Range Map from Brodman 2004 (p. 10).

STATUS

The green salamander is considered to be a species of conservation concern in every single state in its range and by Northeast Partners in Amphibian and Reptile Conservation (NEPARC 2010). It is listed as endangered by the states of Indiana, Ohio, Maryland, Mississippi, and North Carolina, as threatened by Pennsylvania, and as protected by Georgia (Arkive 2015, AmphibiaWeb 2015). It is considered to be vulnerable rangewide and is ranked as critically imperiled to vulnerable in every state in its range (NatureServe 2015).

The green salamander's area of occupancy, number of subpopulations, and especially abundance apparently have declined significantly over the past several decades (NatureServe 2015). Herpetologists believe that green salamanders used to be more common range wide than they are now and the species is thought to be declining overall (International Union for Conservation of Nature 2004, Criswell 2014, p. 53; Cantrell 2012, abstract; Kentucky Wildlife Action Plan 2013).

The reasons for green salamander decline are not understood. Cantrell (2012) reports that the salamanders are declining in a study area in Tennessee for unknown reasons, even though suitable habitat is present and despite intensive searching. Other researchers have also reported unexplained declines (Snyder 1991, Mitchell et al. 1999, Corser 2001) pointing to climate change, bad weather, habitat loss, collection or disease as possible causes.

Regarding the decline of green salamanders in the Blue Ridge Mountains of Georgia, South Carolina and North Carolina, Corser (2001) states: “Long-term monitoring of seven historical green salamander populations throughout the 1990s showed a 98% decline in relative abundance since 1970. Three out of six populations first discovered in 1991 also crashed in 1996-1997. The synchronized suddenness of the declines, their region-wide impact, and effects on both small and larger populations, suggest the role of a novel agent of mortality beginning in the mid-late 1970s. Acting alone, but more likely in concert, habitat loss, overcollecting, epidemic disease and climate change could account for this region-wide decline” (p. 119).

Historically green salamanders likely used the peeling bark of downed chestnut trees as habitat, and the widespread loss of chestnut forest across the eastern United States likely contributed to historic green salamander decline, confining the species largely to rock outcrops (Barbour 1971, AmphibiaWeb 2015). The slabs of separating bark on large old-growth chestnut logs likely provided more microhabitat opportunity than is now available in secondary forests (Petranka 1998). This idea is supported by the habitat use of the closely related clouded salamander (*Aneides ferreus*) in the Pacific Northwest, which is found at highest densities in old-growth forests with abundant downed wood where the bark has split from the trunk (http://www.californiaherps.com/salamanders/pages/a.ferreus.html). For green salamanders, old growth chestnuts likely both provided habitat and facilitated dispersal (Criswell 2014, p. 53).

LIFE HISTORY

Several aspects of green salamander life history make them vulnerable to decline and hinder the ability of populations to rebound. Green salamanders do not reach sexual maturity until age three (AmphibiaWeb 2015), which slows the potential rate of population re-growth. Moreover, due to the energy demands of egg-laying and guarding, females only breed every other year (Jensen et al. 2008). Since females reach sexual maturity at age three and thereafter only breed every other year, the number of reproductive events in a lifetime is very limited. Corser (2001) reported that as of 1999, green salamanders in the Blue Ridge Mountains had not recovered from declines that took place in the 1970’s (p. 122). Likewise, Hardman (2014) reports that even in seemingly good habitat, recolonization following past land use change has been slow or impeded (p. 30).

Green salamander reproduction is remarkable. Female green salamanders lie on their backs in a rock crevice and glue their eggs to the ceiling one by one over a period of 20 to 30 hours (Gordon 1952). Eggs transform directly into tiny adult forms, with no larval stage. Females lay 10 – 30 eggs and guard them for 10 – 12 weeks, after which the hatchlings remain with the female for an addition one to two months (Jensen et al. 2008). Females do not eat during brooding (Gordon 1952). Both females and males are extremely territorial and ferociously defend their territories against invaders (Gordon 1952, Cupp 1980).

