Arkansas' Resiliency and Changing Environmental Conditions

Cooperative Report: Funded by the U.S. Geological Survey and U.S. Fish and Wildlife Service

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Foreword

Series Overview

The following report is part of a multi-part series synthesizing the potential hazards of changing environmental conditions on southeastern states' and territories' ecoregions and vulnerability of wildlife. This work was conceived as part of an interagency effort to facilitate the inclusion of adaptation considerations into 2025 revisions of State Wildlife Action Plans (SWAPs) motivated by the Association of Fish and Wildlife Agencies' voluntary guidance for states to incorporate adaptation into SWAPs and formal encouragement from the U.S. Fish and Wildlife Service (USFWS) in 2012 (AFWA, 2022). To best provide capacity to each agency, the reports are tailored to the needs of each state or territory agency within the Southeast region undergoing said revisions to their plans. This work was developed as a collaboration between the U.S. Geological Survey (USGS) Southeast Climate Adaptation Science Center (CASC) and the USFWS Southeast Conservation Adaptation Strategy with input from the South-Central CASC the Southeastern Association of Fish and Wildlife Agencies' Wildlife Diversity Technical Committee.

Process

To effectively synthesize the potential hazards of changing environmental conditions on ecoregions of the Southeast and vulnerability of their wildlife, the SE CASC developed a process comprised of the following steps: 1) summarize historical means and future projected changes of select environmental risks by ecoregion; 2) summarize available vulnerability assessments and niche models (i.e., species distribution models) for each state's/territory's revised Species of Greatest Conservation Need (SGCN) list; 3) conduct a literature review of impacts from changing environmental conditions to a specific taxon or habitat of each agency's choosing. Ecoregions as characterized by the Environmental Protection Agency (EPA) were chosen to summarize historical means and projections for the continental states of the southeastern U.S., in accordance with how SWAPs are generally organized and to efficiently inform management. We used EPA Level III Ecoregions due to the popularity of use by Southeast state wildlife agencies. Existing data collections of both historical climatology and future projections were used to calculate means for each ecoregion within each state's boundaries and maps of future projections were created using the NCA5 Interactive Atlas in ArcGIS Pro (Alder, 2024; Pierce et al., 2021; NCA5 Atlas Data). Each state or territory wildlife agency cooperator chose which Global Warming Levels and projection scenarios for inclusion. For coastal Southeast states and territories, information pertaining to sea-level rise was taken from the National Oceanic and Atmospheric Administration (NOAA) via their Sea-level Rise Technical Reports and Sea-level Rise Viewer Tool (Sweet et al., 2022). Additionally, existing data collations were used to summarize vulnerability assessments and niche models conducted for each state's and territory's SGCN (Armsworth et al., 2025a, 2025b). For each habitat or taxonomic group identified by a state or territory wildlife agency, we reviewed and synthesized available scientific literature. We searched for relevant literature related to these habitats and species that either explicitly mentioned or indirectly discussed impacts of changing environmental conditions.

Executive Summary

Changing environmental and weather conditions in Arkansas may warrant adaptive management strategies

In the Southeast, changes in weather patterns and environmental conditions may have pervasive impacts on habitats, SGCN, and ecosystem services. Environmental conditions and weather patterns in the Southeast may continue to change, such as the increasing frequency, intensity, and duration of heatwaves and freezing temperatures, and risks from extreme events. Arkansas is similarly undergoing changes due to weather variability and long-term trends in environmental conditions. Historically marked by hot, humid summers and short, cool winters, the state is now experiencing rising temperatures, altered precipitation patterns, and more frequent extreme weather events. Since the early 20th century, Arkansas has warmed by 0.5°F, with projections indicating an increase in extremely hot days, particularly in the Boston Mountains and Mississippi Valley Loess Plains, and a decline in extremely cold days, which could shift species distributions and ecosystem dynamics. While total annual precipitation may remain relatively stable, the state is seeing an increase in the number of extreme rainfall events and therefore experiencing increased flood risks, especially in the northeast. Tornado activity, though difficult to model, is becoming more clustered and geographically shifting toward Arkansas and neighboring states, with ecological impacts such as altered forest structure and bird species composition. Despite recent wetter years, Arkansas remains vulnerable to severe droughts, with rising temperatures expected to intensify soil moisture loss and increase the frequency of droughts These climatic shifts pose particular risks to freshwater ecosystems, which are home to high aquatic biodiversity, including rare fish and mussel species. Changes in water temperature, streamflow, and dissolved oxygen levels could disrupt ecological relationships and affect populations of SGCN, underscoring the need for adaptive management strategies in the face of a changing world.

Arkansas's diverse topography and ecoregions support a rich variety of amphibians, including several rare and endemic lungless salamanders found only in the Ouachita Mountains. However, amphibians across the state are increasingly threatened by changing environmental conditions, habitat degradation, and disease. Rising temperatures and increased variability are expected to constrict species' ranges, particularly for cold-adapted, moisture-dependent species like the endemic *Plethodon* salamanders and the federally endangered Ozark Hellbender (*Cryptobranchus alleganiensis bishopi*). Amphibians' limited dispersal ability and reliance on cool, well-oxygenated aquatic habitats make them especially vulnerable to warming and reduced water quality. Droughts, intensified by higher temperatures and evapotranspiration, threaten both aquatic and terrestrial species by degrading critical microhabitats and shortening hydroperiods in ephemeral wetlands, which are essential for breeding. Species like the Crawfish Frog (*Lithobates areolatus*) and Tiger Salamander (*Ambystoma tigrinum*) are already experiencing reproductive challenges due to these shifts. Additionally, extreme precipitation and flooding events increase sedimentation, turbidity, and pollutant runoff, further degrading habitats and introducing fish predators of amphibians into previously isolated wetlands. Landslides in the Ozark and Ouachita Mountains, linked to more frequent storms, may threaten stream-dwelling species by altering flows and damaging riparian zones. While some species show consistent scores in their vulnerability across assessments, others may need further study to clarify their conservation needs. These findings underscore the possible importance of targeted conservation actions, including habitat restoration, disease monitoring, and demographic studies, many of which are already underway through the Arkansas Game and Fish Commission's Wildlife Diversity Program.

Arkansas and changing environmental conditions

Arkansas has moderately large variations in temperatures and abundant precipitation, being characterized by hot, humid summers, while winters are typically short and cool with episodic blasts of cold arctic air (Runkle et al. 2022; Buckner 2024). The northwestern quadrant of Arkansas that includes the Ozark Mountains, and particularly the Boston Mountains portion of the range, is generally higher in elevation than the rest of the state and thus usually experiences cooler temperatures (Runkle et al. 2022; Buckner 2024). Precipitation is abundant throughout the year, with winter and spring being the wettest seasons, and heavy rains can produce totals of over 10 inches per storm event (Runkle et al. 2022; Buckner 2024). In the future, Arkansas may experience changes in its seasonal weather variations and conditions. Generally, the state may experience rising temperatures, increased extreme weather and flooding events, and more frequent droughts (USGCRP 2023US EPA 2016; Hoffman et al. 2023). We present how these changes may influence the landscape so that the state can consider how habitats could also shift.

Hotter days, nights and warmer winters

Temperatures in Arkansas have risen by 0.5°F since the beginning of the 20th century, which is about less than a third of the average rate of change for the contiguous U.S. (Runkle et al. 2022; NOAA NCEI 2025). Since the mid 1950's the annual number of extremely hot days (i.e., maximum daytime temperature of 100°F or higher) per year has generally been below average for Arkansas through 2014 based on 5-year periods; presumably due to increased cloud cover and precipitation and other factors (Runkle et al. 2022). However, heatwaves throughout the Southeast are happening more frequently and are occurring during a longer heat season (Hoffman et al., 2023). The warmest consecutive 5-year interval for the state was 2015-2019 but in 2023 much of the southern portion of the United States experienced a multi-month heat wave that saw large parts of Arkansas placed under heat advisory alerts, with daytime temperatures exceeding 100°F and heat indices reaching even higher (Runkle et al. 2022; Passe-Smith 2025). Water temperatures, which are generally correlated with air temperatures, dictate many species ranges and dissolved oxygen conditions as they are directly correlated, with a higher temperature allowing for lower levels of dissolved oxygen (Ingram et al., 2013). In general, temperature regimes of freshwater ecosystems correspond with shifts in air temperatures, which in turn may influence plant and animal communities (Princé and Zuckerberg 2015).Table 1 summarizes approximate values for historical observed and future projections of the number of extremely hot days (e.g., days with maximum temperatures ≥95°F) per year under different shared socioeconomic pathways for Arkansas ecoregions; while Figure 1 shows the projected future change in the number of extremely hot days per year in Arkansas at Global Warming Level (GWL) GWL 2 (3.6°F increase globally) compared to the last 30 years. Overall, the number of extremely hot days are projected to increase across Arkansas, though not as rapidly as the rest of the country, with the South Central Plains Ecoregion and the Mississippi Alluvial Plain Ecoregion seeing the largest percent changes (Table 1; Figure 1).

