Before the Secretary of the Interior

Petition to list

the Southwest spring firefly

***Bicellonycha wickershamorum* Cicero, 1982**

as an endangered species

under the U.S. Endangered Species Act

Bicellonycha wickershamorum from Empire Gulch, AZ (photo: Scott Cylwik).

Submitted by

The Xerces Society for Invertebrate Conservation and

The New Mexico BioPark Society

Prepared by Candace Fallon, Anna Walker, and Sharon Selvaggio

March 30, 2023

NOTICE OF PETITION

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PETITIONERS

The **Xerces Society for Invertebrate Conservation** is a nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. For fifty years, the Society has been at the forefront of invertebrate protection worldwide, harnessing the knowledge of scientists and the enthusiasm of citizens to implement conservation programs. Xerces is a leader in firefly conservation, working with partners to better understand the distributions of vulnerable species through a Firefly Atlas, assess the extinction risk of North American species, identify and implement priority conservation actions, and engage land managers, policymakers, researchers, and the public in their protection.

The **New Mexico BioPark Society** is the nonprofit support organization for the ABQ BioPark, a zoo, botanic garden, and aquarium in Albuquerque, New Mexico. It also hosts the Center for Species Survival New Mexico (CSS New Mexico), which supports strategic species conservation through a partnership with the International Union for Conservation of Nature (IUCN) Species Survival Commission. From local to global, the CSS New Mexico utilizes the IUCN Red List to produce critical baseline data to guide conservation planning and action for invertebrates, plants, and freshwater fishes.

The Honorable Deb Haaland
U.S. Department of the Interior
1849 C Street NW
Washington D.C., 20240

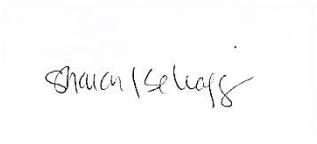
Dear Secretary Haaland,

Pursuant to Section 4(b) of the Endangered Species Act ("ESA"), 16 U.S.C. § 1533(b); Section 553(e) of the Administrative Procedure Act, 5 U.S.C. § 553(e); and 50 C.F.R. § 424.14(a), the Xerces Society for Invertebrate Conservation and New Mexico BioPark Society hereby petition the Secretary of the Interior, through the United States Fish and Wildlife Service ("FWS," "Service"), to protect the Southwest spring firefly (*Bicellonycha wickershamorum* Cicero, 1982) under the ESA as an endangered species. Petitioners also request that critical habitat be designated for the firefly concurrently with the listing, pursuant to 16 U.S.C. § 1533(a)(3)(A) and 50 C.F.R. § 424.12.

Fireflies are iconic insects that perform important functions in ecosystems and are awe-inspiring components of our natural and cultural heritage. The Southwest spring firefly—a species found only in southern Arizona and Sonora, Mexico—is threatened by wetland and riparian degradation, hydrological alterations, mining, climate change, recreation, and artificial light at night. Existing regulatory mechanisms are inadequate to protect this species from extinction.

We are aware that this petition sets in motion a specific process placing definite response requirements on the U.S. Fish and Wildlife Service and very specific time constraints upon those responses. 16 U.S.C. § 1533(b). We will therefore expect a finding by the Service within 90 days regarding whether our petition contains substantial information to warrant a full status review.

Sincerely,



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Executive summary

The Southwest spring firefly, *Bicellonycha wickershamorum*, is a rare and threatened species first described by Joseph M. Cicero in 1982. Occurring in southern Arizona and Sonora, Mexico, this species has been documented from just over two dozen localities. There are two subspecies: *B. w. wickershamorum*, which is more widespread, and *B. w. piceum*, which is known only from two locations in Arizona.

This firefly is a habitat specialist associated with permanent springs and streams in the Madrean Archipelago and Arizona/New Mexico Mountains ecoregions. Adults of both sexes flash and are active during the summer, typically from early June through late July, although August occurrences have also been reported. Because this species is nocturnal and associated with wetland and riparian habitats, it is threatened by drought, riparian corridor severance, habitat degradation and direct trampling due to cattle, intrusive recreation, light pollution, and hydrological modification for farming, ranching, and copper mining. The larval stage may be particularly sensitive to environmental change due to restricted dispersal capabilities and vulnerability to desiccation. There are no sufficient regulatory mechanisms in place to protect this species. With many imperiled wildlife species, including fish, birds, mammals, and even freshwater mussels, Arizona Fish and Game Department (AZFGD) has management authority, expertise, and staff capacity to work to conserve species and avoid the need for ESA listing. However, AZFGD lacks management authority over all insects, and as such they are unable to address the conservation needs of the Southwest spring firefly, representing a major gap in regulatory mechanisms that leaves this animal vulnerable. While the Southwest spring firefly has been recorded from federal lands and protected areas, no species-specific management plans currently exist. The passive protection that may be allotted from these managed areas, such as the Las Cienegas National Conservation Area, is insubstantial to prevent the species from going extinct, especially in light of new and emerging threats such as long term drought, increased use and intrusion of off-road vehicles, and increasing light pollution from population expansion.

The Southwest spring firefly is threatened by four of the ESA listing factors: (1) modification or curtailment of habitat or range, (3) disease or predation, (4) inadequacy of existing regulatory mechanisms, and (5) other natural or manmade factors affecting this firefly's continued existence. ESA protection, coupled with further research and conservation actions, is critically needed to protect this species from extinction. Accordingly, we hereby request that the Service list the Southwest spring firefly (*Bicellonycha wickershamorum*) as an endangered species. Once listed, we recommend that the Service facilitate activities that promote the conservation of the species by expediting and streamlining the permitting process; such activities include: scientific research and monitoring, community science monitoring, and limited collection for research and identification purposes.

Introduction

Fireflies are highly charismatic beetles revered among the public with significant cultural (Bascom 1979; Schuettler 2007; Faust 2017; Lewis et al. 2020), biological (Woods Jr. et al. 2007; Bauer et al. 2013; Oba & Schultz 2022), and economic importance (Bauer et al. 2013; Lewis 2016; Lewis et al. 2020). Fireflies are often associated with summer nights (Lewis 2016), and viewing fireflies is a pastime shared around the world (Laurent & Ono 1999; Faust 2010; Vance & Kuri 2017). Recreational viewing of fireflies is growing significantly globally, bringing fireflies even further into the public's attention (Faust 2010; Vance & Kuri 2017; Lewis et al. 2021).

Fireflies belong to the order Coleoptera and can be found on every continent except Antarctica (Lewis 2016). Globally, there are over 2,000 species of fireflies (Coleoptera: Lampyridae), with over 170 of these species residing in North America, classified into 4-5 subfamilies and 20 genera (Stanger-Hall et al. 2007; Faust 2017; Lloyd 2018; Heckscher 2021; Ferreira et al. 2022). Only some genera exhibit the characteristic flashing as adults, but larvae of all known species produce light (Faust 2017). Firefly larvae use bioluminescence to warn predators of unpalatable steroids they contain (Underwood et al. 1997), while the adults use bioluminescence both as a form of mate communication and predator avoidance (Faust 2017).

