FIREFLY SPECIES FACT SHEET:
Southwest spring firefly (*Bicellonycha wickershamorum*)

An adult male Southwest spring firefly in southern Arizona (Scott Cylwik).

March 2024
Updated April 2024

Candace Fallon
Xerces Society for Invertebrate Conservation

Anna Walker
New Mexico BioPark Society

XERCES SOCIETY
for Invertebrate Conservation

Scientific Name:

Bicellonycha wickershamorum Cicero, 1982
Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Lampyridae
Subfamily: Photurinae
Tribe: Photurini
(ITIS 2023)

Synonyms: None

Common Names:

Southwest spring firefly, Gila Southwest spring firefly

Taxonomic Note:

The Southwest spring firefly, *Bicellonycha wickershamorum*, was formally described by Joseph Cicero in 1982 along with one subspecies, *B. w. piceum* (Cicero 1982; ITIS 2023). The nominate subspecies (*B. w. wickershamorum*) carries the same common name as the species, while the *piceum* subspecies is referred to as the Gila Southwest spring firefly (Fallon & Cicero 2021a, 2021c).

Conservation Statuses:

Species

Global Status: G2G3 – Imperiled (last reviewed 22 November 2021)
National Status (United States): NNR – Nation Not Ranked
State Statuses: SNR – State Not Ranked (AZ)
(Fallon & Cicero 2023a)

Federal Status (United States): Petitioned for listing, awaiting 90-day finding (Fallon et al. 2023)
IUCN Red List: Vulnerable (Fallon & Cicero 2021b; Fallon et al. 2021)

Subspecies: wickershamorum

Global Status: G2G3T2T3 – Imperiled Subspecies (last reviewed 9 December 2021)
National Status (United States): NNR – Nation Not Ranked
State Statuses: SNR – State Not Ranked (AZ)
(Fallon & Cicero 2023b)

IUCN Red List: Vulnerable (Fallon & Cicero 2021c)

Subspecies: piceum

Global Status: G2G3T1T2 – Critically Imperiled Subspecies (last reviewed 9 December 2021)
National Status (United States): NNR – Nation Not Ranked
State Statuses: SNR – State Not Ranked (AZ)
(Fallon & Cicero 2023c)

IUCN Red List: Endangered (Fallon & Cicero 2021a)

Technical Description:

Adult: The Southwest spring firefly is the only representative of its genus in the United States, and one of only two flashing firefly species recorded from Southern Arizona. The other flashing species, the Southwest synchronous firefly, *Photinus knulli*, is typically active later in the year, is morphologically dissimilar, and belongs to a different subfamily, Lampyrinae.

Diagnostic characteristics of the adult Southwest spring firefly (*B. w. wickershamorum*) include their length (8.9-10.3 mm) and the presence of black elytra (wing covers) with yellow inner and lateral margins (Cicero 1982; Figure 1). The median pronotal vitta (center stripe on the dorsal plate of the prothorax) is black and the hind corners of the pronotum are strongly acute (Cicero 1982). Interestingly, individuals lacking this yellow margin have been observed in some *B. w. wickershamorum* populations (Figure 2), and such an observation of intergradation provides justification for the original naming of the all-black populations as a different subspecies instead of a different species. The Gila subspecies, *B. w. piceum*, lacks the yellow striping and can appear more brown-black (piceous) in color (Cicero 1982). Some of the Arizona *B. w. piceum* specimens also have a somewhat dark pronotal margin which is lacking in the New Mexico specimens (Figure 3).

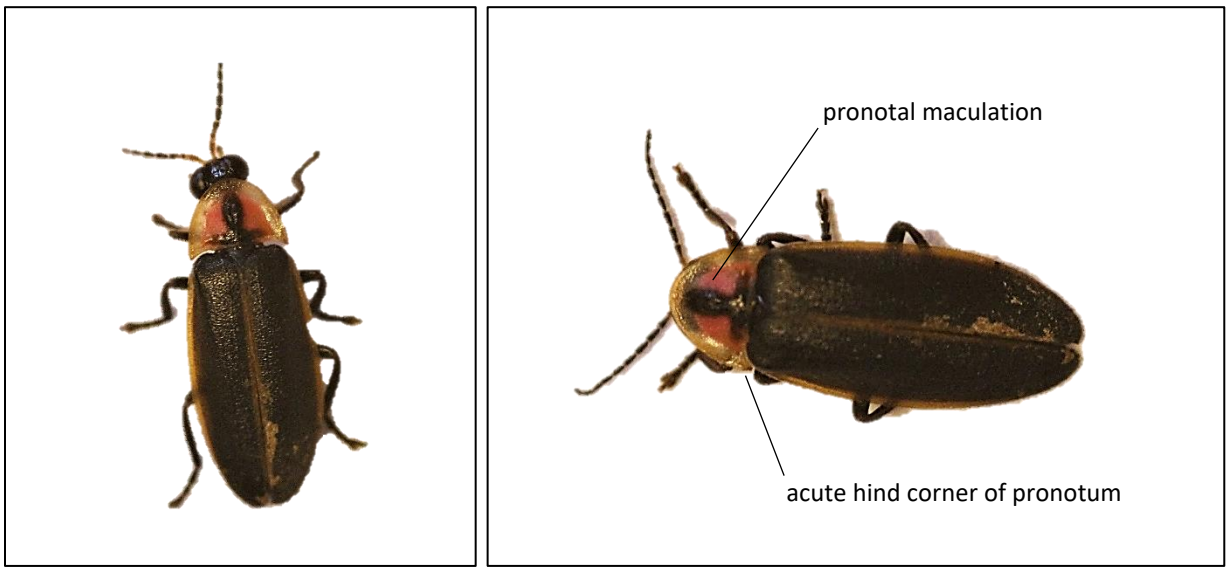

Figure 1. Dorsal images of an adult Southwest spring firefly (*B. w. wickershamorum*) from Arizona (Tony Palmer, iNaturalist, CC BY-NC; photos have been altered to remove backgrounds).

Figure 2. Some *B. w. wickershamorum* adults lack the characteristic yellow elytral margins, such as this individual from Las Cienegas National Conservation Area, AZ (Candace Fallon/Xerces Society). Lines on the page are 5 mm apart.

Figure 3. An adult male *B. w. piceum* from the Gila Mountains, NM (Anna Walker). Each scale mark is 1 mm.

In contrast, *P. knulli* can be distinguished by its smaller size (7.5-8 mm) and more slender shape (Green 1956). *P. knulli* also has a dark pronotal marking similar to that of *B. wickershamorum*, but its hind

corners are only weakly acute (J. Cicero pers. comm. 2022). While not yet recorded to co-occur in the same habitats in Arizona, *Bicellonycha* can be distinguished from other Photurinae fireflies (e.g., *Photuris*) by the tarsal claws: in both male and female *Photuris*, the outer claw of each leg is apically bifid (cleft), while the inner claw of each leg is simple; in male *Bicellonycha*, both claws of each leg are apically bifid (Figures 4a and b), while both claws in the female are simple (Cicero 1982; J. Cicero pers. comm. 2024).