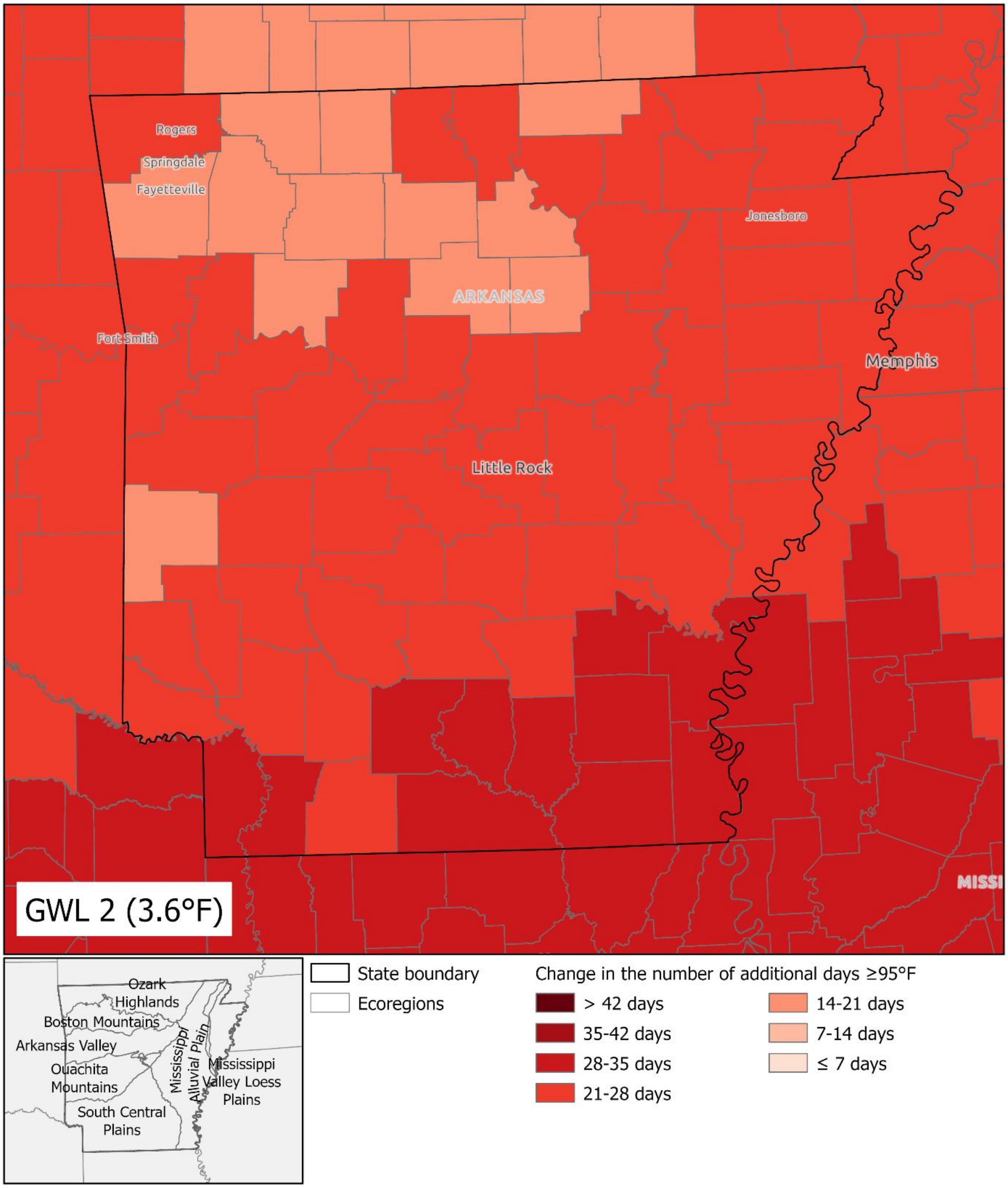

Figure 1. *Projected future changes in the number of extremely hot days per year (extreme maximum temperature of 95°F or greater) compared to preindustrial levels (1851-1900) based on GWL 2 (global temperature increase of 3.6 F°). Figure created from data in the 'NCA5 Interactive Atlas" web tool (NCA5 Atlas Data | Interactive Atlas accessed on 1 February 2024) via ArcGIS Pro.*

Table 1. *Approximate observed historical and the future projected number of extremely hot days per year (i.e., days with afternoon high temperatures of at least 95°F) by EPA Level III ecoregions within Arkansas. The table summarizes projected future number of days for low, moderate, and high shared socioeconomic pathways (SSPs) using CMIP6-LOCA2 threshold and extreme event metric projections (Alder, 2024) summarized at the ecoregion level. For each future time period, numbers in parentheses represent the percent change between the models' future projections and the models' historical simulations. Observed historical summaries were generated with data from Pierce et al. (2021).*

Historical & Future Projections: Number of Days with Maximum Temperatures ≥ 95°F			
SSP	**Observed Historical:** 1950-2014	**2025-2049** projections (approximate percent change from historical simulation)	**2050-2074** projections (approximate percent change from historical simulation)
Ozark Highlands Ecoregion			
Low (SSP2-4.5)	16 day/year	40 days/year (153%↑)	52 days/year (235%↑)
Moderate (SSP3-7.0)		38 days/year (140%↑)	56 days/year (256%↑)
High (SSP5-8.5)		43 days/year (171%↑)	66 days/year (322%↑)
Boston Mountains Ecoregion			
Low (SSP2-4.5)	11 days/year	30 days/year (185%↑)	41 days/year (298%↑)
Moderate (SSP3-7.0)		28 days/year (169%↑)	44 days/year (324%↑)
High (SSP5-8.5)		32 days/year (204%↑)	54 days/year (415%↑)
Arkansas Valley Ecoregion			
Low (SSP2-4.5)	25 days/year	54 days/year (121%↑)	68 days/year (179%↑)
Moderate (SSP3-7.0)		52 days/year (114%↑)	71 days/year (193%↑)
High (SSP5-8.5)		56 days/year (132%↑)	81 days/year (233%↑)
Ouachita Mountains Ecoregion			
Low (SSP2-4.5)	24 days/year	47 days/year (129%↑)	60 days/year (194%↑)
Moderate (SSP3-7.0)		45 days/year (120%↑)	64 days/year (210%↑)
High (SSP5-8.5)		49 days/year (140%↑)	73 days/year (255%↑)
Mississippi Alluvial Plain Ecoregion			
Low (SSP2-4.5)	21 days/year	51 days/year (156%↑)	66 days/year (232%↑)
Moderate (SSP3-7.0)		49 days/year (145%↑)	70 days/year (248%↑)
High (SSP5-8.5)		54 days/year (167%↑)	80 days/year (300%↑)
Mississippi Valley Loess Plains Ecoregion			
Low (SSP2-4.5)	18 days/year	46 days/year (183%↑)	61 days/year (277%↑)
Moderate (SSP3-7.0)		44 days/year (170%↑)	65 days/year (297%↑)
High (SSP5-8.5)		49 days/year (201%↑)	76 days/year (363%↑)
South Central Plains Ecoregion			
Low (SSP2-4.5)	26 days/year	58 days/year (129%↑)	74 days/year (191%↑)
Moderate (SSP3-7.0)		55 days/year (119%↑)	77 days/year (204%↑)
High (SSP5-8.5)		61 days/year (139%↑)	87 days/year (244%↑)

Arkansas is experiencing not only an increase in maximum temperatures, but a decrease in its coldest minimum temperatures. Table 2 summarizes approximate values for historical observed and future projections of the number of extremely cold days under different shared socioeconomic pathways for Arkansas ecoregions; while Figure 2 shows the projected future percent change in the number of extremely cold days per year (e.g., days with low temperatures of ≤ 32°F) in Arkansas at GWL 2 (3.6°F increase globally) compared to the last 30 years. Overall, the number of extremely cold days in Arkansas is projected to decrease between 14 to21 fewer days under GWL 2 across the vast majority of the state, with the exception of Chicot County, though the magnitude of change often varies by location within the state (Table 2; Figure 2). Additional evidence comes from the number of very warm nights (i.e., nights with (minimum temperature of 75°F or higher) has been above average in the state since 1995, which have approximated or exceeded previous record levels from 2010-2016, that reflects an increasing winter temperature trend for the state (Runkle et al. 2022; NOAA NCEI 2025). Winter conditions are key drivers of individual species performance and community composition in terrestrial habitats because species vary in susceptibility to these winter drivers (Williams et al., 2014). Shorter and warmer winters may cause species range shifts that would allow for warm-adapted species to dominate and shift distributions of cold-adapted species – examples of the impacts of changing temperatures on Arkansas' amphibian SGCN can be found in section "A Closer Look…" of this report.