Fireflies, like many insect groups, have undergone population declines globally in the past few decades (Khoo et al. 2009; Wong & Yeap 2012; Lewis 2016; Lewis et al. 2020), prompting firefly researchers at the 2010 International Firefly Symposium in Selangor, Malaysia, to sign the Selangor Declaration, a document that calls for urgent action to conserve fireflies (Fireflyers International Network 2014). Causes of global firefly decline are thought to include loss of habitat (De Cock 2009; Lewis et al. 2020; Gardiner & Didham 2020), water pollution (Lewis et al. 2020), pesticides (Lewis et al. 2020), commercial harvesting (Bauer et al. 2013; Lewis et al. 2020), and light pollution (Owens & Lewis 2018; Thancharoen & Masoh 2019; Lewis et al. 2020; Mbugua et al. 2020), among others.

Recent assessments of North American fireflies have revealed that up to a third of assessed U.S. species may be at risk of extinction, and approximately half of the assessed species are so poorly understood that they have been classified as data deficient (Fallon et al. 2021). The Southwest spring firefly (*Bicellonycha wickershamorum*) is one of these at-risk species. Assessed as Vulnerable by the IUCN Red List of Threatened Species (Fallon & Cicero 2021c), it is the only representative of its genus in the U.S. (Cicero 1982). It is also one of only two flashing firefly species known to occur in Arizona. The Southwest spring firefly is a nocturnal species associated with permanent streams and springs in desert montane regions of southern Arizona and Sonora, Mexico. There are two described subspecies: *B. w. piceum*, which occurs in the Arizona/New Mexico Mountains ecoregion, and *B. w. wickershamorum*, which occurs within the Madrean Archipelago.

The Southwest spring firefly is threatened by habitat loss and degradation due to groundwater depletion and modification of waterways for agriculture, livestock grazing, and mining. 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 ephemeral 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 in fact have already led to the destruction of the *B. w. wickershamorum* type locality.

Conservation status and listing history

The Southwest spring firefly (*Bicellonycha wickershamorum*) has no legal protection under the U.S. Endangered Species Act or any state endangered species statutes. To our knowledge, it has never been petitioned for listing under the Endangered Species Act and it has no federal status. NatureServe (Fallon & Cicero 2023a) ranks this species as G2 (Imperiled) throughout its range. It has not been ranked at the national or state level (Fallon & Cicero 2023a). The International Union for Conservation of Nature (IUCN) ranks the species as Vulnerable on its Red List of Threatened Species (Fallon & Cicero 2021a; Fallon et al. 2021). There are two known subspecies, both of which are imperiled: *B. w. piceum* is categorized as Endangered by the IUCN Red List, while the nominate subspecies *B. w. wickershamorum* is categorized as Vulnerable (Fallon & Cicero 2021b, 2021c). NatureServe (Fallon & Cicero 2023b, 2023c) ranks the subspecies *B. w. piceum* as G2G3T1T2 (Critically Imperiled) and the subspecies *B. w. wickershamorum* as G2G3T2T3 (Imperiled).

Natural history

Taxonomy

The Southwest spring firefly, *Bicellonycha wickershamorum*, is a beetle (Order: Coleoptera) in the family Lampyridae. It was formally described by Joseph Cicero in 1982 and is considered a valid species with two described subspecies (Cicero 1982; Integrated Taxonomic Information System 2023; Table 1). The nominate subspecies carries the same common name as the species, while the *piceum* subspecies is referred to as the Gila Southwest spring firefly (Fallon & Cicero 2021b, 2021c).

Table 1. Taxonomy of Bicellonycha wickershamorum

Taxonomic Level	Taxonomic Designation
Order	Coleoptera
Superfamily	Elateroidea
Family	Lampyridae
Subfamily	Photurinae
Tribe	Photurini
Genus	*Bicellonycha*
Species	*Bicellonycha wickershamorum*
Subspecies	*Bicellonycha wickershamorum piceum*
	Bicellonycha wickershamorum

Description

The Southwest spring firefly is the only representative of its genus in the United States, and one of only two flashing species known to occur in Arizona (the other being the Southwest synchronous firefly,

Photinus knulli, which is sympatric in range [and known to co-occur at two sites] but typically active later in the year, morphologically dissimilar, and belonging to a different subfamily, Photininae). Diagnostic characteristics of adult Southwest spring fireflies are 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). In contrast, *P. knulli* can be distinguished by the concolorous gray background color of its similarly yellow-margined elytra; *P. knulli* also has a pronotal maculation similar to that of *B. wickershamorum*, but its hind corners are only weakly acute (J. Cicero pers. comm. 2022). Departing in appearance from the nominate subspecies, the Gila Southwest spring firefly, *B. w. piceum*, is cast with a melanism, lacking the yellow striping and appearing brown-black (piceous) in color (Cicero 1982). *Bicellonycha* can be distinguished from other Photurinae fireflies (e.g., *Photuris*) by the tarsal claws, which are apically bifid (cleft) in males and entire in females (Cicero 1982).

Figure 1. Bicellonycha wickershamorum from a newly discovered site in Las Cienegas NCA (right). Grid cells on paper are 0.25 x 0.25 inches (6.35 x 6.35 mm). (Photo: Candace Fallon/Xerces Society).

Distribution

The Southwest spring firefly occurs in the mountains, foothills, and canyons of southeastern Arizona, USA, and Sonora, Mexico (Cicero 1982; J. Cicero pers. comm. 2022; Figure 2). In Arizona, it has been documented from just seven counties: Cochise, Graham, Greenlee, Pima, Pinal, Santa Cruz, and Yavapai.

In Mexico, it has been reported from a single site at Cajón Bonito in the Peloncillo Mountains of Sonora (J. Cicero pers. comm. 2022). The nominate subspecies, *B. w. wickershamorum*, is more widespread than *B. w. piceum*, and can be found in several sky island mountain ranges within the Madrean Archipelago ecoregion, including the Huachuca-Patagonia complex and the Galiuro and Santa Rita Mountains, as well as the surrounding canyons and foothills. Historically, populations of this subspecies have been observed in Bear Canyon, Scotia Canyon, and Canelo Hills, as well as sites near Fairbank and Sonoita (Cicero 1982; C. Mollohan pers. comm. 2020; BugGuide 2023). Until 2022, the *piceum* subspecies appeared to be restricted to a single location in the Arizona/New Mexico Mountains ecoregion outside the town of Morenci, AZ; however, a historic (1981) Yavapai County, AZ, specimen in the University of Arizona Insect Collection that was examined in January 2023 has been confirmed as *B. w. piceum*, greatly expanding this subspecies' known range (by approximately 160 miles) within the Arizona/New Mexico Mountains ecoregion (J. Cicero pers. comm. 2023). Given its distribution, it is possible that the Southwest spring firefly occurs in the sky island mountain ranges in the extreme southwestern tip of New Mexico or the Gila Mountains just east of the Arizona border.