The green salamander is largely sedentary, with a maximum reported movement of around 100 meters (Gordon, 1952, Corser 2001, p. 120). Because it is lungless, it must remain cool and moist to be able to breathe via its skin and this greatly restricts its capacity for dispersal.

HABITAT

The green salamander is found in rock outcrops, cliff faces, and old-growth forests (Petranka 1998, Wilson 2003, Waldron and Humphries 2005, Brand et al. 2014, p. 237). Schneider (2010) reports finding a green salamander in an ephemeral stream channel in eastern Kentucky (p. 40), and recommends that land managers maintain appropriate microhabitat conditions in both upland and riparian communities to maintain salamander diversity (Schneider 2010, p. 15).

The relative abundances of some green salamander populations are correlated with the presence of certain hardwood tree species, such as American beech (Fagus grandifolia) (Wilson 2003, Waldron and Humphries 2005, Hardman 2014, p. 10).

THREATS

The green salamander is very vulnerable to population declines because of its specific habitat requirements, limited dispersal ability, and life history characteristics that lead to slow population re-growth. It faces multiple threats in its patchy distribution in the Appalachian Mountains. The Endangered Species Act states that a species shall be determined to be endangered or threatened based on any one of five factors (16 U.S.C. § 1533 (a)(1)). The green salamander is threatened by all five of these factors and thus warrants federal protection. It is threatened by modification or curtailment of habitat or range due to climate change, logging, mining, fracking, and development; it is threatened by other factors including population isolation, synergies between threats, and unknown factors that are causing declines in this and other salamander species. It is also vulnerable to overutilization and disease. There are no existing regulatory mechanisms that safeguard it from these factors.

MODIFICATION OR CURTAILMENT OF HABITAT OR RANGE

The green salamander is threatened by numerous activities that degrade its habitat and microhabitat. AmhibiaWeb (2015) states: “Several types of perturbations can negatively impact green salamanders. Obviously, removal of emergent rocks in forests eliminates this species in such areas. Road cuts and other larger corridors adjacent to emergent rocks and outcrops can result in an increase in airflow and greater insolation, thus increasing temperatures and decreasing moisture. Removal of trees that shade rock outcrops also results in greater insolation that ultimately dries nesting and foraging crevices. In clearcuts, Petranka (1998) suggests a buffer zone of 100 m or more around rock outcrops with known green salamander populations."

Climate Change

Climate change is an emerging, dire, and primary threat to the green salamander. In a study to identify the amphibians most vulnerable to climate change in the southeastern United States, Barrett et al. (2014) report that the green salamander was the most frequently identified species of concern for climate change impacts by state agency biologists (p. 286).

Salamanders are particularly susceptible to climate change because of their restrictive physiological requirements and low vagility (Sutton et al. 2014, p. 1). Sutton et al. (2014) evaluated species-specific vulnerabilities to projected climate change by the year 2050 and found that all analyzed salamander species were projected to lose a portion of their climatic niche, defined as the collective climatic patterns that regulate an organism's distribution (p. 2, 3). For the green salamander, the authors found that it will likely lose 49 percent of its climatic niche by 2050 (p. 14). Other researchers have predicted an even greater loss of habitat for the green salamander due to climate change. Barrett et al. (2014) predict that 93 percent of the green salamander's range will become climatically unsuitable by 2050 (p. 287).

Climate change also exacerbates the negative effects of other threats to the green salamander, such as habitat degradation due to logging, mining, pipelines, or fracking. Mantyka-Pringle et al. (2011) examined how climate change affects the negative impacts of other threat factors such as habitat loss. They found that the "most important determinant of habitat loss and fragmentation effects, averaged across species and geographic regions, was current maximum temperature, with mean precipitation change over the last 100 years of secondary importance" (p. 2). They highlight the rapid population decline of green salamanders in fragmented habitats in the southern Appalachians as an example of the synergistic effects between habitat degradation and climate change (Mantyka-Pringle et al. 2011, p. 2).