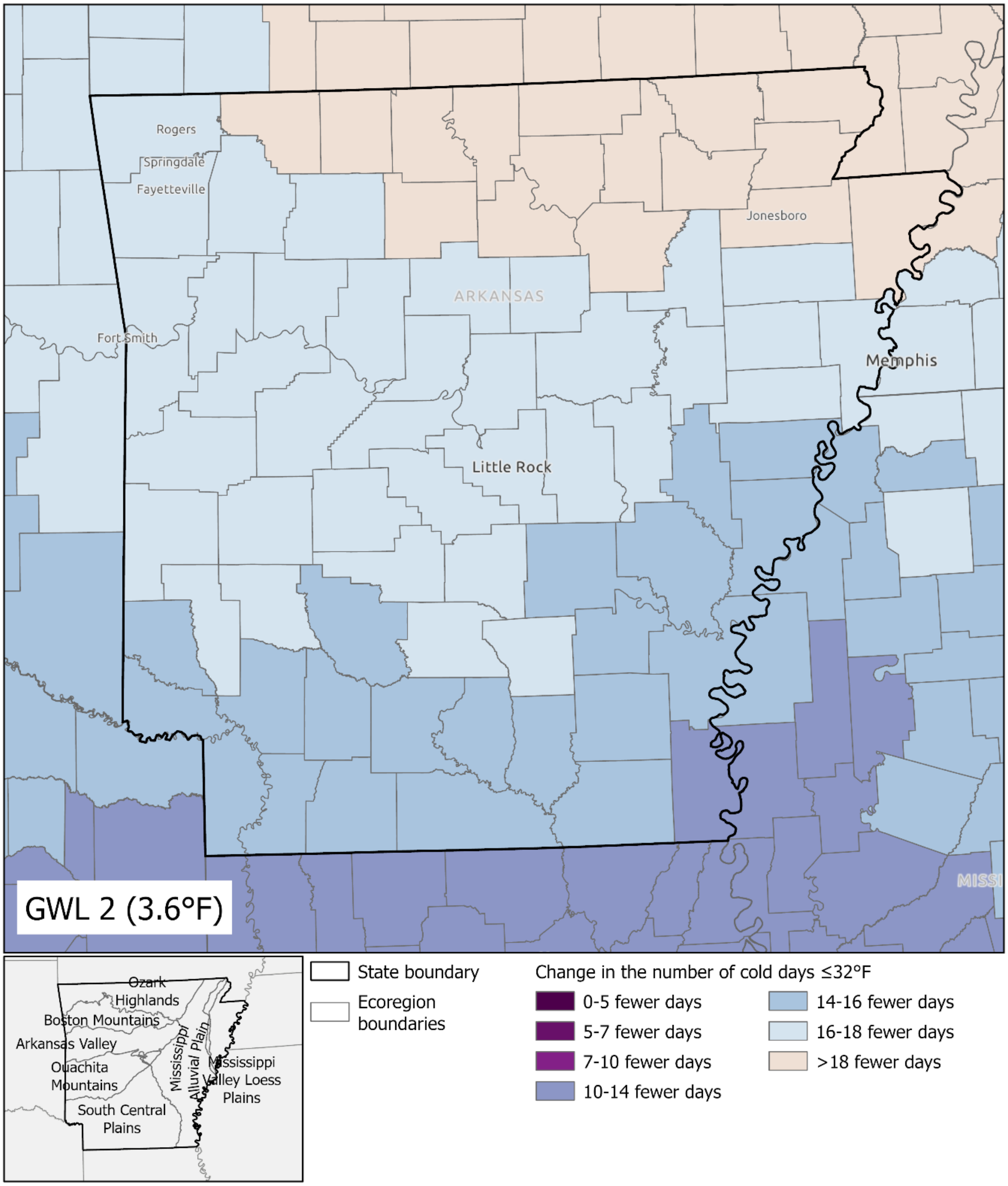

Figure 2. *Change in the number of extremely cold days per year (minimum temperatures reaching or below freezing 32°F) compared to preindustrial levels (1851-1900) based on GWL 2 (global temperature increase of 3.6 °F). Figure created from data in the ‘NCA5 Interactive Atlas” web tool (NCA5 Atlas Data | Interactive Atlas accessed on 1 February 2024) via ArcGIS Pro.*

Table 2. *Approximate observed historical and future projected number of extremely cold days per year (days with minimum temperatures that dip below32°F) for EPA Level III ecoregions within Arkansas. The table summarizes projected future number of days for low, moderate, and high shared socioeconomic pathways (SSPs) using CMIP6-LOCA2 threshold and extreme event metric projections (Alder, 2024) summarized at the ecoregion. For each future time period, numbers in parentheses represent the percent change between the models' future projections and the models' historical simulations. Observed historical summaries were generated with data from Pierce et al. (2021).*

Historical & Future Projections: Number of Extremely Cold Days (Min Temperatures ≤ 32°F)			
SSP	**Observed Historical:** 1950-2014	**2025-2049** projections (approximate percent change from historical simulation)	**2050-2074** projections (approximate percent change from historical simulation)
Ozark Highlands Ecoregion			
Low (SSP2-4.5)	91 day/year	71 days/year (21%↓)	64 days/year (29%↓)
Moderate (SSP3-7.0)		72 days/year (21%↓)	62 days/year (32%↓)
High (SSP5-8.5)		69 days/year (24%↓)	57 days/year (37%↓)
Boston Mountains Ecoregion			
Low (SSP2-4.5)	88 days/year	72 days/year (20%↓)	66 days/year (28%↓)
Moderate (SSP3-7.0)		74 days/year (20%↓)	63 days/year (31%↓)
High (SSP5-8.5)		70 days/year (24%↓)	58 days/year (37%↓)
Arkansas Valley Ecoregion			
Low (SSP2-4.5)	75 days/year	56 days/year (25%↓)	49 days/year (34%↓)
Moderate (SSP3-7.0)		57 days/year (24%↓)	47 days/year (37%↓)
High (SSP5-8.5)		53 days/year (28%↓)	42 days/year (43%↓)
Ouachita Mountains Ecoregion			
Low (SSP2-4.5)	59 days/year	57 days/year (25%↓)	51 days/year (32%↓)
Moderate (SSP3-7.0)		58 days/year (23%↓)	49 days/year (36%↓)
High (SSP5-8.5)		55 days/year (27%↓)	44 days/year (42%↓)
Mississippi Alluvial Plain Ecoregion			
Low (SSP2-4.5)	57 days/year	41 days/year (30%↓)	35 days/year (40%↓)
Moderate (SSP3-7.0)		42 days/year (28%↓)	34 days/year (43%↓)
High (SSP5-8.5)		39 days/year (33%↓)	30 days/year (49%↓)
Mississippi Valley Loess Plains Ecoregion			
Low (SSP2-4.5)	57 days/year	49 days/year (28%↓)	43 days/year (37%↓)
Moderate (SSP3-7.0)		59 days/year (26%↓)	51 days/year (40%↓)
High (SSP5-8.5)		47 days/year (31%↓)	37 days/year (46%↓)
South Central Plains Ecoregion			
Low (SSP2-4.5)	57 days/year	38 days/year (30%↓)	34 days/year (40%↓)
Moderate (SSP3-7.0)		41 days/year (28%↓)	33 days/year (43%↓)
High (SSP5-8.5)		38 days/year (33%↓)	29 days/year (49%↓)

Extreme weather events, drought and altered flows

Precipitation and flooding

Since 1970, Arkansas’ annual precipitation has increased by 4.3 inches (NOAA ACIS).

Although little change in total annual precipitation is projected over this century for the Southeast region, long-term records show conditions are becoming wetter in Arkansas, although precipitation in the state remains highly variable (Hoff 2022; Hoffman et al. 2023; Stevens et al. 2023). Extreme precipitation events, (i.e., severe thunderstorms and tornados) and the subsequent increased flooding may occur in Arkansas (Wong et al. 2014). While there is no significant trend observed for Arkansas over the historical record, the 5-year time period between 2015 and 2020 had the highest multiyear rainfall averages for both annual and summer precipitation, and the wettest consecutive 5-year interval for the entire state was 2015 to 2019 with 59.6 inches per year on average (Runkle et al. 2022). Additionally, since 1900, there has been an observation of an upward trend in the number of annual 3-inch extreme precipitation events with the average number of days with these events for the 2015-2020 period was 1.8 days per year while the long-term average is 1.1 days per year (Runkle et al. 2022). Wintertime precipitation may also increase in Arkansas by midcentury, with the increase being in the form of rain rather than snow (Runkle et al 2022). Table 3 summarizes approximate values for historical observed and future projections of extreme rainfall under different shared socioeconomic pathways for Arkansas ecoregions; while Figure 3 shows the projected future percent change in the number of days per year with extreme precipitation (e.g., days with the top 1% of rainfall) in Arkansas at GWL 2 (3.6°F increase globally) compared to the last 30 years. While all ecoregions within Arkansas may experience changes in days with extreme precipitation, the northeast part of the state, in the Mississippi Valley Loess and Alluvial Plains Ecoregions, is projected to experience the greatest percent change by GWL3 (Figure 3). A recent study also found high-intensity precipitation vents to be increasing in the Interior Highlands of Arkansas (Mantooth-Hendrix 2021).