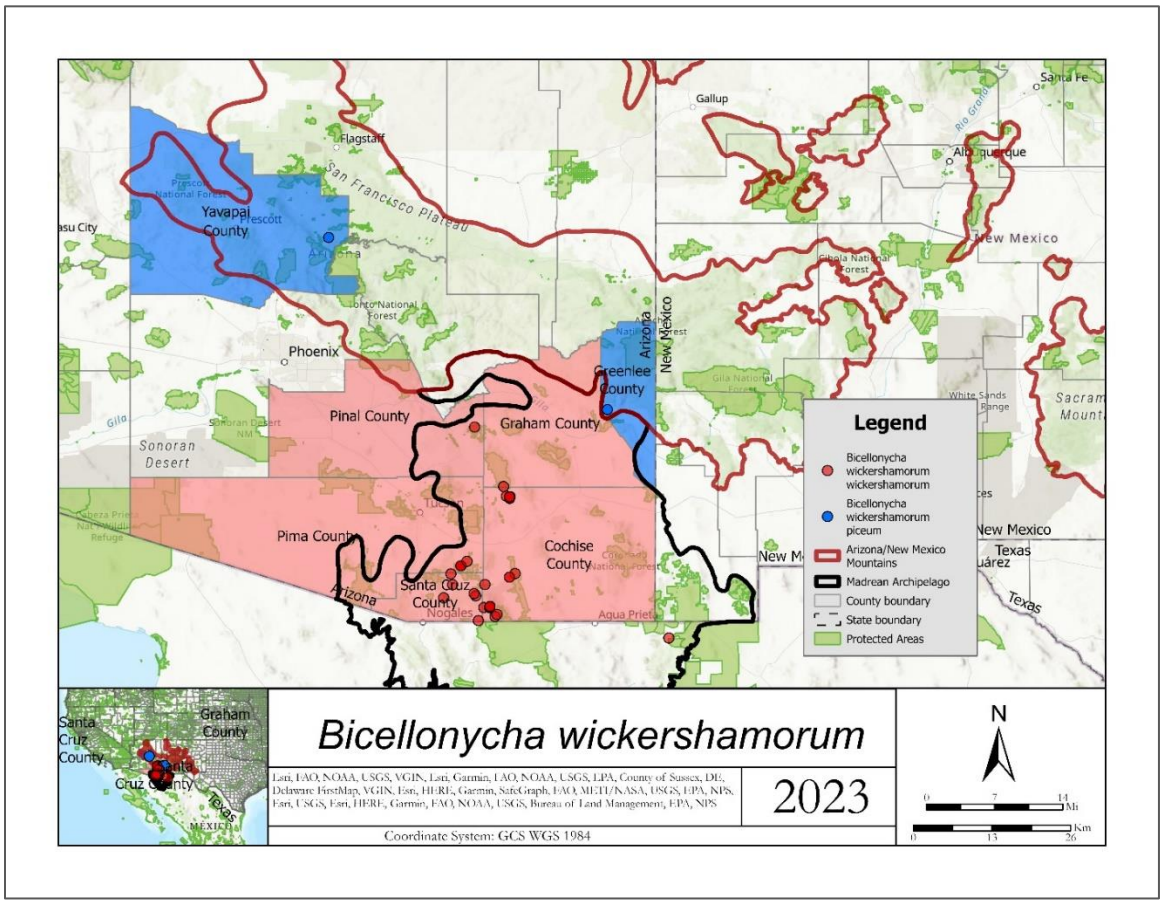

Figure 2. Distribution of Bicellonycha wickershamorum in Arizona and Mexico. Highlighted polygons indicate US counties where the species has been detected. These are color coded to illustrate the ranges of the two subspecies, which are not known to overlap. Note that records with vague locality information have not been added to the map, but do occur within the highlighted counties.

Land ownership and management

The Southwest spring firefly has been documented from a total of 27 sites in Arizona, the majority of which (23 sites) occur on federal and private lands (Table 2). Ownership of the remaining 4 sites remains uncertain, primarily due to vague locality descriptions that make it difficult to determine the exact location of records.

Table 2: Land managers of known populations of Bicellonycha wickershamorum in Arizona.

Manager type	Land manager	No. of populations
Federal	Coronado National Forest (U.S. Forest Service)	5
Federal	Gila BLM District (Bureau of Land Management)	7
Private	The Nature Conservancy	6
	Canelo Hills	*(1)*
	Muleshoe Ranch CMA	*(4)*
	Patagonia-Sonoita Creek	*(1)*
Private	Unknown	5
Unknown	Unknown (vague locality descriptions)	4
	Total number of populations	**27**

Population size, status, and trends

Population size, trends, and abundance data are not available for this species. 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; Table 3). Las Cienegas 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 (Table 3). Reliable methods of measuring population abundance of fireflies have not yet been developed, although work is underway to address this.

Survey efforts for this species over time have been inconsistent. Research and surveys conducted by Dr. Cicero in the early 1980s (which led to formal description of the species) resulted in a number of newly documented populations, but further survey efforts stalled until the early 2020s, when Tucson-based biologists, including Cheryl Mollohan and Ron Day, began revisiting some of Cicero's historic sites and searching for new populations. Xerces Society biologists joined the search in 2022 as part of a newly launched Firefly Atlas initiative (www.fireflyatlas.org). These combined efforts in recent years have led to the discovery of approximately 10 newly reported sites, suggesting that increased survey efforts may yield additional populations. However, given the species' close ties to permanent water sources with ephemeral features such as marshes, its distribution likely remains extremely habitat-limited.

At least one site—the species' type locality at the Wickershamorum house—is likely extirpated due to habitat degradation by cattle (Fallon & Cicero 2021a). This and other sites near the Babocomari River in the San Pedro River Basin are located within an area where groundwater levels have dropped substantially (Schmerge et al. 2009); if cattle contributed to the loss of the type locality, it is possible

Table 3: Known B. wickershamorum populations in Arizona, their status, and number of individuals last observed. A separate file with locality data will be provided to the Service at the time of submission.