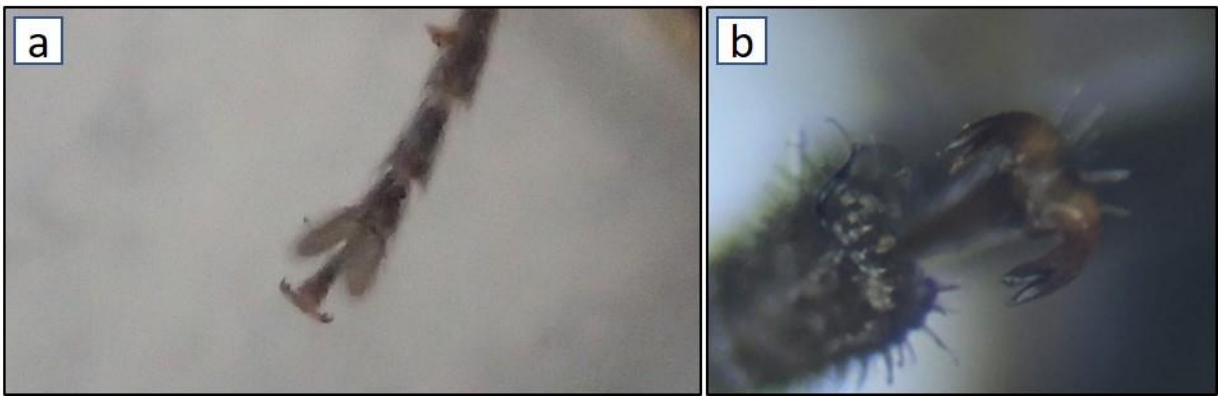

Figure 4. (a) Tarsal claw of an adult male *Bicellonycha* firefly from Costa Rica, displaying the characteristic cleft (Richard Joyce, iNaturalist, CC BY-NC). (b) Close-up of the tarsal claw of an adult male *B. w. piceum* from New Mexico, with the cleft clearly visible (Anna Walker).

Immature: Last instar larvae are 9-12 mm in length, not counting the head, which retracts (Cicero 1982). Pupae are whitish pink with golden setae; they can be recognized by the soil 'igloos' they are housed in, which are created during the larval stage just prior to pupation (Cicero 1982). Larval illustrations and photos of the pupa are available in Cicero (1982).

Life History:

Flash behavior and phenology

Flash pattern and activity period can be used as distinguishing features from other fireflies, such as *Photinus knulli*, that may occur in the same county or region at a different time of year. Both male and female Southwest spring fireflies flash, and can be found flying and flashing from early June through late July and sometimes into August (Fallon et al. 2023). Adult activity typically precedes but sometimes occurs at about the same time as the North American summer monsoons (Cicero 1982; Buschman 2016; C. Mollohan pers. comm. 2022). Until 2023, *B. w*. *piceum* had only been recorded in June, but the subspecies has now been observed in August as well (The Xerces Society 2023).

Courtship flash patterns consist of a single green flash (Figure 5). Analysis of video recordings of *B. wickershamorum* from July 2022 revealed an average inter-flash gap of about 0.8 seconds and a flash duration of 0.14 seconds (Martin et al. 2023). Displays begin at dusk and continue into the night as adult males fly and flash along the stream in search of females. Early on, males fly close to vegetation along the ground and may be able to find females directly, without seeing their response flashes. Later in the

evening, males fly higher and mate-finding takes place through a flash-answer dialog, typically zigzagging back and forth to cover more ground (J. Cicero pers. comm. 2022). Most males drop out of flight once it is fully dark, but some individuals continue flashing, moving up to 10-12 feet above the ground for the broadest view of female response flashes. When these males see a response, they descend to it while flashing in a fast strobe flutter that differs from their typical flash pattern (J. Cicero pers. comm. 2022).

Figure 5. Southwest spring fireflies flashing at dusk (Scott Cylwik).

Dispersal capacity

In general, fireflies are thought to be weak fliers that rarely disperse beyond the habitat in which they were born (Lewis 2016), although some species, such as *Photinus signaticollis*, are capable of dispersing across large distances (Koken et al. 2022). Adult Southwest spring fireflies can be observed flying and flashing well away from streams, possibly dispersing to other nearby areas (Fallon & Cicero 2021b). They may also disperse during flood events that could move them downstream.

Life cycle

The Southwest spring firefly is a beetle with a holometabolous life cycle, meaning it undergoes four life stages: egg, larva, pupa, and adult. After mating, females likely lay their eggs in moist soil, duff, or leaf

litter. While life stage lengths are not known for this species, other photurine firefly species typically lay an average of 28 eggs, deposited singly or in batches over the course of several days to weeks (Faust 2017; Lloyd 2018). Two to three weeks later, these eggs hatch into flat brown or gray beetle larvae that are spindle-shaped (Faust 2017; J. Cicero pers. comm. 2024). Fireflies spend the majority of their lifetime (1-2 years) as larvae, undergoing 4-7 growth stages called instars (Faust 2017; Lloyd 2018). As with *Photuris*, *Bicellonycha* larvae construct mud chambers ("igloos") on the soil surface and pupate inside them. They emerge as adults a few weeks later in late spring or early summer (Cicero 1982). Researchers suggest the larvae may be more sensitive to environmental change than adults (C. Mollohan pers comm. 2023) because, like other soft-bodied soil inhabitants, they are dependent on soil moisture and are therefore vulnerable to desiccation (Evans et al. 2019).

Diet

Larvae, which are predaceous and active at night along gentle stream banks, have been observed preying on snails (J. Cicero pers. comm. 2020), although it is unknown if they are generalist or specialist snail predators, or if they eat other organisms as well. Adults of this species have not been observed feeding. It is possible that adult *Bicellonycha* females will predate other fireflies. This has been recorded in adult females of other photurine fireflies, including *Photuris* and other North American *Bicellonycha*, which are specialized predators of other fireflies (Lloyd 1997, 2018). This behavior, in which adult females mimic the female flash patterns of other firefly species (including those of *Photinus* and *Pyractomena*), attracts males which are then eaten by the females. In doing this, the female fireflies sequester protective toxins, called lucibufagins, which are produced by other firefly species and can be passed on to their offspring.

Range, Distribution, and Abundance:

Type Locality: Arizona, Cochise County, 4.8 mi. W. Fairbank, 0.8 mi. S. on Sanders rd. (sic) to the Babocomari River (Wickersham house), 4,000'. 3141 '42"N, 1 10014'23"W. (Cicero 1982)

Range: The Southwest spring firefly occurs in southern Arizona, southwestern New Mexico, and Sonora, Mexico.