Researchers believe that climate change is already harming green salamanders. Corser (2001) identifies climate change and increasing summer temperatures and more variable winter temperatures specifically as a primary factor in the population crash of green salamanders in the Blue Ridge Mountains (p. 122). He also identifies a population lost to drought that contributed to total reproductive failure (p. 122). Because green salamander females only brood every other year and do not become sexual mature until age three (Jensen et al. 2008), the number of times a female can reproduce in her lifetime is limited, which will exacerbate the negative effects of climate change on failed broods.

Logging

Because green salamanders lack lungs and breathe through their skin, they require stable moist microhabitat conditions. Mature, closed canopy forests better maintain habitat conditions for lungless salamanders (Petranka 1998, Connette and Semlitsch 2013). It is well established in the scientific literature that logging can cause decreased salamander abundance (Brand et al. 2014, p. 234). Logging can directly remove the trees needed by green salamanders and also harm the microhabitat conditions of their rock outcrops, as reviewed in our listing petition.

The loss of chestnut forests likely contributed to historical decline of green salamanders (AmphibiaWeb 2015). The loss of chestnut old-growth forests and arboreal foraging sites due to the chestnut blight and logging may have restricted green salamanders to crevices of rock outcrops in recent times (Brodman 2004, p. 6).

Brodman (2004) states that deforestation is the main threat to green salamander populations (p. 2). In addition to direct timber harvest, clearing of land for other reasons threatens green salamanders include fracking, mining, and pipeline construction. Hardman (2014) reports that green salamanders are slow to recover from past logging (p. 30).

Fracking

The development of natural gas through the fracking of oil shale poses a threat to many wildlife species (Brittingham et al. 2014). Kiviat and Schneller-McDonald (2011) identify fracking as a threat to salamanders due to habitat fragmentation and chemical pollutants (p. 2, 3). In a study in West Virginia, amphibians were detected at higher densities in forested habitats than in clearings for gas wells and infrastructure (Moseley et al. 2010).

Brand et al. (2014) conclude that the proposed, permitted, and ongoing development of the Marcellus Shale will lead to significant range reductions for terrestrial salamanders due to the construction of wells, roads, storage ponds, and other infrastructure that will cause habitat loss and fragmentation (p. 234). Forest clearings have increased fluctuations in solar radiation, ground temperature, and humidity. They report, "salamander populations are affected by forest clearings and edges via direct mortality (Fahrig et al., 1995; Carr and Fahrig, 2001; Gibbs and Shriver, 2005), reduced dispersal and recolonization potential (Gibbs, 1998; deMaynadier and Hunter, 2000; Marsh et al.,2005), reduced genetic diversity (Reh and Seitz, 1990), and an increased risk of population extinction, especially in isolated or small habitat patches (Lande, 1988; Vos and Chardon, 1998)" (Brand et al. 2014, p. 234). Impacts of fracking on salamander habitat will include canopy loss, contamination with fracking fluids, soil compaction, and establishment of invasive species (Brand et al. 2014, p. 234).

Brand et al. (2014) estimated the potential impact of Marcellus shale gas extraction activities on green salamanders and four other species using conservative estimates of range, habitat specificity, and well development, and concluded that the pace and scale of energy development may require re-assessment of extinction risk (p. 237). They concluded (p. 239) that the green salamander could lose up to 20 percent of its habitat in the Marcellus Shale region (see Figure 3). It is important to note that this figure is conservative and does not include projected impacts from additional factors such as fragmentation, construction of roads, or indirect impacts on dispersal or survival of different life stages (Brand et al. 2014, p. 239) so the actual loss of habitat is likely even higher.

The green salamander is threatened by fracking not only in the Marcellus Region of West Virginia and Pennsylvania, but also in the Cambrian Rogersville Shale area of Kentucky, West Virginia, and Virginia (see Figures 4 and 5). The area potentially affected by fracking underlies the majority of the salamander's range.

Brand et al. (2014) further report that gas development on federal and state lands may be particularly damaging for the green salamander, especially so if well pads and infrastructure fragment existing contiguous forest tracts or more mature forest stands, and that larger forest patches may be more vulnerable to fracking development (p. 238).