Site name	County	Basin	Status	No. individuals last observed (date)
B. w. piceum				
Lower Eagle Creek	Greenlee	Upper Gila River	Extant	7 (2022)
Sycamore Creek	Yavapai	Verde	Unknown (historic)	Unknown (1981)
B. w. wickershamorum				
Babocomari Canyon	Cochise	San Pedro River	Unknown (historic)	Unknown (1969)
Bass Canyon	Cochise	San Pedro River	Extant	20 (2021)
Bear Canyon	Cochise	San Pedro River	Extant	Unknown (2009)
Canelo Hills	Cochise	San Pedro River	Extant	<12 (2022)
Double R Confluence	Cochise	San Pedro River	Extant	10-15 (2021)
Hookers Hot Springs	Cochise	San Pedro River	Extant	Unknown (2021)
Mint Springs	Cochise	San Pedro River	Extant	50+ (2021)
San Pedro River	Cochise	San Pedro River	Unknown (historic)	Unknown (1973)
Wickershamorum house	Cochise	San Pedro River	Likely extirpated	Hundreds (1980)
Wildcat Canyon	Cochise	San Pedro River	Extant	10-15 (2021)
Parker Canyon	Cochise	Santa Cruz River	Unknown (historic)	Few (1977)
Scotia Canyon	Cochise	Santa Cruz River	Extant	>50 (2021)
Sunnyside Canyon	Cochise	Santa Cruz River	Unknown (historic)	Few (1978)
Swamp Canyon	Graham	San Pedro River	Extant	2-4 (2021)
Cienega Creek	Pima	Santa Cruz River	Unknown (historic)	Unknown (1993)
Empire Gulch	Pima	Santa Cruz River	Extant, potentially declining	10 (2022)
Gardner Canyon	Pima	Santa Cruz River	Extant	Unknown (2021)
Las Cienegas NCA	Pima	Santa Cruz River	Extant	100+ (2022)
Aravaipa Canyon	Pinal	San Pedro River	Extant	12 (2022)
Canelo	Santa Cruz	San Pedro River	Unknown (historic)	Few (1954)
Monkey Spring	Santa Cruz	Santa Cruz River	Unknown (historic)	Unknown (1974)
Patagonia-Sonoita Creek	Santa Cruz	Santa Cruz River	Extant	Unknown (2022)
Sonoita	Santa Cruz	Santa Cruz River	Unknown (historic)	Unknown (2015)

that lower groundwater levels have contributed to a lack of recolonization from nearby populations. Cattle may be negatively impacting other sites as well. Anecdotal evidence over three years of surveys at the Empire Gulch site 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). 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 on the soil surface (C. Mollohan pers. comm. 2023), a life stage that is more vulnerable to trampling since it is immobile. The statuses of

numerous other populations—nearly a third of known localities—are unknown, as these sites have not been revisited in recent years (Table 3).

Life cycle and behavior

The Southwest spring firefly breeding season lasts from early June to late July, with a few lingering individuals sometimes recorded into mid-August (Figure 3); 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). The *piceum* subspecies has only been observed in June, while *B. w. wickershamorum* is active longer into the summer season (Cicero 1982; C. Mollohan pers. comm. 2022).

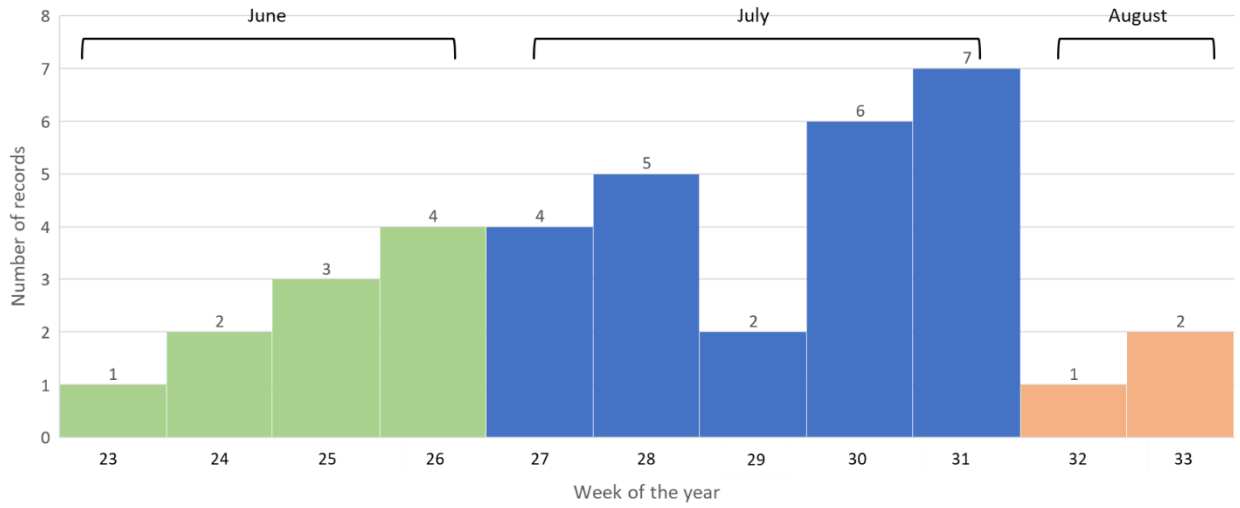

Figure 3. Bicellonycha wickershamorum records by week of the year, illustrating a peak in activity in late July, concurrent with the typical onset of monsoon rains in the area. Records span June 6 through August 12. Note that a single record from February 16, 1969, has been excluded from this figure for sizing purposes.

Both males and females are winged and capable of flight. Flashing courtship displays begin at dusk and continue into the night as adult males fly and flash along the stream in search of females. At dusk, males fly close to vegetation along the ground and may be able to find females directly, without seeing their response flashes. During this early, low position, males will entrain themselves in two single-file lines corresponding to linear stream banks, stall their forward motion when they come to a clump of vegetation, and swing their lights into it with a longer streak than when moving between vegetation clumps (J. Cicero, pers. comm. 2022). Then each male moves on to the next clump while the aft male swings into the same clump. When a female emerges and crawls up a stem, a male will spot her and dart straight to her. 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). Flashes appear green in color. Adults can be observed flying and flashing well away from streams, possibly dispersing to other nearby areas.

Adults of this species have not been observed feeding; however, adult females of photurine fireflies, including *Photuris* and other North American *Bicellonycha*, are specialized predators of other fireflies (Lloyd 1997 p. 187), and so it is possible that *B. wickershamorum* females share this behavior. Larvae, which are predaceous and active at night along gentle stream banks, have been observed preying on snails (J. Cicero pers. comm. 2020). Late instar larvae construct subterranean mud chambers along slow-running stream banks where they undergo pupation (Cicero 1982). Their annual abundance and activity period are related to progression of the eggs and larvae during the summer monsoons (following the adult flight period) and the winter and spring rains of the following year, when the larvae are active and searching for snails. 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). In addition, they are also incapable of dispersing to more suitable habitats, except during flood events that may move them downstream.