Distribution:

This species has been documented from approximately 30 localities on federal and private lands (Figure 6). In Arizona, the species has been documented from seven counties: Cochise, Graham, Greenlee, Pima, Pinal, Santa Cruz, and Yavapai (Fallon et al. 2023). It has also recently been recorded from Grant County in western New Mexico (The Xerces Society 2023). In Mexico, it has been reported from a single site at Cajón Bonito 10 km south of Rancho Nuevo in Sonora (J. Cicero pers. comm. 2022).

The nominate subspecies, *B. w. wickershamorum*, is currently documented from a greater number of sites than *B. w. piceum*, and can be found in several sky island mountain ranges within the Madrean Archipelago EPA Level III ecoregion, including the Huachuca-Patagonia complex and the Galiuro and

Santa Rita Mountains, as well as the surrounding canyons and foothills. Until 2022, the *piceum* subspecies appeared to be restricted to a single location in the Arizona/New Mexico Mountains EPA Level III ecoregion outside the town of Morenci, AZ; however, a historic (1981) Yavapai County, AZ, specimen found in the University of Arizona Insect Collection in 2022 was confirmed as *B. w. piceum* in 2023 (J. Cicero pers. comm. 2023), greatly expanding this subspecies' known range (by approximately 160 miles) within the Arizona/New Mexico Mountains ecoregion. Follow-up surveys by the US Forest Service and volunteers in the summer of 2023 confirmed that this subspecies is present in at least one other location in the county, along Oak Creek outside of Cornville, AZ (The Xerces Society 2023). As part of this effort, flashing fireflies were detected at several other sites in Yavapai County, although surveyors were unable to confirm they were *B. wickershamorum* (J. Agyagos pers. comm. 2023). Also in 2023, the *piceum* subspecies was discovered at Turkey Creek Hot Springs in New Mexico—the first known record for the species in that state (The Xerces Society 2023). It is possible that the Southwest spring firefly could occur in additional mountain ranges in the extreme southwestern tip of New Mexico, more extensively in northern Mexico, further throughout New Mexico's Gila Mountains, or in other areas of the Arizona/New Mexico Mountains ecoregion. Surveys in these remote regions are needed to better understand the distribution limits of the species.

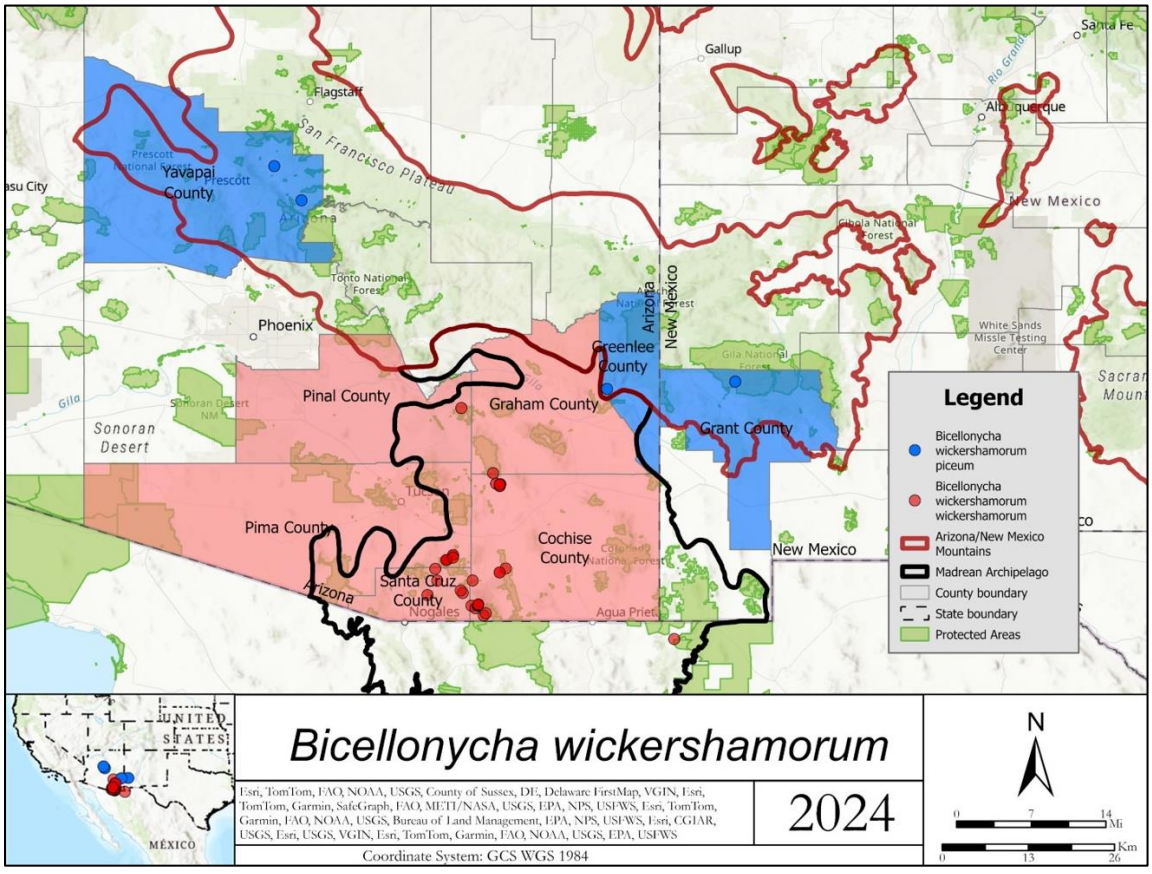

Figure 6. Distribution of *Bicellonycha wickershamorum* in Arizona, New Mexico, and Mexico. Highlighted polygons indicate US counties where the species has been detected. These are color coded to illustrate the ranges of the two subspecies, which are not known to overlap.

Note that records with vague locality information or that have not been verified have not been added to the map, but do occur within the highlighted counties.