In addition to land clearing for fracking, the chemicals in fracking fluid can harm habitat. The U.S. Forest Service allowed fracking operators to dispose of fracking fluid by deliberately spraying it into the Monongahela National Forest. Adams (2011) and Adams et al. (2011) report that spraying the fluid onto the vegetation had unexpected consequences and killed trees and other vegetation.

Table 2
Predicted percent loss (±SE) of forest and terrestrial salamander habitat within the Marcellus shale play for five species under two different Marcellus development futures and three levels of development intensity (10,000, 20,000, 50,000 new well pads). Development Future (suitability) predicts well location based on suitable Marcellus shale characteristics, while Future (proximity) predicts new wells will most likely be located near current permitted wells. Percent loss is calculated under two definitions for occupied habitat: (a) occupancy probabilities greater than 1SD and (b) greater than 2SD above the mean occupancy across the modeled species range. *P. electromorphus* and *P. richmondi* had no cells with a predicted occupancy above the 2SD threshold within the Marcellus shale play.

Species	Future (suitability)			Future (proximity)		
	10,000	20,000	50,000	10,000	20,000	50,000
(a)						
A. aeneus	3.6% (0.05)	7.4% (0.07)	19.3% (0.10)	3.1% (0.04)	6.1% (0.06)	16.0% (0.07)
P. electromorphus	4.4% (0.05)	8.8% (0.06)	21.4% (0.08)	2.8% (0.04)	5.8% (0.05)	15.6% (0.06)
P. hoffmani	3.4% (0.06)	7.0% (0.09)	19.5% (0.13)	2.8% (0.05)	5.3% (0.07)	11.7% (0.07)
P. richmondi	1.6% (0.08)	3.2% (0.11)	8.3% (0.16)	6.2% (0.15)	12.6% (0.18)	32.1% (0.20)
P. wehrlei	4.4% (0.04)	8.8% (0.05)	21.8% (0.08)	3.1% (0.04)	6.1% (0.05)	15.2% (0.05)
Forest habitat	3.8% (0.02)	7.7% (0.02)	19.1% (0.03)	4.0% (0.01)	7.9% (0.02)	20.0% (0.02)
(b)						
A. aeneus	3.6% (0.08)	7.4% (0.11)	19.6% (0.15)	2.9% (0.07)	5.9% (0.09)	15.8% (0.10)
P. electromorphus	–	–	–	–	–	–
P. hoffmani	2.7% (0.08)	5.6% (0.12)	16.2% (0.19)	2.4% (0.07)	4.6% (0.09)	10.1% (0.09)
P. richmondi	–	–	–	–	–	–
P. wehrlei	19.6% (1.30)	37.2% (1.62)	75.6% (1.44)	0% (–)	0% (–)	0% (–)
Forest habitat	3.8% (0.02)	7.7% (0.02)	19.1% (0.03)	4.0% (0.01)	7.9% (0.02)	20.0% (0.02)

Figure 3. Predicted Loss of Green Salamander Habitat in the Marcellus Shale Region, Table 2 from Brand et al. 2014, p. 239. The species' is expected to lose up to 20 percent of its habitat in West Virginia and Pennsylvania due to fracking.

Figure 4. Cambrian Rogersville Shale. Map copyright Tye Ward, Sunday Gazette-Mail Graphic, Available at: http://www.wvgazette.com/article/20150412/GZ01/150419888