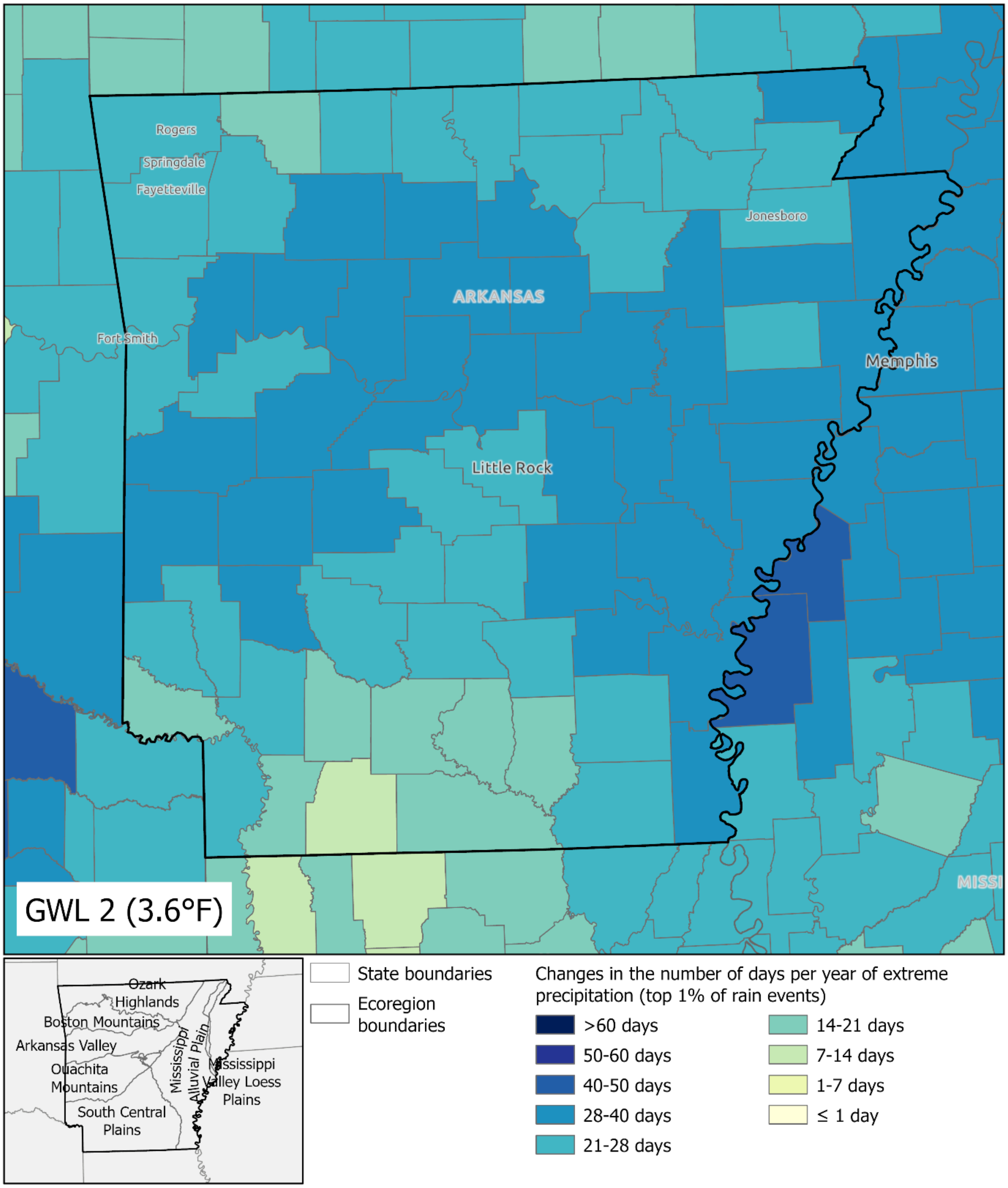

Figure 3. *Future projected changes in the number of days per year of extreme precipitation (top 1% of rain events) compared to preindustrial levels (1851-1900) based on GWL 2 (global temperature increase of 3.6 °F). Figure created from data in the 'NCA5 Interactive Atlas" web tool (NCA5 Atlas Data | Interactive Atlas accessed on 1 February 2024) via ArcGIS Pro.*

Table 3. *Approximate observed historical and future projected chance in the number of days per year with extreme precipitation events (in the top 1% of historical rainfall events) for EPA Level III ecoregions within Arkansas. The table summarizes the projected future percent change in the number of days for low, moderate, and high shared socioeconomic pathways (SSPs) using CMIP6-LOCA2 threshold and extreme event metric projections (Alder 2024) summarized at the ecoregion level. For each future time period, numbers represent the percent change between the models' future projections and the models' historical simulations. Observed historical summaries were generated with data from Pierce et al. (2021).*

Historical & Future Projections: Number of Days with Extreme Rainfall (Days with Rainfall > 99th percentile)			
SSP	**Observed Historical:** 1950-2014	**2025-2049** projections (approximate percent change from historical simulation)	**2050-2074** projections (approximate percent change from historical simulation)
Ozark Highlands Ecoregion			
Low (SSP2-4.5)	4 days/year	27% increase	37% increase
Moderate (SSP3-7.0)		27% increase	45% increase
High (SSP5-8.5)		33% increase	54% increase
Boston Mountains Ecoregion			
Low (SSP2-4.5)	4 days/year	31% increase	39% increase
Moderate (SSP3-7.0)		28% increase	47% increase
High (SSP5-8.5)		36% increase	59% increase
Arkansas Valley Ecoregion			
Low (SSP2-4.5)	4 days/year	26% increase	40% increase
Moderate (SSP3-7.0)		25% increase	43% increase
High (SSP5-8.5)		36% increase	59% increase
Ouachita Mountains Ecoregion			
Low (SSP2-4.5)	3 days/year	24% increase	37% increase
Moderate (SSP3-7.0)		25% increase	46% increase
High (SSP5-8.5)		36% increase	56% increase
Mississippi Alluvial Plain Ecoregion			
Low (SSP2-4.5)	3 days/year	26% increase	37% increase
Moderate (SSP3-7.0)		25% increase	43% increase
High (SSP5-8.5)		32% increase	54% increase
Mississippi Valley Loess Plains Ecoregion			
Low (SSP2-4.5)	3 days/year	27% increase	40% increase
Moderate (SSP3-7.0)		24% increase	46% increase
High (SSP5-8.5)		32% increase	55% increase
South Central Plains Ecoregion			
Low (SSP2-4.5)	4 days/year	21% increase	32% increase
Moderate (SSP3-7.0)		21% increase	26% increase
High (SSP5-8.5)		27% increase	41% increase

Extreme precipitation events often lead to subsequent high-impact flooding events. Arkansas has also been subject to impacts from upstream flooding of the Mississippi River. The most destructive flood in US history, the Mississippi River Flood of 1927, inundated 36 counties in Arkansas with floodwaters as deep as 30 ft in some places, which led to the Flood Control Act of 1928 (Runkle et al. 2022). In 2017, severe weather and upstream floods led to flood damage in northeast Arkansas that impacted infrastructure and crops that impacted supply chains (Hoffman et al. 2023). Flood magnitudes and frequency are increasing West of the Mississippi River on the southern Great Plains, including in Arkansas: since the early 1900's the state has seen a statistically significant increasing trend (5-12% increase) in large flood magnitude and much of the northern and eastern portions of the state have seen statistically significant increasing trends in large flood frequency (USDA Forest Service- Flood Potential Portal; Stevens et al. 2023) (Figure 4). Flash-flood producing storms are projected to increase the most for Arkansas compared to the rest of the country (Dougherty and Rasmussen 2020).