Habitat

The Southwest spring firefly is known from wetland and riparian areas within montane desert habitats at elevations ranging from 2,780-6,100 ft. above sea level (Cicero 1982; C. Mollohan pers. comm. 2021, 2023). This includes springs, pools, marshes, and other riparian areas in oak and pine woodlands. Each subspecies occurs in a distinct ecoregion, with all populations of *B. w. wickershamorum* located within the Madrean Archipelago (also known as the Southwest Sky Islands) and both populations of *B. w. piceum* found in the Arizona/New Mexico Mountains.

The Southwest 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. They are considered global biodiversity hotspots due to their unique and diverse assemblages of plants and animals which are often found nowhere else (Sky Island Alliance 2023). Within this ecoregion, *B. wickershamorum* typically occurs in marshy areas and other ephemeral 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; Figure 4a). 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, boasting more species of birds and mammals than any other place in the Southwest (Bell et al. 1999). At the Gila Southwest firefly type locality, the species 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 4b). It has also been observed in scattered locations upstream from the seep area for approximately 91 m (100 yards) (C. Mollohan pers. comm. 2022).

Figure 4. The Southwest spring firefly is associated with marshes, seeps, and other ephemeral 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) Seepage habitat at the B. w. piceum type locality near Morenci, AZ (photo: Anna Walker).

Current and potential threats – An assessment of factors

The following factors pose substantial threats to the survival of the Southwest spring firefly: 1) the present or threatened destruction, modification, or curtailment of its habitat or range, 4) the inadequacy of existing regulatory mechanisms, and 5) other natural or manmade factors affecting its continued existence. In addition, factor 3) disease or predation, may be amplified by these factors, exacerbating the existing threats and putting the Southwest spring firefly at further risk of extinction.

Factor 1: Present or threatened destruction, modification, or curtailment of habitat or range

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.

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). Prior to these drastic changes, Arizona had a river system which flowed year-round and spanned the state (Fretwell et al. 1996). 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.

Of the fourteen river basins in Arizona, the Southwest spring firefly is known to occur in four of them: the San Pedro River, Santa Cruz River, Upper Gila River, and Verde Basins. In the following sections, we examine the state of each of these basins as it relates to this firefly, with a focus on relevant sub-basins and, at times, individual watersheds in which the species is found.

Groundwater depletion in the San Pedro River Basin: Upper & Lower San Pedro sub-basins

The San Pedro River flows north from the Mexican State of Sonora into southeastern Arizona, draining 13,500 km^2 before joining the Gila River (Whittier & Maddock 2006). The San Pedro River is divided into two main basins, the Upper and Lower San Pedro sub-basins, which are separated by a geological constriction called "The Narrows," just north of Benson. As one of the last undammed rivers in the desert Southwest, the San Pedro provides refuge for aquatic and terrestrial life and is an important corridor for migratory birds.

Both the Upper and Lower San Pedro sub-basins provide important habitat for the Southwest spring firefly. There are seven known occurrence localities for the Southwest spring firefly in the Lower San Pedro sub-basin (Hot Springs Canyon, Lower Aravaipa Creek, and Redfield Canyon-San Pedro River Watersheds), and five in the Upper San Pedro sub-basin (Babocomari River, Clifford Wash-San Pedro River, and Headwaters Las Nutrias Watersheds) (Figure 5). Groundwater use in the Upper San Pedro sub-basin, and to a lesser extent in the Lower San Pedro sub-basin, exceeds the aquifer recharge rates, which has resulted in fewer perennial reaches of water and has lowered the water table in many areas (Arias 2000; Haney 2005; Cordova et al. 2015). As this firefly seems to be dependent on habitats with perennial water sources, localized drawdown of groundwater may result in further loss of habitat.

The primary source of water in Cochise County, where most of the Upper San Pedro sub-basin is located, is groundwater. Groundwater pumping to meet the needs of agriculture, mining, and municipal use, has increased steadily over the last 100 years, and now greatly exceeds the natural recharge rates of the aquifers (Arias 2000). Consequently, the water table is lower and the average baseflow in the San Pedro River at the Charleston and Redington gages has been reduced by at least 50% since 1968 (Cordova et al. 2015). There are also fewer perennial stretches of water than there used to be, and the ephemeral reaches dry out earlier in the year, and stay dry for longer periods of time (Arias 2000).

While agricultural use and mining remain responsible for most of the groundwater use in the basin (Arias 2000), urban development is increasingly problematic, especially in the Sierra Vista sub-area, which includes Fort Huachuca. Fort Huachuca is already one of the single largest water users in the Upper San Pedro sub-basin (Harris et al. 2001), and if the Fort continues to grow as planned, a U.S. Army Commissioned report found that increased groundwater use would further diminish base flows along

stretches of the San Pedro and Babocomari Rivers (GeoSystems Analysis, Inc. 2010). While Sierra Vista and Fort Huachuca have made attempts to reach a sustainable level of water use by 2011, so far, they have been unable to meet this goal (Gungle et al. 2016).