Documented

This species has been documented from the following public lands:

- Las Cienegas National Conservation Area (Gila BLM District), AZ
- San Pedro National Conservation Area (Gila BLM District), AZ
- Coronado National Forest (Nogales, Sierra Vista, and Santa Catalina Ranger Districts), AZ
    - Scotia Canyon
    - Parker Canyon
    - Sunnyside Canyon
    - Bear Canyon
    - Gardner Canyon
- Coconino National Forest (Red Rock Ranger District), AZ
    - Sycamore Spring along Fossil Creek Rd
    - Oak Creek at Windmill Park
- Gila National Forest (Wilderness Ranger District), NM
    - Turkey Creek Hot Springs

Suspected

The Southwest spring firefly is suspected to occur in additional areas with appropriate habitat. Potential areas where flashing fireflies like the Southwest spring firefly may occur include the following public lands (note that not all areas are open after dark, and some may require permits and/or special access permissions):

- San Pedro National Conservation Area (Lewis Springs), AZ
- Gila Box Riparian National Conservation Area (Bonita Creek), AZ
- Pima County (Buehman/Edgar Canyon), AZ
- Cienega Creek Preserve, AZ
- Sharp Springs Ciénega, AZ
- Coronado National Forest (Bog Hole), AZ
- Coconino National Forest (Fossil Creek, Spring Creek), AZ
- San Bernardino National Wildlife Area (Leslie Canyon and Black Water Draw), AZ
- White Water Draw Wildlife Area, AZ
- Needles Eye Wilderness, Gila BLM District (Mescal Creek and Mescal Warm Spring), AZ
- Blue River at the Juan Miller road crossing, AZ
- Guadalupe/Baker Canyons, AZ and NM
- Lower San Francisco Wilderness Study Area, NM

Abundance:

Detailed data on abundance are not available. This species has a relatively patchy distribution across its range, and population connectivity is likely low. The number of individuals has not been documented for most known populations, and many species records lack abundance estimates, although recent surveys at several sites have resulted in sightings of approximately 20-100 individuals (C. Mollohan pers. comm. 2020, C. Fallon pers. obs. 2022). Where the species does occur, it can be locally abundant; Buschman (2016) notes "they can occur in large numbers in marsh areas along permanent streams." Las Cienegas National Conservation Area (NCA) and Mint Springs, managed by the Bureau of Land Management and Nature Conservancy, respectively, boast the two largest known populations in the U.S., based on single evening count estimates. Reliable methods of measuring population abundance of flashing fireflies have not yet been developed, although work is underway to address this (e.g., Sarfati et al. 2020).

Habitat Associations:

The Southwest spring firefly is known from wetland and riparian areas within otherwise arid habitats at elevations ranging from 2,780-6,100 ft. above sea level (Fallon et al. 2023). This includes springs, pools, marshes, and other riparian areas in montane oak and pine woodlands and oak-studded grasslands. Each subspecies occurs in a distinct ecoregion, with all populations of *B. w. wickershamorum* located within the Madrean Archipelago ecoregion (also known as the Madrean Sky Islands) and populations of *B. w. piceum* found in the Arizona/New Mexico Mountains ecoregion.

The Madrean Sky Islands are composed of approximately 60 "islands" (mountains) in the southwestern U.S. and northern Mexico, spanning a total area of 181,300 km^2 (70,000 square miles) (Yanahan & Moore 2019; Dumke 2022). These islands of pine-oak woodlands are surrounded by oceans of desert scrub and grassland, which effectively isolate each mountain from the next, limiting genetic exchange between organisms. Within this ecoregion, *B. wickershamorum* typically occurs in marshy areas and other wetland habitats along permanent streams, including seeps and areas with standing water and perennially moist soil (Cicero 1982; Buschman 2016; C. Mollohan pers. comm. 2020; Figures 7a, 7b). To the north of the Madrean Archipelago, the Arizona/New Mexico Mountains ecoregion encompasses the largest contiguous ponderosa pine (*Pinus ponderosa*) forest in the United States, supporting more species of birds and mammals than any other place in the Southwest (Bell et al. 1999). In this ecoregion, the Gila Southwest spring firefly has been found in the Arizona transition zone and Mogollon Mountains. At the subspecies' type locality near Morenci, AZ, it is described as living near heavy seepage emitting from a creek-side bluff along an approximately 10-year floodplain (Fallon & Cicero 2021b; A. Walker pers. obs. 2021; J. Cicero pers comm. 2021; Figure 7c). It has also been observed in scattered locations upstream from the seep area for approximately 91 m (100 yards) (C. Mollohan pers. comm. 2022). In New Mexico, *B. w. piceum* has been documented at a spring-fed marshy area, adjacent to a small montane creek (A. Walker pers. obs. 2023; Figure 7d).