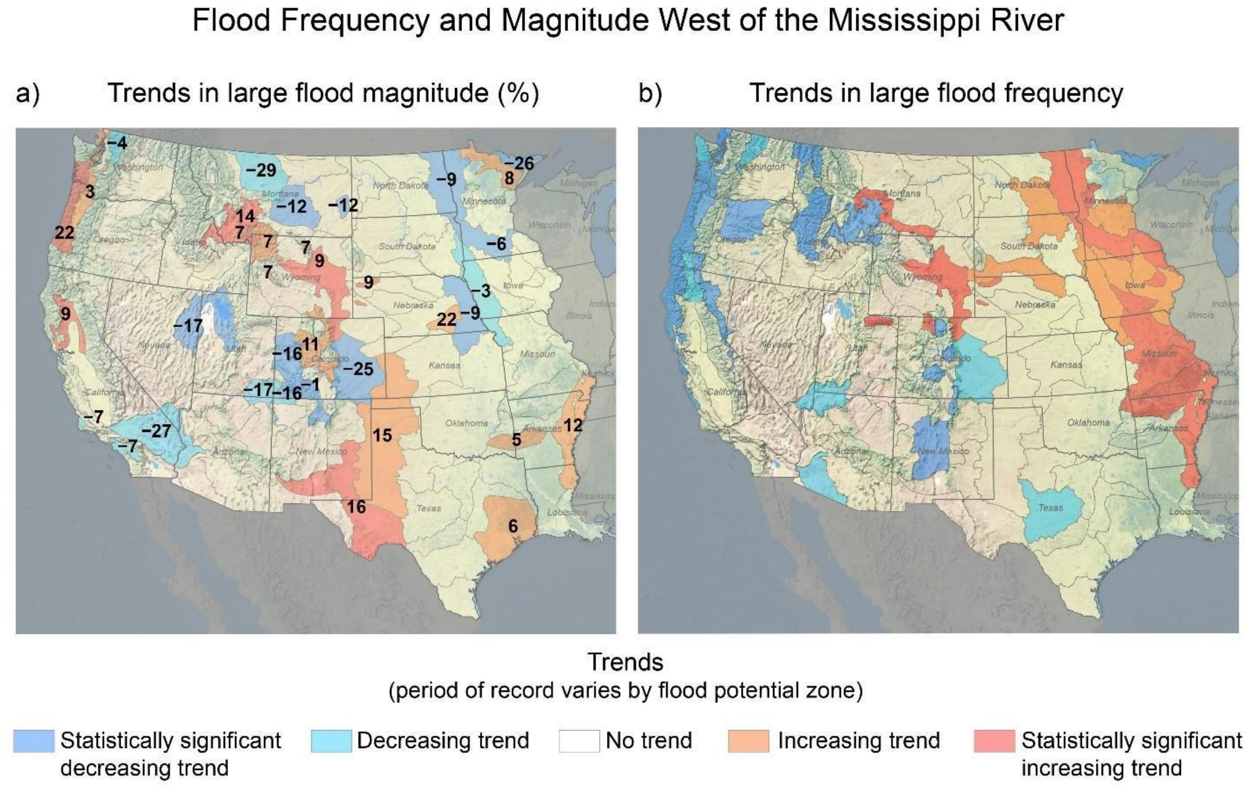

Figure 4. *Trends in the a) magnitude and b) frequency of large floods West of the Mississippi River. Shading in warm colors (reds) represents increasing trends, in contrast with cool colors (blues) representing decreasing trends. Darker shades indicate where trends are statistically significant. Trends in magnitudes vary by the available record length (most commonly from the early 1900s through 2020), while (b) trends in frequency are for 1945 to about 2020. Additional information related to trends in large floods is provided in the Flood Potential Portal at https://floodpotential.erams.com/. Figure credit: USDA Forest Service and Stevens et al. (2022).*

Droughts

The Southeast is the only region in the eastern half of the U.S. that is prone to extreme drought and longer-term droughts in the Southeast appear to be increasing in severity (Hoffman et al. 2023). Droughts are most frequent in eastern and southern Arkansas, especially in the Mississippi Alluvial Plain.

Flash droughts strongly affect vegetation on the Arkansas landscape, with grasslands being the most vulnerable of ecosystems (Alzurqani et al. 2024). The highest frequency of droughts in Arkansas occurs during the months of March and August (Alaurqani et al. 2024).The annual number of consecutive dry days (i.e., consecutive days without rainfall) in Arkansas may increase by 4-6% by 2050-2074, and higher temperatures throughout the year may increase the rate of soil moisture loss (i.e., evapotranspiration) during dry spells in Arkansas, which could lead to more intense droughts (Alder 2024; Runkle et al. 2022; Stevens et al. 2023). Overall hydrology could be altered by changes in precipitation and rising temperatures leading to increased evapotranspiration, more intense droughts, and reduced stream base flow (Ingram et al. 2013). The Southeast has the highest aquatic diversity of any temperate system; however, the ecological relationships and life histories of many of the endemic species are not yet well understood within the constraints of changing weather patterns and conditions (Ingram et al. 2013). Freshwater ecosystems (e.g., streams, rivers, lakes, and wetlands) in the Southeast may change if conditions continue to change and impacts on rare species of fish and mussels would be of particular concern.

Tornadoes

Arkansas regularly experiences tornados and between 1985-2020, the state averaged approximately 32 tornadoes per year (Runkle et al. 2022). Tornadoes are short-lived, lasting from a few seconds to hours as opposed to days or weeks at time and span a much shorter area than hurricanes, which makes them very difficult to model. Instead, we can examine potential changes in individual weather "ingredients" that support the development of supercell thunderstorms that then produce tornadoes (e.g., warm, moist air, an unstable atmosphere, and wind shear s). Recent tornado research has been showing evidence for two phenomena: 1) tornado events are becoming more clustered (i.e., there are fewer days with at least one tornado per year but more days with over 30) (Tippett et al. 2016), and 2) tornado patterns have shifted geographically (Gensini and Brooks 2018). The number of tornadoes in the states that used to make up "Tornado Alley" are falling, while tornado events have been on the rise in Arkansas and its bordering states (Gensini and Brooks 2018). There is also evidence that tornadoes are becoming more powerful in the U.S., with increased tornado activity now in the Southeast region than previously (Elsner and Schroder 2018; Gensini and Brooks 2018). The number of favorable tornado days per decade since 1979 has also increased throughout the region with many counties in central and northeast Arkansas having three more days per decade and the percentage of deadly nighttime tornadoes increasing between 35-45% for the state since 1950 (Figures 5A&B). The Southeast region is especially experiencing an increase in fall tornado activity which also has cascading impacts on wildfire season (Moore 2017). Wildlife is impacted by tornadoes via wind damage to their habitats, for example, the removal of forest canopy. Lastly, tornado damage has been found to change species composition of breeding bird populations: in the Arkansas Ozarks bird species have been found to differ between forests of varying tornado damage - with heavily damaged forests exhibiting significantly less abundance of typical forest species (e.g., red-eyed vireo [*Vireo olivaceus*], ovenbird [*Seiurus aurocapilla*]) than undamaged forests, and with undamaged forests containing higher abundance of edge species (e.g., indigo bunting [*Passerina cyanea*], white-eyed vireo [*Vireo griseus*]) (Smith et al. 2004).

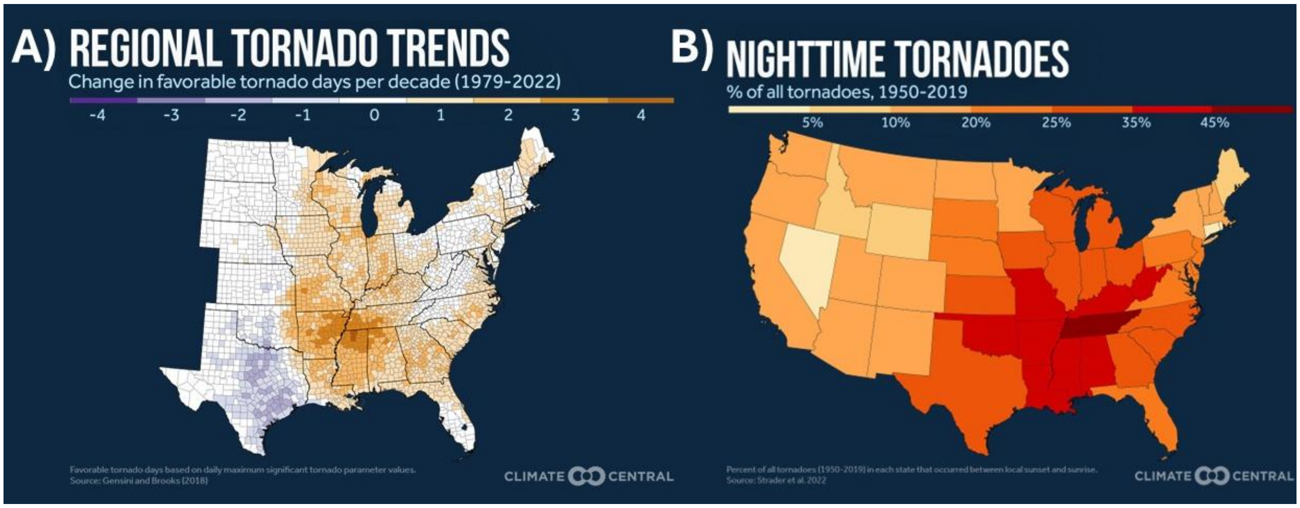

***Figure 5**. Calculations showing A) the change in the number of favorable tornado days per decade from 1979 to 2022 at the county-level for the eastern United States (U.S.), and B) changes in nighttime occurring tornadoes as*

percent of total from 1950 to 2019 for the U.S. Reprinted from Climate Central using data from NOAA NCEI (Climate Central 2024; NOAA NCEI 205).