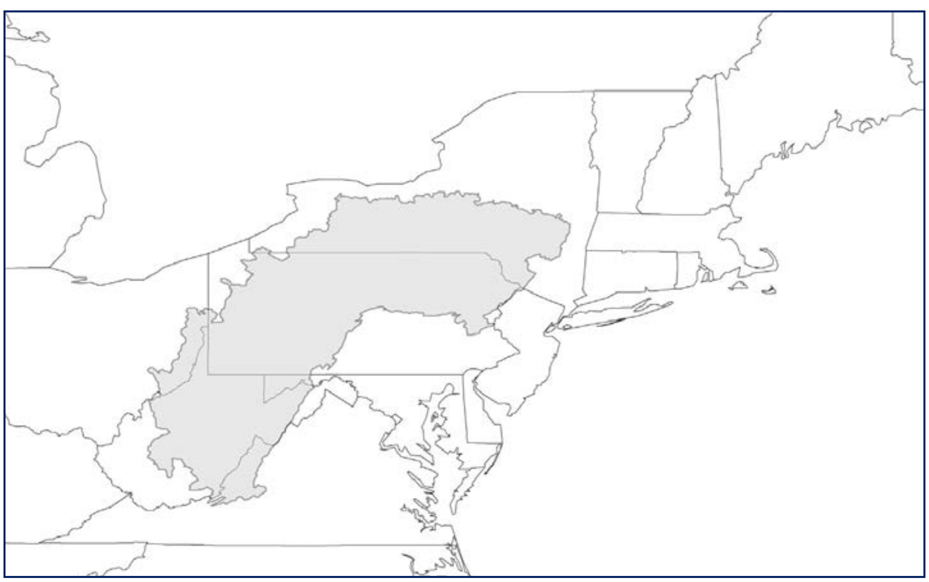
Figure 5. Marcellus Shale, from Brand et al. 2014

Mining

Coal mining is a primary threat to the green salamander, as explained in detail in our petition to protect the species. The green salamander's range largely overlays the range of surface coal mining in the Appalachian Region. More than a million acres of land in the region have been surface mined for coal (EPA 2005). Mitigation does not return the mined areas to their formal condition (see references in listing petition). Petty et al. (2013) did not find green salamanders in reclaimed forested areas following mining mitigation activities (p. 48).

Residential Development

Corser (2001) reports that green salamander habitat in the Blue Ridge Mountains has been lost to residential development for vacation homes and resorts (p. 120). He reports the direct destruction of two known green salamander sites for development (p. 120), and the loss of a large swath of habitat in the early 1970s due to an impoundment to create a lake (p. 124).

Pipelines

Criswell (2014) cites pipelines as a threat to green salamanders (p. 53). Numerous proposed fossil fuel pipelines across the salamander's range could harm its habitat.

Wind Energy Development

Criswell (2014) cites wind turbines as a threat to green salamanders (p. 53). Industrial wind facilities can lead to desiccation of adjacent habitat. Turbines can lead to warming and drying of surface air (Baidya Roy and Traiteur 2010).

DISEASE

The green salamander is potentially threatened by disease such as ranaviruses and chytrid funguses. Disease can rapidly wipe out salamander populations, even in areas that are protected from other threats such as land use change.

Ranavirus (Family Iridoviridae) is a pathogen that has been implicated in amphibian die-offs throughout the world including North America (Sutton et al 2014, p. 1). Most studies on ranavirus have focused on pond-breeding amphibians, but Sutton et al. (2014) examined ranavirus in lungless salamanders in Great Smoky Mountains National Park and found ranavirus-positive individuals in 11 of the 14 sampled lungless salamander species. More than 80 percent of sampled individual salamanders tested positive for the virus. They conclude that environmental stressors such as drought can increase virus prevalence (Sutton et al. 2014, p. 1). The green salamander is not known to occur in Great Smoky Mountains National Park, but this study demonstrates that as a lungless salamander it is susceptible to ranavirus infection.