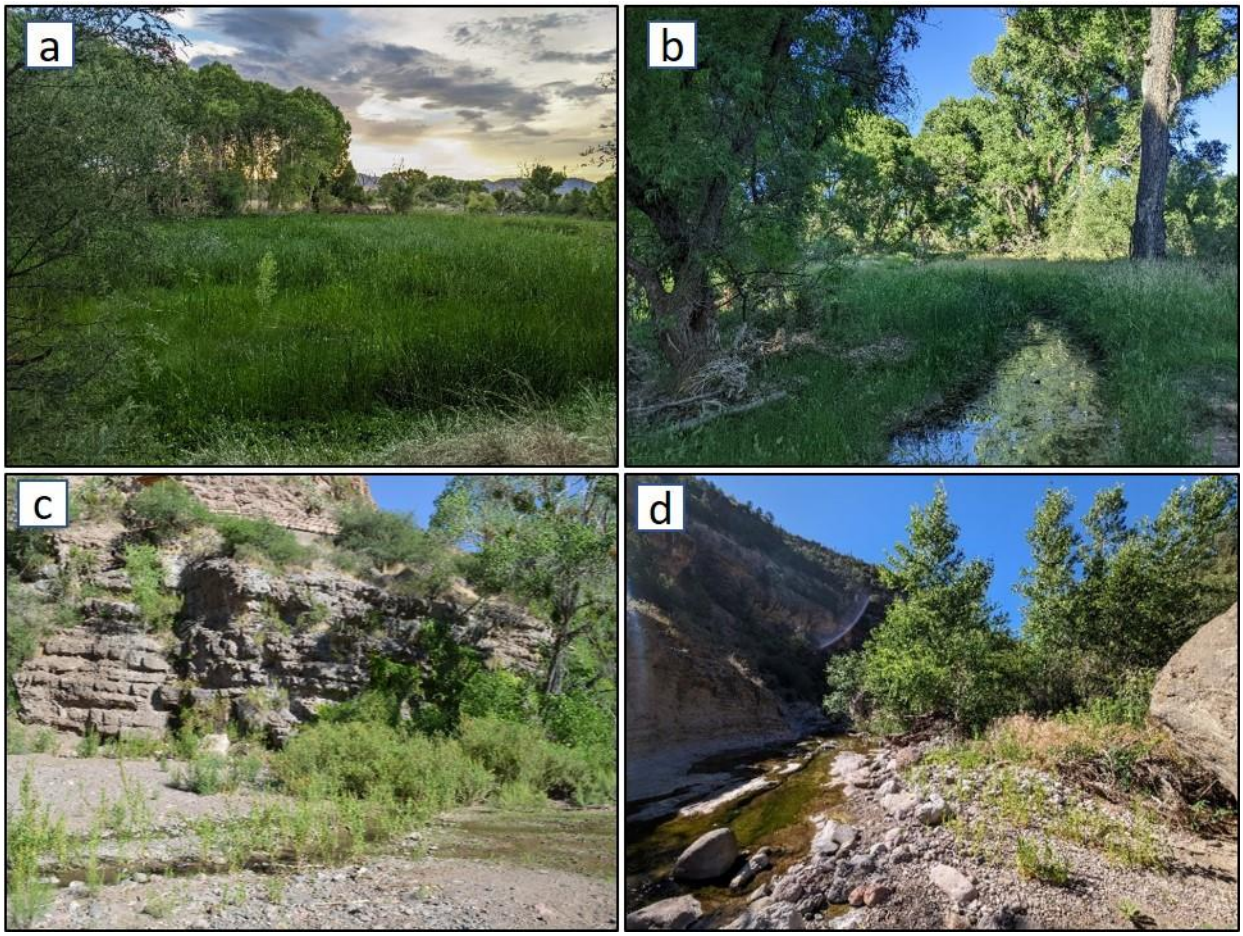

Figure 7. The Southwest spring firefly is associated with marshes, seeps, and other wetland habitats in southern Arizona. (a) *B. w. wickershamorum* marsh habitat at Las Cienegas National Conservation Area, AZ. Adults were seen displaying in and above the vegetation in this wetland (photo: Candace Fallon/Xerces Society). (b) *B. w. wickershamorum* riparian habitat along the Babocomari River in AZ (photo: Candace Fallon). (c) Seepage habitat at the *B. w. piceum* type locality near Morenci, AZ (photo: Anna Walker). (d) *B. w. piceum* habitat in the Gila Mountains of New Mexico (photo: Anna Walker).

Recent studies suggest that *B. w. wickershamorum* is only found in habitats with perennial water. When researchers used wet/dry stream data (which is collected at the peak of the dry season) to predict occurrence of the Southwest spring firefly at numerous Nature Conservancy sites in the Muleshoe, they found this species at each site surveyed (C. Mollohan pers. comm. 2022; Figure 8). A species distribution model built in Maxent assessed 122 variables and highlighted the following as being significant predictors in the occurrence of this firefly (listed in order of importance): distance from streams, minimum temperatures in December and February, artificial light at night levels, annual and June flow velocity of streams and rivers, drought conditions, greenness (NDVI), slope, and wind velocity and isothermality (Shamgochian 2023). A second version of the model that included the original variables as well as wet/dry survey data for parts of the region highlighted the wet/dry dataset as the most important predictor of *B. wickershamorum* occurrence, accounting for 34.8% of the variation, followed by artificial light at night levels and drought index, to explain approximately 95% of the variation

(Shamgochian 2023). These results suggest that the presence of perennial water at the hottest, driest time of year is an important predictor for this species' occurrence.

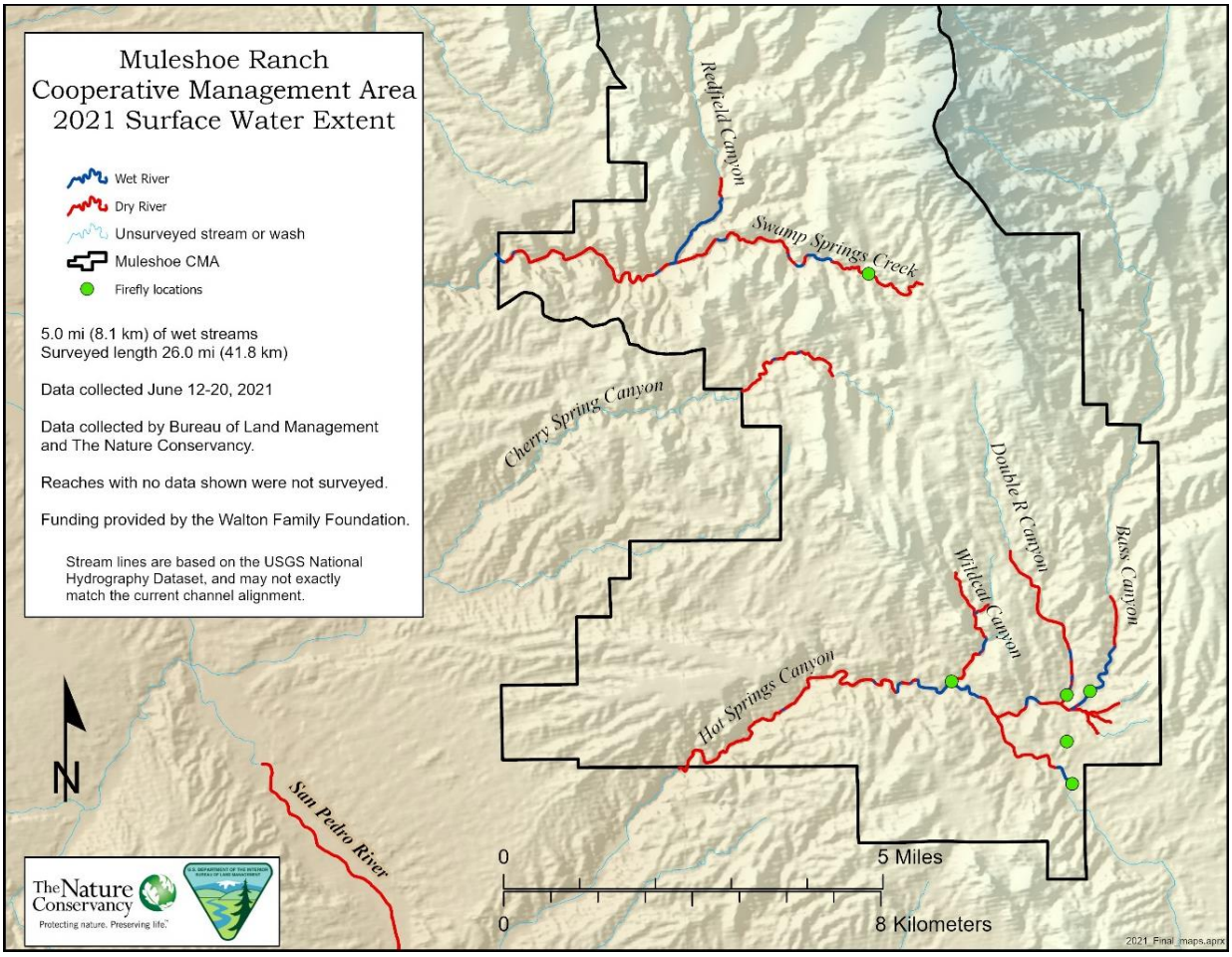

Figure 8. The Southwest spring firefly appears to depend on perennial water sources, as seen in this wet/dry stream survey map conducted during the driest part of the year in the Muleshoe Cooperative Management Area in southern Arizona (courtesy of The Nature Conservancy of Arizona).