Arkansas Species Reponses to Changing Environmental Conditions

Tools and models available

Identification of species of greatest conservation need (SGCN) and regional SGCN (RSGCN) that are vulnerable to changing environmental conditions may be important to developing adaptive management strategies. A species may be considered vulnerable if it is both sensitive to changing environmental conditions and also exposed to the impacts of that change (Williams et al., 2008). Two common tools that have been used to determine a species' vulnerability to changing environmental conditions include 1) assessments like NatureServe's CCVI tool (Lyons et al. 2024), and 2) environmental niche modeling-based vulnerability estimates produced by the academic research community. The CCVI is a worksheet-based tool where users apply readily available information about a species' natural history, distribution, landscape circumstances, and expert opinions to predict whether it will likely suffer a range contraction and/or population reduction due to changing environmental conditions (e.g., temperature, precipitation) that then produces a vulnerability score. By design, this score is distinct from NatureServe's global and national conservation status ranking system that considers other threats. For example, a species could score as not particularly vulnerable in terms of its Global or State rank (G- or S-rank), which is based on other factors, but could still rate as vulnerable to climate change. To date, several Southeastern Association of Fish and Wildlife Agencies (SEAFWA) states have used the CCVI tool to conduct assessments of their SGCN in order to inform previous SWAPs, management priorities, and research and conservation planning, and these previous assessments can serve as references for what has been done before and to shape planning and conservation efforts (Armsworth et al. 2025a). Ecological niche models (also called species distribution models) start by identifying shared environmental conditions (i.e., the species' niche) at sites where a species is known to have occurred and then predict where similar conditions may be found on the landscape in the future. Some models also consider the ability of a species to disperse to reach any new areas that may become suitable. The resulting predictions from these models allow researchers to create spatially explicit estimates of whether suitable environmental conditions for a species are likely to remain stable, become more widespread in the landscape (i.e. increase), or become more geographically rare in the future (i.e. decrease).

Niche model results may be used in tandem with CCVI estimates to enhance the understanding of a given species' vulnerability, because assessments and niche models have complementary strengths that may help land managers make informed conservation decisions. Niche models offer spatially explicit predictions (i.e., changes in suitable habitat) about the direct exposure of a species to changing environmental conditions but are only available for a limited set of species, in part because the models require extensive data on a species before they can be applied. Assessments use an expert judgment-based approach that allows integration of different types of information about species and what might make them vulnerable (e.g., their natural history). Therefore, outputs from both of these tools may be used to paint a full picture of a given species 'vulnerability while keeping in mind the geographic (e.g., region or habitat that was evaluated) and biological contexts (e.g., estimated dispersal distance) used.

Summary of available vulnerability indices

For Arkansas, 130 SGCN have been scored via 372 CCVI estimates to date by other institutions; most of which to date have focused on birds (Armsworth et al., 2025a). Many of these CCVI assessments indicate that while some bird species may be vulnerable, a larger proportion may remain stable or increase under changing environmental conditions (Figure 6). Though more assessments are needed for all other taxa besides birds, these current CCVI estimates show that some Arkansas SGCN across all taxa are vulnerable: with amphibians, fish, invertebrates, and plants having the highest proportions (Figure 6). For example, all of the assessed amphibian, fish and plant SGCN in Arkansas to date were found to be vulnerable (Figure 6).

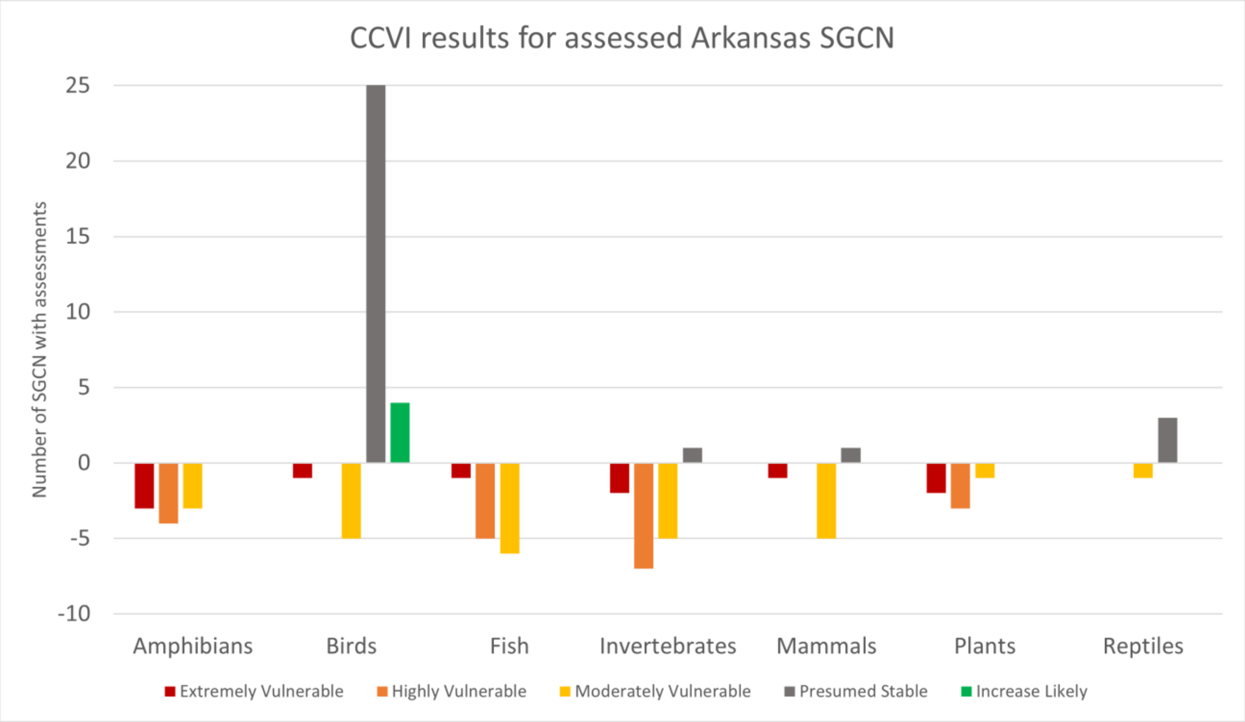

Figure 6. Arkansas SGCN estimated to be vulnerable, stable, or may increase in population based on available CCVI estimates (Armsworth et al. 2025a).

Summary of available ecological niche models

For Arkansas, 121 SGCN have been evaluated across 12 large-scale studies to date, which consists of 336 vulnerability estimates (note: some species have multiple scores for different future climate scenarios) (Armsworth et al., 2025b). Similarly, to the CCVI assessments, most relevant niche modeling efforts to date have focused on birds and have found that many species may experience increases in their suitable landscape within the Southeast Region under changing environmental conditions (Figure 7). Modeling efforts are needed for other taxonomic groups, especially for understudied species like plants, for which there were only two species on Arkansas's SGCN list that have been evaluated (Figure 7). Results from this collation of niche models show that some Arkansas amphibians and birds have the highest numbers of assessed SGCN that were found to be vulnerable, but many species from other taxonomic groups need to be modeled to understand their future vulnerability (Figure 7).

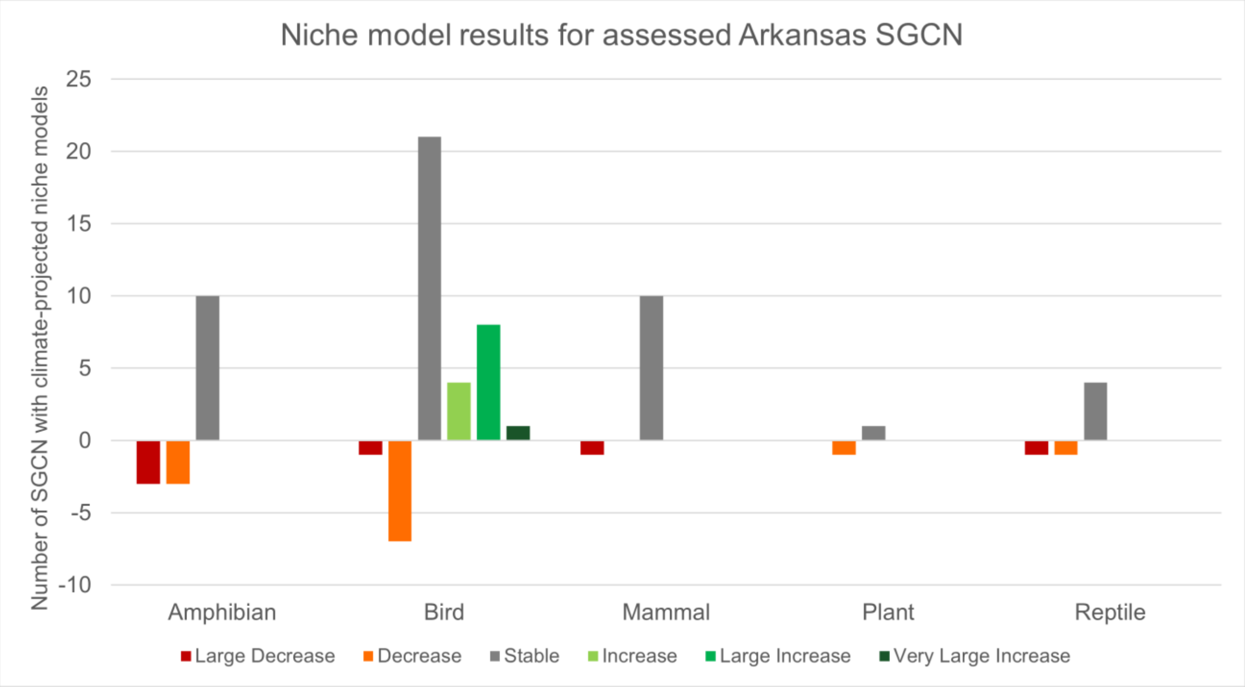

Figure 7. *Arkansas Species of Greatest Conservation Need (SGCN) whose ranges may decrease, remain stable, or increase based on estimates from available ecological niche models across 12 studies (Armsworth et al. 2025b).*