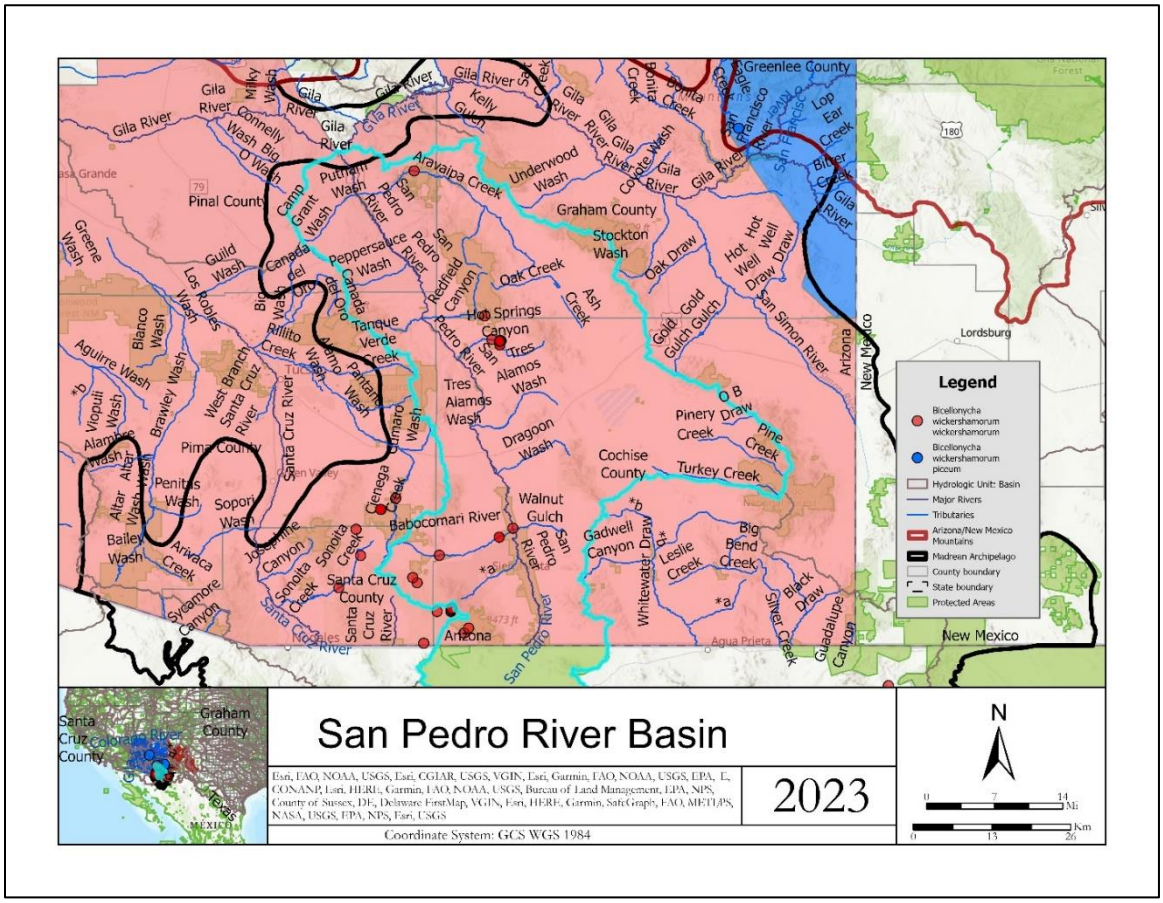

Figure 5: B. wickershamorum occurrences in the San Pedro River Basin, AZ (basin is highlighted in turquoise).

There are two historical occurrences of the Southwest Spring Firefly along the Babocomari River that will likely be directly impacted by continuing increases in water use by Sierra Vista and Fort Huachuca. In fact, hydrographs from most wells in this area, downstream of Huachuca City along the Babocomari river, have shown long term declines in groundwater levels (Schmerge et al. 2009). The only recent records of the firefly in this sub-basin comes from Turkey Creek, where water levels have actually increased in recent years (Schmerge et al. 2009).

Urban development in other areas of the sub-basin is a growing threat to groundwater resources. For example, a 28,000-home, 12,167 acre development called Villages at Vigneto has been proposed southwest of Benson (Porier 2021). If built, the development would support about 70,000 residents, and the demands on groundwater resources would grow from 800 acre-feet per year to an estimated 8,427 acre-feet per year (Sierra Club 2019). In 2017, the U.S. Fish and Wildlife Service and the Army Corps of Engineers decided that issuing a Clean Water Act permit to the project would not harm threatened or endangered species or their critical habitat in the watershed (U.S. Fish and Wildlife Service 2021), and

the developer, El Dorado Holdings LLC, was initially issued permits to proceed with the plans. However, in 2021, the U.S. Fish and Wildlife Service conducted an internal review of the 2017 decision and found that its decision to greenlight the project was the result of political interference. The Service thus revoked its concurrence. In response, the Army Corp of Engineers suspended the Section 404 Clean Water Act permit that had been in place (Porier 2021). Section 404 of the Clean Water Act regulates the deposition of dredge or fill material into the waters of the United States, including wetlands (U.S. EPA 2022). The permit would have allowed the developers to discharge fill material into 51 acres of desert washes (Dept of the Army, Corps of Engineers 2019). To compensate, the developer proposed measures to enhance 144 acres along the west bank of the river (Westland Resources, Inc 2005). An environmental impact assessment on the increased groundwater use by the development has not been carried out, but modeling shows that the pumping would drawdown the aquifer below the San Pedro River (Prucha 2016).

Similarly, in the Lower San Pedro sub-basin, groundwater pumping primarily for mining and agriculture has lowered the water table and decreased base flows in the river (Whittier & Maddock 2006), though to a lesser extent than in the Upper San Pedro sub-basin. At least 50 river miles which once had perennial flow have been lost in recent years (Haney 2005). This part of the sub-basin has been the focus of major private, federal, state and corporate conservation efforts for decades, but additional groundwater pumping for future development projects would likely lead to further losses of perennial stretches of river and degradation of potential firefly habitat. The firefly occurrences in this sub-basin are known from the Aravaipa and Redington sub-areas, where for the time being, groundwater use does not exceed the natural recharge of the aquifers (The Nature Conservancy 2008). However, future development or groundwater pumping could lead to water drawdowns similar to those seen in the Upper San Pedro sub-basin.

Groundwater depletion in the Santa Cruz River Basin: Upper Santa Cruz and Rillito sub-basins

The Santa Cruz River Basin drains the west side of the Huachuca Mountains and the east side of the Patagonia Mountains in Arizona, before flowing south into northern Mexico. Once in Mexico, the river eventually turns west, then north, flowing back up into Arizona near Nogales. It then runs north through Tucson and joins the Gila River southwest of Phoenix (Condes de la Torre 1970). Of the six sub-basins of the Santa Cruz River Basin, the Southwest spring firefly is found only in the upper reaches of the westernmost sub-basins: the Upper Santa Cruz and Rillito (Figure 6). There are eight known occurrences of the firefly in the Upper Santa Cruz sub-basin, seven of which are in the headwaters of the river, in the San Rafael Valley-Santa Cruz River Watershed of the Huachuca Mountains, and one of which is along Sonoita Creek, a tributary of the Santa Cruz, in its namesake watershed. The Rillito sub-basin, which drains a 2,419 km^2 area from the Santa Catalina, Rincon, Empire and Whetstone Mountains before joining the Santa Cruz River near Tucson (Condes de la Torre 1970), has three known occurrences of the Southwest spring firefly (all within the Cienega Creek Watershed). Most reaches of the Santa Cruz River and its tributaries are ephemeral and are dry for long periods (Uhlman et al. 2008), which may be why the Southwest spring firefly is restricted to the upper reaches of the watershed, or other places with perennial water, such as Sonoita Creek near Patagonia and Pantano Wash near Vail, where groundwater is pushed to the surface.