Threats:

Documented threats to the Southwest spring firefly include habitat loss and fragmentation from livestock grazing, residential development, water diversion, mining, and other landscape modifications for agriculture and pasturing. Researchers predict that the quality of this species' habitats will continue to decline within its known range due to climate change and associated drought, which can cause drying of permanent rivers and nearby wetland habitats upon which this species depends. More localized threats such as trampling by cattle, water and light pollution, declines in prey species, pesticide use, off-road vehicle use, and other intrusive recreational or tourist activities are also likely drivers of decline, and may in fact have already led to the destruction of the *B. w. wickershamorum* type locality.

Loss and degradation of wetland habitats

From the 1780s to the 1980s, an estimated 36% of the wetlands in Arizona were lost (Dahl 1990), largely due to increased demand for water from agriculture, urbanization, and industry (Fretwell et al. 1996). Many of the major rivers have been dammed, diverted, or otherwise modified and many perennial streams and wetlands have been lost due to groundwater drawdown of aquifers and altered hydrology of drainages (Fretwell et al. 1996). In a study assessing the distribution, conservation status, and restoration potential of ciénegas in the Apache Highlands Ecoregion (a region which encompasses most of the Southwest spring firefly's known range), more than 20% of ciénegas with adequate data for analysis were found to be so degraded that they had lost their basic ecological function (Minckley et al. 2013). Prior to these drastic changes, Arizona had a river system which flowed year-round and spanned the state (Fretwell et al. 1996), and ciénegas were thought to be widespread (Minckley et al. 2013). As wetland habitats have been lost or degraded throughout this system, the firefly populations that depend on them have likely become increasingly fragmented. Fragmented firefly populations are at increased risk of genetic isolation and potentially even local extinction since fireflies are, in general, poor fliers that do not disperse very far (Lower et al. 2018).

As a wetland and riparian habitat specialist, the Southwest spring firefly is reliant on surface and groundwater resources along waterways. Outside of three Active Management Areas (AMAs), which were created by the 1980 Groundwater Management Act to work toward safe-yield of groundwater resources, there are no regulations on groundwater use in the state (Ferris & Porter 2021). As such, in rural areas, which cover 80% of the state, there is no limit on the number of new wells drilled, or on the amount of water that can be pumped from a well (Holmes 2022). This unmanaged pumping has led to wells going dry, ground fissures, and land subsistence.

Cattle grazing

Cattle are a major threat to fireflies since they wallow in fragile freshwater habitats and pollute it while eating streamside vegetation and breaking down streamside walls, greatly accelerating erosion. Cattle can also lead to higher mortality by trampling and killing immature fireflies or adults resting on vegetation. The Southwest spring firefly was named in honor of the land owner whose property it was discovered on, but on a subsequent visit by the species' author, the habitat had been destroyed by cattle trampling (J. Cicero pers. comm. 2022), and is now likely extirpated. Cattle may be negatively impacting other sites as well. Anecdotal evidence over three years of surveys at Empire Gulch, Las Cienegas National Conservation Area indicates that the firefly population there may be declining, potentially due to habitat degradation and direct trampling of larvae by cattle (C. Mollohan pers. comm. 2023; Figure 9). Surveyors at this site counted approximately 40 Southwest spring fireflies in 2020, approximately 20 in 2021, and just 10 in 2022 (C. Mollohan pers. comm. 2023). In 2022, a bull was active in the site during the time when *Bicellonycha wickershamorum* was probably pupating in its igloo on the soil surface (C. Mollohan pers. comm. 2023), a life stage that is more vulnerable to trampling since it is immobile. However, 2023 surveys documented increased levels of the Southwest spring firefly. It is important to note that many of the historical sites for this species, including those at Las Cienegas NCA,

have been grazed for well over 100 years and fireflies still persist, although likely at greatly reduced levels and with more fragmented distributions. The statuses of numerous other populations—nearly a third of known localities—are unknown, as these sites have not been revisited in recent years.

Figure 9. Cattle grazing is a major threat to Southwest spring firefly habitats. Fireflies can be physically crushed by cattle, and habitat can be degraded, as depicted in this photo from Arizona (Sarina Jepsen/Xerces Society).

Mining

Mining poses a threat to the Southwest spring firefly throughout its range. Mining activities have the potential to compromise watershed integrity and can lead to the loss and degradation of firefly habitat through water and air pollution, water drawdowns, deposition of toxic materials into the environment, and physical removal and destruction of habitat. Mining is widespread across Arizona, with over 45,000 mining claims recorded on Arizona's public lands alone (Bureau of Land Management 2022). With extensive copper reserves throughout the state, Arizona is also the largest producer of mined copper nationwide, accounting for over 60% of copper produced since 1970 and 71% of domestic production in 2021 (Garcia et al. 2021; U.S. Geological Survey 2022). Copper occurs in a variety of minerals and is the most commonly mined metal in the state, with 17 of 27 active mines or advanced stage development

projects focused on copper extraction (Garcia et al. 2021). There are at least fifteen active mines within the range of *B. wickershamorum* in southern Arizona, all but three of which are dedicated to copper mining. Most copper deposits are mined in open pits, which generate enormous amounts of waste and tailings–more so than any other metal mining process–and are among the largest earth-moving efforts on the planet (Dudka & Adriano 1997). Half of the active mines within the range of *B. wickershamorum* are open pit mines. Many of these mines–including Morenci Mine, Sierrita Open Pit, Mission Complex, Silver Bell Mine, and Ray Operations–consistently fail to capture and control wastewater (Gestring 2019), resulting in significant water quality impacts that degrade the habitat and pose a threat to the continued persistence of the Southwest spring firefly.

Climate change

Climate change is widely considered one of the most serious threats to the environment, with particularly severe impacts on insects (Harvey et al. 2023). Climate change can take many forms on the landscape, including warming, extreme rainfall, temperature extremes, drought, fire, and shifts in seasonality (Harvey et al. 2023). Increased warming, extreme rainfall, drought, and fire may be particularly devastating for the Southwest spring firefly. Arizona is characterized by an arid climate with highly variable precipitation between wet (El Niño) and dry (La Niña) years, which typically occur every three or four years, respectively, and last for a year or two. There are two principal precipitation events each year: winter rainstorms and summer monsoons. Because of the annual variability that comes along with these different rain events, drought is a normal phenomenon for the region. However, the levels of drought that Arizona is currently experiencing are far beyond what was once considered normal. The state is now in its 26th year of long-term drought; annual precipitation has been less than average for nearly two-thirds of this period (Arizona State Climate Office 2022). It is likely that this ongoing drought is impacting the health of firefly populations that depend on freshwater resources. Future climate predictions are similarly sobering: global climate change is expected to increase the frequency and intensity of severe weather events such as droughts and create drier overall conditions. This, coupled with growing and competing water demands for agriculture, mining, and human consumption, threatens the survival of imperiled, moisture-dependent species such as the Southwest spring firefly and its molluscan prey.