A closer look – Arkansas's endemic amphibian species and potential impacts from changing environmental conditions

Arkansas's unique topography and diverse ecoregions harbor many different kinds of amphibians: the highlands of the Ozarks, the Boston and Ouachita Mountains and the Arkansas Valley providing forest habitat species of the area's streams, caves and high elevations; to the South Central Plains and Mississippi Alluvial Plain providing lowlands for the floodplain and pond-loving species. In fact, Arkansas has several rare "lungless salamander" species (family Plethodontidae) that are endemic (native and restricted to a certain place) to the woodlands of the greater Ouachita Mountains: the Caddo Mountain Salamander (*Plethodon caddoensis*) known only from Caddo Mountain and surrounding areas; the Fourche Mountain Salamander (*Plethodon fourchensis*) known only from Fourche and Iron Forks mountain ranges; the Kiamichi Slimy Salamander (*Plethodon kiamichi*) found in the Kiamichi Mountains of western Arkansas and eastern Oklahoma; and the Rich Mountain Salamander (*Plethodon ouachitae*) known in Arkansas only from the Rich, Black Fork and Kiamichi mountain ranges (Figure 7). Additionally, the Ouachita Streambed Salamander (*Eurycea subfluvicola*) is a newly described rare and endemic species known only from Hot Spring County in Arkansas, and so is a candidate species under the Endangered Species Act
(ESA).

Figure 8. *Photos of the endemic Lungless Salamander species of Arkansas: A) Caddo Mountain Salamande (Plethodon caddoensis); B) Fourche Mountain Salamander (Plethodon fourchensis); C) Kiamichi Mountain Salamander (Plethodon kiamichi); and D) Rich Mountain Salamander (Plethodon ouachitae). Photos by Kory G. Roberts (HerpsofArkansas.com).*

However, concerningly, amphibians are consistently listed in the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species and their declines may be more widespread than currently documented (Adams, 2013; Li, Cohen, & Rohr, 2013; Halsted et al., 2022). Across the country, the average rate of decline is 3.79% per year, and on a local level, this means populations go extinct (Adams et al. 2013; Grant et al., 2016; Luedtke et al., 2023). In fact, many of Arkansas's amphibian species have conservation statuses of 'vulnerable', 'imperiled', or 'critically imperiled' due to a number of threats (Table 4). Amphibians are particularly vulnerable to changes in their environment, relying on water to reproduce and being ectotherms (define), and thus, susceptible to small changes in temperature (Luedtke et al., 2023).

However, species-specific traits of amphibians and their varying adaptive capacity mean that not all species respond the same to these changes (Davis et al., 2017). Table 4 lists Arkansas's updated amphibian species of greatest conservation concern and results from NatureServe conservation status and CCVI assessments, results from ecological niche modeling, and trends in their abundance from monitoring to date. Results agree across the board for some species like the Fourt-toed Salamander (*Hemidactylium scutatum*), Louisiana Slimy Salamander (*Plethodon kisatchie*), and the Eastern Spadefoot Toad (*Scaphiopus holbrookii*) that all show moderate to extremely vulnerable and large decreases of their suitable habitat (Table 4). When regional niche model results disagree with CCVI assessments in the table, it can be due to the niche models representing the projected trend for the region or even the whole eastern North America geographic area, whereas CCVI assessments were conducted at a state level but are still useful as they show the projected regional trends for the species (Table 4). Additionally, to date, many species have either not been assessed using the NatureServe CCVI tool or been the subject of regional ecological niche modeling efforts as is indicated by the gray “Not Assessed” boxes in Table 4.

Table 4*. Arkansas amphibian species of greatest conservation need (SGCN) conservation and vulnerability assessments to date. Each species’ conservation status for Arkansas, also called the state rank, was provided by the Arkansas Game and Fish Commission. X’s for the RSGCN column indicates whether the species is a regional SGCN for the Southeast (SERSGCN - SE Regional Species of Greatest Conservation Need). If available, assessments of vulnerability based on NatureServe calculations from southeastern states and labeled as “NatureServe CCVI by SE States”, and ecological niche model vulnerability scores from recent studies using eastern North America geographic areas labeled as “Niche Models for SE Region” (Armsworth et al., 2025a & b).*

	Species	**RSGCN**	**Conservation Status for AR (state rank)**	**NatureServe CCVIs by SE States**	**Niche Models for SE Region**
Frogs					
Crawfish Frog	*Lithobates areolatus*	X	Imperiled	Highly Vulnerable	Stable
Illinois Chorus Frog	*Pseudacris illinoensis*	X	Critically Imperiled	Not Assessed	Not Assessed
Boreal Chorus Frog	*Pseudacris maculata*		Imperiled	Moderately Vulnerable	Not Assessed
Strecker's Chorus Frog	*Pseudacris streckeri*	X	Imperiled	Extremely Vulnerable	Decrease
Salamanders					
Ringed Salamander	*Ambystoma annulatum*	X	Vulnerable	Not Assessed	Stable
Tiger salamander	*Ambystoma tigrinum*		Vulnerable	Extremely Vulnerable	Stable
Ozark Hellbender	*Cryptobranchus alleganiensis bishopi*	X	Critically Imperiled	Highly Vulnerable	Large Decrease
Spotted Dusky Salamander	*Desmognathus conanti*		Possibly extirpated	Moderately Vulnerable	Stable
Grotto Salamander “eastern clade”	*Eurycea spelaea eastern*	X	Vulnerable	Not Assessed	Stable
Grotto Salamander “northern clade”	*Eurycea spelaea northern*	X	Imperiled	Not Assessed	Stable

	Species	RSGCN	Conservation Status for AR (state rank)	NatureServe CCVIs by SE States	Niche Models for SE Region
Grotto Salamander “western clade”	*Eurycea spelaea western*	X	Vulnerable	Not Assessed	Stable
Ouachita Streambed Salamander	*Eurycea subfluvicola*	X	Critically Imperiled	Not Assessed	Not Assessed
Four-toed salamander	*Hemidactylium scutatum*		Imperiled	Moderately Vulnerable	Large Decrease
Caddo Mountain Salamander	*Plethodon caddoensis*	X	Imperiled	Not Assessed	Stable
Fourche Mountain Salamander	*Plethodon fourchensis*	X	Imperiled	Not Assessed	Not Assessed
Kiamichi Slimy Salamander	*Plethodon kiamichi*	X	Critically Imperiled	Not Assessed	Large Decrease
Louisiana Slimy Salamander	*Plethodon kisatchie*	X	Imperiled	Extremely Vulnerable	Large Decrease
Rich Mountain Salamander	*Plethodon ouachitae*	X	Imperiled	Not Assessed	Stable
Sequoyah Slimy Salamander	*Plethodon sequoyah*	X	Critically Imperiled	Not Assessed	Decrease
Toads					
Great Plains Narrowmouth Toad	*Gastrophyrne olivacea*	X	Imperiled	Not Assessed	Stable
Eastern Spadefoot Toad	*Scaphiopus holbrookii*		Imperiled	Highly Vulnerable	Large Decrease
Hurter’s Spadefoot Toad	*Scaphiopus hurterii*	X	Imperiled	Not Assessed	Stable

Increased temperatures and variability

Being ectotherms, amphibians are particularly susceptible to small changes in temperatures. Future projections predict more extreme temperatures, which will further constrict the viable range of many amphibian species distribution in the region (Salas et al., 2017; Ansley et al., 2022). Increased maximum air temperatures and drier conditions, for example, will likely threaten terrestrial salamander species such as the endemic lungless salamanders (*Plethodon* species), that need cool, moist substrate to take refuge in on hot summer days (Spotila, 1972; Shepard and Burbrink, 2008, 2011; Figure 7). Additionally, most amphibians have a limited ability to disperse long distances, thereby reducing their ability to escape and adapt to harsher extreme temperatures. Behavioral exploitation of microhabitat, therefore, is an important adaptive capacity trait for salamanders and other amphibians (e.g., burrowing under logs and leaf litter to find cooler, moister conditions) (Farallo et al. 2019). Warmer air temperatures will consequently also result in increased water temperatures and reduced dissolved oxygen in aquatic habitats. Aquatic amphibians that require cool and well-oxygenated rivers and streams, such as the federally endangered Ozark Hellbender (Figure 8B) and other stream-dwelling salamanders, could be negatively impacted by increased stream temperatures and lower dissolved oxygen levels (Walls et al., 2013; Hardman et al., 2020; Sutton et al., 2023).