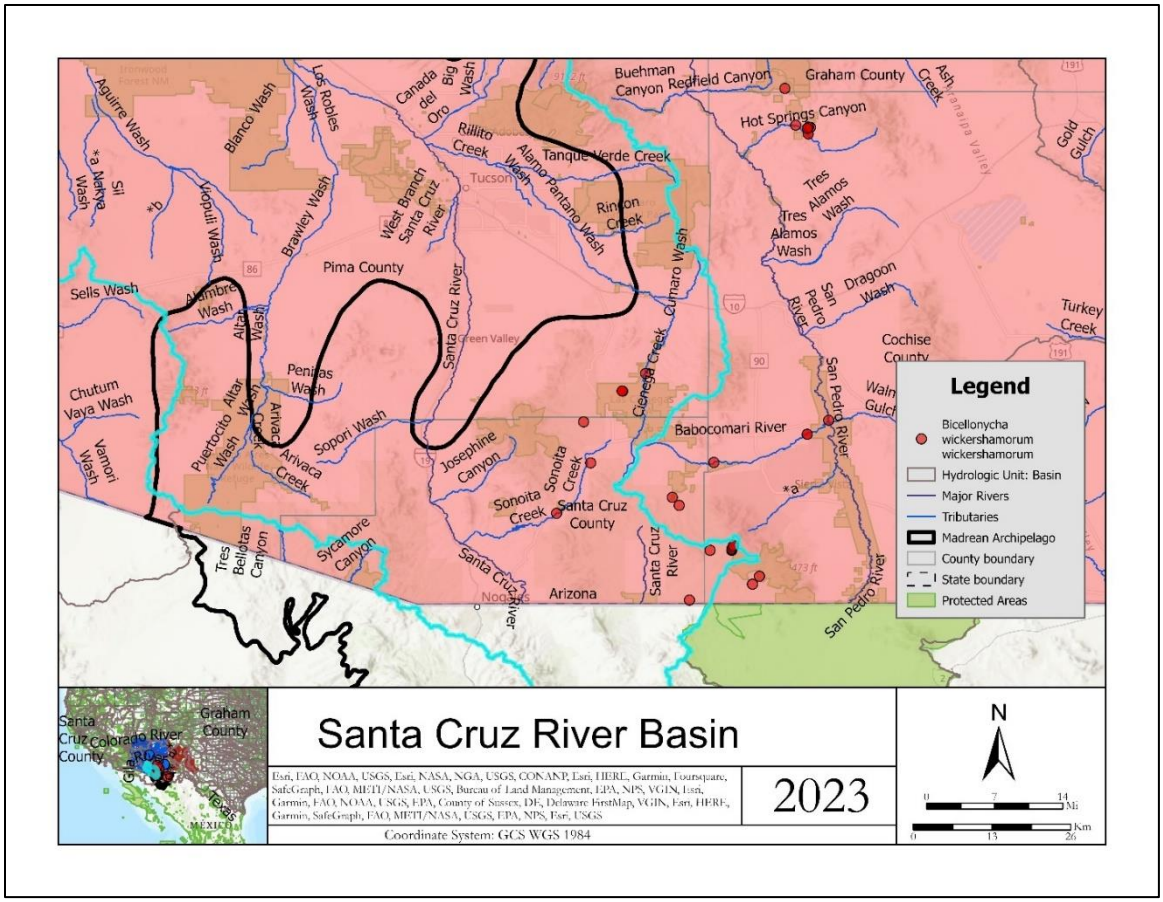

Figure 6. B. wickershamorum occurrences in the Santa Cruz River Basin, AZ (basin is highlighted in turquoise).

The majority of water needs in the Santa Cruz River Basin are fulfilled by groundwater (Water Resource Center at the University of Arizona 2022). Prior to the 1940s, discharge rates were equal to recharge rates from natural sources (Uhlman et al. 2008). Since then, however, growing water demands due to rapid development of cities like Tucson has resulted in overdraft from the basin's aquifers. Groundwater resources in the region are now maintained via the Central Arizona Project (CAP), which pulls water from the Colorado River. A portion of this water is used to recharge the Santa Cruz River Basin's aquifers (Uhlman et al. 2008). Despite this, some areas are still seeing groundwater levels fall, and due to a Colorado River shortage, which was declared in 2022, future CAP water reductions are likely (Water Resource Center at the University of Arizona 2022).

Water use in the Upper Gila River Basin: Upper Gila-San Carlos Reservoir sub-basin

The type locality for the Gila Southwest spring firefly (*B. w. piceum*) is located along the Eagle Creek tributary to the Gila River in the Lower Eagle Creek Watershed of the Upper Gila-San Carlos Reservoir sub-basin (Figure 7). The Gila River flows from the Gila Mountains of western New Mexico to join the Colorado River in Yuma, Arizona. The Upper Gila River Basin covers 19,036 km^2 of Arizona and 20,254 km^2 in New Mexico. The average mean flow of Eagle Creek, which is perennial, is 67.5 cfs (University of Arizona Water Resources Research Center & Stillwater Sciences 2018). This flow is supplemented by

water diverted from the Black River, 21 miles to the west; as such, it is unclear whether use by the Morenci Mine and Clifton's municipal supply, both of which pump water from Eagle Creek, impacts surface flows of the creek (University of Arizona Water Resources Research Center & Stillwater Sciences 2018). If surface flows are affected, then water use by Morenci Mine and the town of Clifton represent a threat to the Gila Southwest spring firefly, but more research is needed to determine the scope and extent of this threat.