At the other extreme of drought and wildfire, flooding is also a potential threat to the Southwest spring firefly. Heat waves and higher overall temperatures in the desert Southwest can lead to stronger atmospheric conditions for monsoon rainfall, resulting in more extreme monsoon events (Luong et al. 2017; Bhattacharya et al. 2022). These rainfall events tend to unleash large amounts of precipitation in very short periods of time, increasing the likelihood of flash flooding. This is exacerbated by local drought conditions, which result in dry soils that are incapable of absorbing moisture. Many of the localities where the Southwest spring firefly is found are flood-adapted, meaning they endure a natural cycle of flash floods during storm events. These include Empire Gulch at Las Cienega NCA, the TNC Canelo Preserve, and Aravaipa Canyon. The persistence of *B. wickershamorum* at these sites suggests that the firefly is also flood-adapted. However, one common feature of all these localities is the

endurance of streambank-stabilizing riparian flora (e.g., cottonwood, ash, and willow), which means that the Southwest spring firefly may be relying on this flora as refugia to repopulate sites after floods. If the stabilizing flora is swept away in extreme flood events, lost due to wildfires, killed by prolonged drought, or otherwise removed or degraded by humans or cattle, it is possible that these firefly populations would be lost as well (J. Cicero pers. comm. 2023). Even without the loss of this flora, extreme flash flood events may scour out firefly adults and immature life stages, effectively eliminating local populations.

Light pollution

Artificial light at night (also known as light pollution or ALAN) can interfere with the behavior of nocturnal fireflies that require darkness for their courtship displays, negatively affecting their reproductive success (Owens & Lewis 2018; Lewis et al. 2020). Because the Southwest spring firefly begins its courtship displays in early evening and it is largely present in remote areas removed from population centers, this threat was thought to pose less of a threat than it might be for other species that flash in full darkness or are located in urban areas (Fallon et al. 2023). However, ALAN was identified as an important metric in predicting the occurrence of *B. w. wickershamorum* (Shamgochian 2023), suggesting that this firefly is more likely to be found in areas with less light at night. Whether this is indicative of the ecology of the subspecies, or simply correlative in that suitable intact riparian habitat for the subspecies is more likely found further from light sources, is yet to be determined. That said, extremely bright lights at several locations could be interfering with reproductive success. For example, at the *B. w. piceum* type locality near the Lower Eagle Creek Pump House, water, is taken from the creek up to the Morenci Mine and the town of Clifton. The pump house infrastructure is illuminated by a bright light 24 hours a day. The light illuminates beyond the immediate area and into the canyon about a quarter mile in all directions, attracting thousands of flying insects at night (A. Walker pers. obs. 2021). Fireflies can still be observed a couple hundred yards upstream and downstream of this bright light (C. Mollohan pers. comm. 2022), but it may still be reducing the reproductive success of fireflies in the immediate vicinity.

Conservation Considerations:

The Southwest spring firefly is a rare habitat specialist found in approximately 30 localities in southern Arizona, southwest New Mexico, and Sonora, Mexico. This firefly is vulnerable to extinction because it is not known from very many localities, its population size is suspected to be small (rarely documented at more than 100 individuals in an evening), and the species faces numerous threats to its persistence including habitat loss due to groundwater depletion and other factors, cattle grazing, copper mining, light pollution, and climate change. At least one site—the type locality—has been extirpated due to overgrazing. Small population sizes make this species particularly vulnerable to site-disturbing activities and stochastic events including drought, fire, flooding, and climate change. Furthermore, there are no specific conservation measures in place to protect this species or the habitats upon which it relies. Conservation measures are needed on multiple fronts, from answering basic research questions to continued inventorying, long-term monitoring, and species-specific management actions.

Research needs

Despite recent work to assess the Southwest spring firefly's conservation status and compile a comprehensive database of known occurrence records, our understanding of this species' distribution, abundance, and population trends is poor, which hinders our ability to effectively conserve the species. Basic details regarding this firefly's life history, microhabitat requirements, and vulnerability to various threats are also largely unknown, further impeding conservation efforts. Recent (2021-2023) surveys by biologists and community scientists in southern Arizona and western New Mexico have broadened our understanding of this species' range in the Southwest. However, there remain critical data gaps that must be addressed to inform conservation efforts for the Southwest spring firefly, including:

Natural history

- Are the larvae snail specialists? If so, what species are important to them?
- What microhabitat features are important to adults? To the larvae?
- What habitat associations and factors affect the persistence of *B. wickershamorum* populations?

Species range and distribution

- What is the full extent of this species' range? Of the two subspecies' ranges?
- Does this species occur elsewhere in Arizona or New Mexico? How far does it range into Mexico?
- How can we refine existing species distribution models to better inform future survey efforts?
- Can we use occupancy modeling to determine the survey- and site-level variables that influence the detection and presence of fireflies at known sites?
- What is the dispersal capacity of this species?

Population size, trends, and abundance

- What are the global and local population sizes and trends for this species?
- What monitoring protocols and/or programs do we need to develop to answer this question?
- What is the most reliable index of abundance for this species?
- What is the geographic pattern of genetic differentiation?

Threats

- To what extent do known threats impact the species?
- What are the impacts of cattle grazing on immature life stages of this firefly?

- Can we model the impacts of drought and other climate change impacts on their populations? What about the impacts of increasing development, water drawdowns, and light pollution?

Conservation impacts

- How do different management activities impact adult firefly populations?
- How do different management activities impact immature firefly populations?
- How can we use this information to guide conservation and restoration activities?

Inventory and monitoring

In addition to addressing data gaps, continued surveys of marshy habitats are needed to determine the full extent of this species' range. This firefly may occur in appropriate habitat elsewhere in Arizona and New Mexico. As core sites for this species are discovered, land managers could work to establish long-term monitoring programs to better understand population size, dynamics, and trends. Trail cameras with the flash disabled were successfully used to detect Southwest spring firefly presence in 2023, with additional trials planned for 2024 (C. Mollohan pers. comm. 2024), and efforts to assess species abundance using density estimates from GoPro cameras are underway (Sarfati et al. 2020). Species distribution models have also been built for this species using Maxent, which can help inform survey efforts (Figure 10). Engaging volunteers who conduct wet/dry stream surveys or leveraging biologists who are already in the field for nocturnal survey work (such as for bats, owls, or amphibians) may help build extra capacity for inventory work.