All salamanders in the United States are threatened by the potential introduction of *Batrachochytrium salamandrivoran*s (Bsal), a highly pathogenic chytrid fungus originating in

Asia that was recently discovered as a novel cause of the amphibian disease chytridiomycosis (Martel et al. 2013). The invasion of Bsal into North America could lead to rapid epizootic declines and extinctions of salamanders, as there are no effective means of controlling its spread once it is established in wild populations (Yap et al. 2015). This disease caused a dramatic and enigmatic mortality event in fire salamanders (*Salamandra salamandra*) in the Netherlands and it has already spread to Belgium (Martel et al. 2013, Burke 2015). There is also evidence of its spread in international trade (Cunningham et al. 2015). Although to date Bsal has not been reported in the United States, few studies have been published since Bsal was described and infection experiments show that the U.S. is home to numerous species from two of the most Bsal-susceptible families (Plethodontidae and Salamandridae) (Martel et al. 2014). There is a high risk of Bsal introduction into the U.S., given the magnitude of international salamander trade originating from Asia and containing potential Bsal reservoirs (Yap et al. 2015). Given the high likelihood of Bsal introduction into and spread throughout the U.S. and its high level of virulence to salamanders, Bsal should be considered a significant risk to the survival of all salamander species in the United States. A recently published predictive model of Bsal host vulnerability in North America identified three zones of high risk in North America, including the southeastern United States.

OVERCOLLECTION

Numerous sources cite overutilization as a threat to the green salamander (Mitchell et al. 1999, Corser 2001, Brodman 2004, Georgia Department of Natural Resources 2009, AmphibiaWeb 2015).

OTHER FACTORS

Unidentified Causes of Salamander Decline

Salamanders, including the green salamander, are declining in the United States for unknown reasons, even in protected areas. Lungless salamanders in Great Smoky Mountains National Park have been declining for thirty years, for unexplained reasons. Caruso and Lips (2012) determined that collecting, logging, and acid rain were unlikely to have caused these population declines, but they were unable to rule out disease or climate change as contributing factors (p. 1). Unidentified causes of salamander decline should be considered as a threat factor to green salamander populations.

Synergies Between Threats

The Service should consider the synergies between threat factors as a threat to green salamander populations. Numerous researchers have identified interactions between threats as a cause of salamander decline. Barrett et al. (2014) state that the current and future effects of climate change are likely to exacerbate existing stressors to amphibian populations (p. 282). Mantyka-Pringle et al. (2011) conclude that climate change magnifies the negative effects of habitat loss and fragmentation on wildlife populations (p. 2). Staudt et al. (2013) identify the green salamander as an example of a species that is threatened by the synergistic combo of habitat fragmentation and global climate change (p. 497), concluding that climate change is likely to interact with land use and land cover change in ways that exacerbate detrimental effects to wildlife species (p. 496).

Corser (2001) identifies the interactions of habitat loss, overcollecting, epidemic disease, and climate change as likely causes of the 98 percent decline of green salamanders in the Blue Ridge Mountains from the 1970s to 1999 (p. 119). He states, “Retrospectively assigning a single causal factor to this region-wide Aneides decline will not be possible. Rather, habitat loss, climate change, overcollecting and susceptibility to a pathogen may have interacted synergistically to cause the near- extinction of this species in its disjunct range” (p. 124).

Sutton et al. (2014) conclude that environmental stressors such as drought can increase prevalence of disease in lungless salamander populations (Sutton et al. 2014, p. 1).

Isolation

Numerous sources cite population isolation as a threat to the green salamander. NatureServe (2015) states, “Smaller populations of the green salamander are at particular risk of extinction, in part because this species rarely crosses barriers such as roads or rivers and lakes, which limits the amount of migration between populations and can lead to inbreeding.” AmphibiaWeb (2015) states, “The total range of the green salamander is fragmented into several disjunct populations, and such isolated populations are always at risk of extinction.”

CONCLUSION

The best available information clearly shows that the green salamander warrants protection under the Endangered Species Act. The salamander likely underwent large historic population decline following the decline of chestnut forest and became largely confined to rock outcrops. It is expected to lose up to 20 percent of its habitat to fracking and up to 90 percent of its habitat to global climate change, in addition to other threats such as mining, logging, disease, collection, and interactions among threats as well as unexplained causes of decline. The Service should act to protect the green salamander before populations become even smaller and more isolated which will make recovery more difficult. We urge you to protect it without delay and to designate critical habitat concurrently with listing.

Thank you for taking our comments into consideration.

On behalf of all parties,

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