Increased regional temperature variability can reduce amphibian defenses against pathogens and may be as significant to their declines as increases in maximum temperatures (Rollins-Smith and Le Sage 2023). In fact, a recent study found that widespread amphibian species declines, including possible extinctions, have been driven by an interaction between increasing temperatures and infectious disease (Cohen et al., 2018). Indeed, the first reports of chytrid fungi (*Batrachochytrium dendrobatidis* [Bd]) were documented in Arkansas's Ozark Hellbender populations in 2017 and emphasizes the importance of ongoing disease monitoring for this endangered species (Hardman et al., 2020; Figure 8B).Moreover, their findings suggest that amphibian hosts adapted to relatively cool conditions, like the endemic lungless salamanders (*Plethodon* species) of the Ouachita Mountains that favor moist microclimates on north-facing slopes, will be most vulnerable to the combination of increases in mean temperature and emerging infectious diseases (Spotila, 1972; Shepard and Burbrink, 2008, 2011; Cohen et al., 2018; Figure 7).

Increased drought

Amphibians are particularly vulnerable to changes in water availability because many species rely on water to reproduce. Recent studies confirm that amphibians' reliance on aquatic environments makes them especially sensitive to drought-induced habitat loss, with both aquatic and terrestrial life stages affected by reduced water availability and increased desiccation risk (Pujol-Buxó and Montori 2025). On average, one of the biggest threats that North American amphibian species are exposed to most frequently is drought (Grant et al. 2016). For aquatic and semi-aquatic species, long-term reduction in available water, either due to decreased precipitation or increased evapotranspiration and drought, could result in reduced stream flows and altered hydrology directly impacting the success of stream-inhabiting species like Hellbenders (Nickerson et al. 2017; Sutton et al., 2023; Figure 8B). Both semi-aquatic and terrestrial amphibian species typically prefer cool, moist microhabitats. Droughts, with increases in temperatures and a decrease in available moisture, can cause some of these microhabitats to be degraded or lost during the drought event. In addition, many amphibians rely on ephemeral wetlands for breeding which may have shorter durations of water availability, called hydroperiods, or may be lost altogether during this critical life history stage due to warmer temperatures and increased drought (Trauth et al. 2006; Walls et al. 2013). Hydroperiods are arguably the most important determinant of salamander presence and general amphibian community diversity in the Southeast (Venne et al. 2012). Shifting hydroperiods and variations in water availability may influence these amphibians' breeding seasons, larval development, and body size, and have profound impacts on extinction rates (Trauth et al. 2006; Walls et al. 2013; Davis et al. 2017; LeSage et al. 2022). Periods of drought, increased temperatures, and rainfall can dramatically alter the hydroperiod of freshwater wetlands over time which rely on precipitation, and over the long-term also affect groundwater-fed wetlands (Trauth et al. 2006; Walls et al. 2013). "Experimental studies show that shortened hydroperiods not only reduce larval survival but also lead to smaller body sizes and reduced locomotor performance post-metamorphosis, which may affect long-term fitness (Amburgey et al. 2012; Ohmer et al. 2023). For example, the Tiger Salamander (*Ambystoma tigrinum*) in the South Central Plains Ecoregion relies on intermittent wetlands, but recently decreased lengths of hydroperiods have made it so the salamander cannot complete its longer larval development period of 3-months during this reduced time of water availability (Ansley et al. 2022; Figure 8C). Another example comes from the Crawfish Frog of the Arkansas Valley Ecoregion: a recent study found that higher temperatures in the driest quarter of the year increase the rate that ponds dry out, leading to shorter hydroperiods and was the most important variable associated with the frog's presence (Boycott et al. 2024; Figure 8D). These findings underscore the importance of incorporating adaptation into amphibian conservation planning, particularly for species with narrow hydroperiod requirements or limited dispersal capacity (Reimer et al. 2025).

Drought can also impact amphibian species by reducing habitat quality and having cascading effects on other animals that amphibians rely on. An interesting example comes again from the Crawfish Frog, which relies on adequate crawfish burrows present in their floodplain habitat of the Arkansas Valley Ecoregion for their young to survive and grow: three to four months after hatching, newly metamorphosed juvenile Crawfish Frogs will quickly seek out crawfish burrows to occupy for 10.5 months of the year in order to avoid predation (Heemeyer et al., 2012; Figure 8D). A recent study found successful juvenile Crayfish Frog burrowing requires not only an adequate number of crawfish, but available burrows (Kross and Wilson., 2022). Pond flooding, in combination with rainfall, allows crawfish to emerge from their burrows, as they are trapped inside the burrow by a dried soil plug they create at the entrance until external moisture softens it (Brown et al., 2020; Lutz, 2024). When burrows are flooded, crawfish can emerge, but when crawfish have burrowed above the water line on levees, they may not be able to emerge until there is heavy rainfall to soften the soil plug, therefore preventing Crawfish Frogs from entering (Brown et al., 2020; Lutz, 2024). Increased periods of drought and reduced precipitation may have negative impacts on crawfish burrowing success and subsequent Crawfish Frog survival.

Extreme precipitation events and flooding

Future projections also predict increases in the frequency of extreme precipitation events in Arkansas. Extreme precipitation events have negative effects on streams and wetlands such as flooding, high-velocity water flow, high levels of water turbidity from suspended sediment, and consequently high-levels of sediment being deposited, which alters streambed geomorphology and habitat (Henley et al., 2000; Walls et al., 2013). Flooding, with its associated high flow and transport of debris, has been linked to declines and extirpations of a variety of stream-dwelling amphibians, such as the Ozark Hellbender (Walls et al., 2013). Increases in the frequency and intensity of flood events would also result in increased nutrient loading and agricultural run-off which can reduced dissolved oxygen and lead to harmful algal blooms. In agricultural areas, such as the Delta of Arkansas and the Mississippi Alluvial Plain Ecoregion of the state, flood events can introduce herbicide and pesticide run-off into wetlands that amphibians rely on.

In the Ozark Highlands and the Ouachita Mountains, rapid shallow landslides and slow-moving (i.e., soil creep) occur on soil-covered low-relief forested hillslopes frequently but overall landslide frequency has significantly increased since 2005 - a period during which the area also experienced increased extreme storm events (Regmi et al., 2024). Landslides in these areas negatively impact amphibians by depositing sediment, altering flows and eroding adjacent riparian zones, which have been suggested as primary causes of declines of Ozark Hellbenders (Jachowski and Hopkins, 2018; Sutton et al., 2023; Figure 8B). Extreme precipitation and landslides also have negative consequences for amphibians living on the hillsides: flash flooding can wash away the softer topsoil upon which the endemic lungless salamanders appear to depend (Potila, 1972; Shepard and Burbrink, 2008, 2011; Figure 7). Indeed, shortly after locations of the newly described Ouachita Streambed Salamander (Figure 8A) were mapped in the Ouachita Mountains, researchers from the Arkansas Game and Fish Commission determined that one site was about to be damaged by sediments washed downstream, which threatened to fill in a pool in which the salamanders were most abundant (McAllister, 2023; Figure 8A). A mitigating project was undertaken by the Commission's Stream Team Program to remove excess sediment from the streambed and construct a sediment trap to prevent movement of additional sediments into the pool (McAllister, 2023).

Additionally, the intermittent nature of the wetlands of the South Central Plains, such as those throughout the southwestern part of Arkansas, excludes most predators (such as fish) and non-native competitors from them, who cannot go for periods of time without water, promoting native amphibian community diversity (Scheffer et al., 2006). During times of flooding and increased waterway connectivity, dispersal-limited predators, such as fishes, can be introduced to wetlands from which they have been previously absent (Davis et al., 2017). For example, the Crawfish Frog relies on ephemeral ponds and wetlands in the grassland habitats of the Arkansas Valley that lack fish for successful breeding and their juveniles to avoid predation (Davis et al., 2017). More frequent and extreme flooding events could introduce fish into currently predator-free habitats that are essential to these amphibians' successful breeding.

Figure 9. *Photos of some of Arkansas's amphibian species greatest conservation concern: A) the Ouachita Streambed Salamander (Eurycea subfluvicola); B) the Ozark Hellbender (Cryptobranchus alleganiensis bishopi); C) the Tiger Salamander (Ambystoma tigrinum); and D) the Crawfish Frog (Lithobates areolatus). Photos by Kory G. Roberts (HerpsofArkansas.com).*

In summary, declines in amphibian populations and impacts from environmental change are a concern and may signal the need for conservation action. The Arkansas Game and Fish Commission's Wildlife Diversity Program has several ongoing SWAP-funded projects for amphibian research and conservation actions including determining species boundaries of Slimy Salamanders (*Plethodon glutinosus* complex), studying habitat-use of adult Crawfish Frogs, and surveying and improving the Saline River watershed. In addition, it could be beneficial to validate some of these reported results to allow for the development of more targeted efforts to reverse declines through conservation action: through the collection and analysis of complementary data, and to initiate amphibian demographic studies throughout the annual cycle in order to understand vulnerabilities of all life stages and to determine where and when declines are most likely to originate.

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