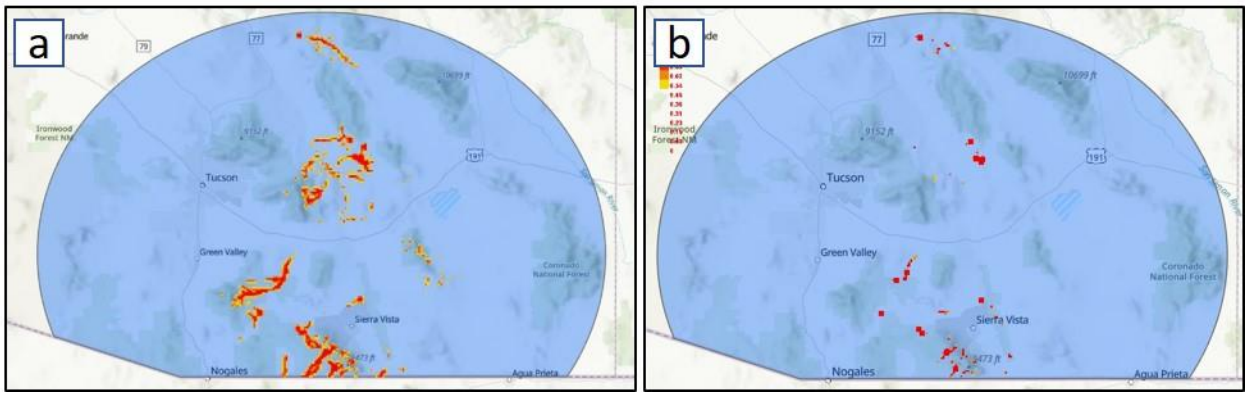

Figure 10. Southwest spring firefly species distribution maps: (a) results without incorporating wet/dry stream data, and (b) results with the wet/dry stream data. Red indicates greater probability of occurrence. Map outputs courtesy of Ben Shamgocian.

Management actions

The Southwest spring firefly is known to occur in approximately 30 sites in the US. Half of these are on private lands, while the remainder are in areas considered protected areas (Protected Planet 2023). Because the passive protection afforded by such designations are inadequate to protect the species from extinction, targeted protection and restoration of known habitats is crucial. Land managers can

play a key role in ensuring that known and potential habitat is not disturbed by development, cattle grazing, harmful pesticide applications, light pollution, or other management activities. Key actions that might help this firefly include:

- establishing and maintaining natural buffers around riparian habitats to maintain hydrology, protect groundwater, and reduce stormwater, pollution, and nutrient run-off
- rerouting roads and trails around sensitive habitat areas
- fencing off sensitive marsh and seep habitats and maintaining these fences to ensure cattle and recreationists are not finding ways through
- removing or modifying artificial light sources such as streetlights that may be negatively impacting populations (e.g., using motion sensors on existing lights, or replacing bright LEDs with dim red bulbs that don't interfere with firefly flash communication)
- protecting occupied sites from excessive or unnecessary pesticide application
- removing invasive plants, which may alter native plant communities and make them uninhabitable for fireflies
- assessing the impacts of proposed mines and other operations that may negatively impact this species' habitat and water resources
- setting up long-term monitoring programs at a subset of occupied sites to gather baseline population data to better understand population trends and conservation status of this species over time, as well as insights into the impacts that various management activities have on firefly health and abundance.

Survey Protocol:

Where:

- *B. w. wickershamorum*: Springs, seeps, wet pastures, wetlands in canyons, and riverbeds in the Madrean Archipelago
- *B. w. piceum*: Springs, seeps and wetlands in canyons and riverbeds of the Arizona/New Mexico Mountains ecoregion
- Studying maps of perennial water sources may be helpful for identifying potential survey sites

When:

- Surveys should begin just before dusk from early June through August, with a focus on June and July
- Air temperature should be at least 62° Fahrenheit (20° Celsius), although most observations have occurred at temperatures in the 70s and 80s (The Xerces Society 2023)
- Wind speed show be at Beaufort scale 2 or lower (0-7 mph) if adults are being targeted
- Moon phase should ideally be last quarter, waning crescent, new moon, or waxing crescent

How:

- Review survey protocols and print data sheets from the Firefly Atlas (www.fireflyatlas.org)
- If needed, secure the appropriate permits and/or site access permissions prior to conducting surveys
- Walk slowly along marshy habitats looking for single, greenish flashes
- Diagnostic morphologic features to look for include black elytra with yellow borders (except for *B. w. piceum*, which has dark borders) and acute back corners of the pronotum, which create a headshield that is shaped like a shovel head
- Consider recording observations using a voice memo app on a cell phone or a voice recorder, using the data sheet as a guide
- If permitted, net several individuals and take high quality dorsal and ventral photos, including a scale to show the length of the firefly. Photos will enable validation of species identification by a Firefly Atlas administrator or relevant species expert.
- Use artificial light sparingly to maintain night vision and avoid disturbing fireflies; a dim red headlamp or a flashlight wrapped in red cellophane can be used as needed to navigate the site
- Submit survey data and photographs to the Firefly Atlas (regardless of whether fireflies were observed)

Additional Resources:

Species-specific

- Petition to list the Southwest spring firefly as an endangered species under the US Endangered Species Act: https://xerces.org/publications/policyposition-statements/petition-for-protection-of-southwest-spring-firefly-under-us
- 'Wanted' poster: Have you seen this rare firefly? https://www.fireflyatlas.org/firefly-posters
- Guide to Fireflies of the Southwest, by Anna Walker https://www.fireflyatlas.org/learn/firefly-publications

Firefly conservation

- Conserving the Jewels of the Night: Firefly-Friendly Lighting Practices: https://xerces.org/publications/fact-sheets/firefly-friendly-lighting
- Conserving the Jewels of the Night: Guidelines for Protecting Fireflies in the United States and Canada: https://xerces.org/publications/guidelines/conserving-jewels-of-night
- State of the Fireflies of the United States and Canada: Distributions, Threats, and Conservation Recommendations: https://xerces.org/publications/scientific-reports/state-of-fireflies-of-united-states-and-canada

Acknowledgements:

We are grateful to Cheryl Mollohan, Jon Day, and Joe Cicero for sharing their knowledge of this species, as well as the many biologists and community scientists who have conducted surveys for the Southwest spring firefly and submitted their observations to the Firefly Atlas. Richard Joyce, Cheryl Mollohan, and Joe Cicero all reviewed and contributed to this fact sheet. We also thank Ben Shamgochian (Tufts

University) for sharing the results of his species distribution models and Jeff Simms (AZ BLM) and Brian Hickerson (AZ Dept of Fish and Game) for suggesting potential firefly survey sites.

Recommended citation:

Fallon, C. and A. Walker. 2024. Firefly species fact sheet: Southwest spring firefly, *Bicellonycha wickershamorum*. The Xerces Society for Invertebrate Conservation and New Mexico BioPark Society. 24 pp. Available at: https://www.fireflyatlas.org/threatened-species-fact-sheets/.

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