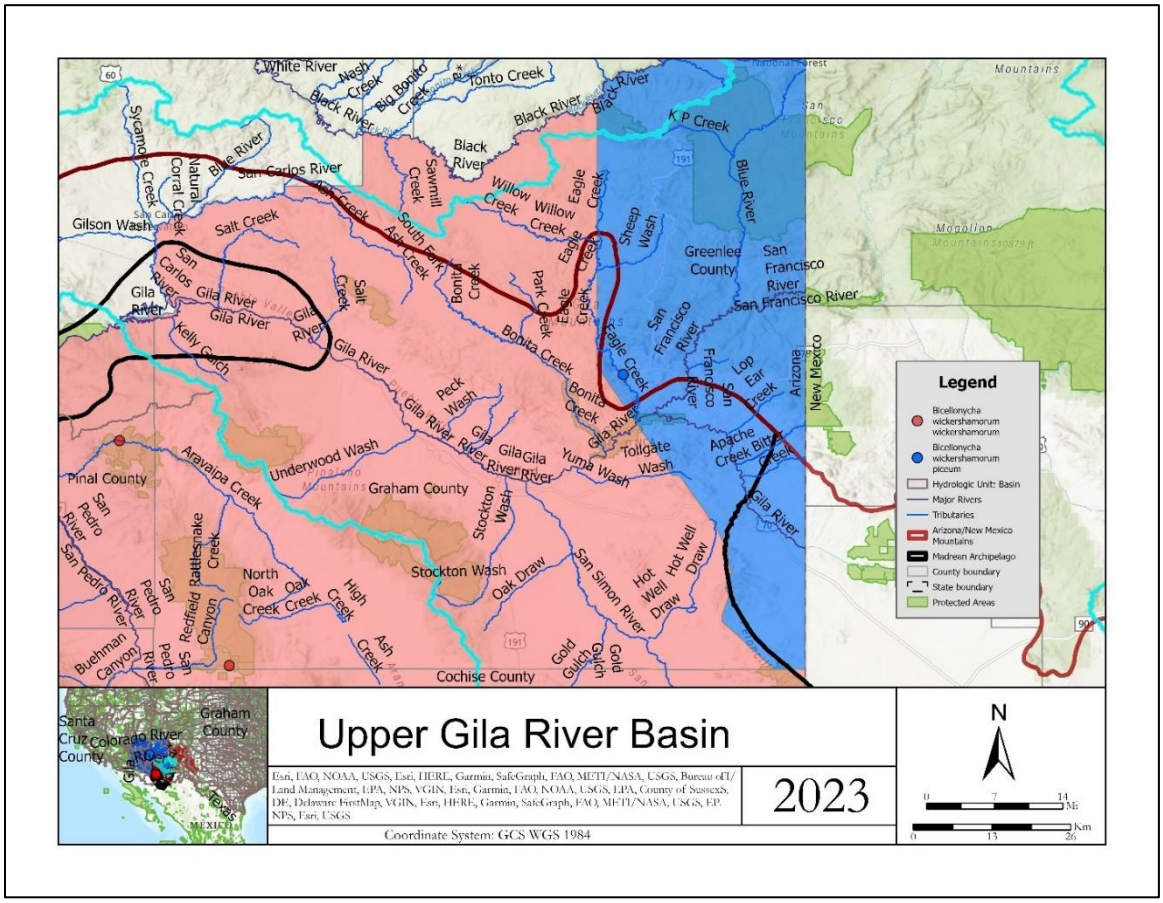

Figure 7. B. wickershamorum occurrences in the Upper Gila River Basin, AZ (basin is highlighted in turquoise).

Groundwater depletion/water use in the Verde Basin

The other known historic location for the Gila Southwest spring firefly is near Camp Verde along Sycamore Creek, a seasonally wet tributary of the Verde River, in the Verde Basin (Figure 8). The Verde River is one of Arizona's largest perennial streams. The flow, which is fed by groundwater, is diverted from the Verde River and its tributaries at around 67 locations, primarily for irrigation of cultivated fields, but also for use by some residential customers (Garner & Bills 2012). Several municipalities in the Verde Valley, including Camp Verde, Clarkdale, Cottonwood, and Sedona pump groundwater to meet their needs, and residents in outlying communities rely on private wells or community water suppliers to meet their needs (Garner et al. 2013). The population in the Verde Valley increased by 82% from between 1990 and 2015 (Greater Cottonwood Chamber of Commerce 2023) and it is expected to

continue growing, raising concerns about future stresses on the Verde River hydrologic system (Garner et al. 2013). Groundwater pumping in particular, has the potential to reduce streamflow in the rivers and streams that are hydrologically connected to the groundwater system. Groundwater storage in the area's aquifers had decreased by about 29,000 acre feet per year, when measured in 2005. About 12,000 acre-ft/yr of this storage decrease in 2005 was attributable to human stresses, while about 17,000 acre-ft/yr of storage decrease was the result of below-average natural recharge, from precipitation (Garner et al. 2013).

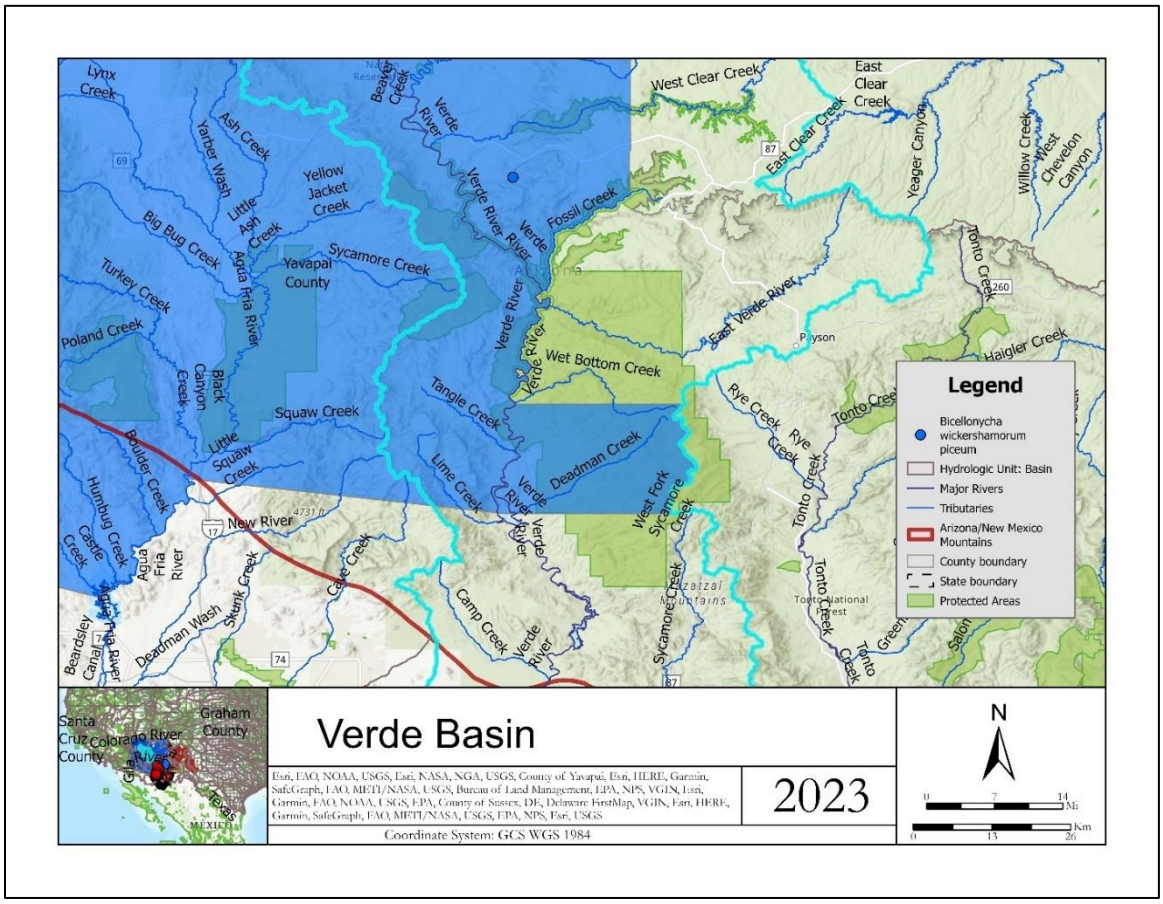

Figure 8. B. wickershamorum piceum in the Verde Basin, AZ (basin is highlighted in turquoise).

While the exact locality of the historical collection site of the Gila Southwest spring firefly in the area is unknown, the locality label suggests the firefly was once found along "Sycamore Creek," near Camp Verde. It is possible this minor tributary, which is dry for much of the year, was much wetter in the past. Site visits are needed to determine whether the firefly can still be found in the area.

Livestock grazing

Grazing by livestock, primarily cattle, is a major threat to fireflies in riparian and wetland ecosystems of the Southwest. Not only does overgrazing contribute to severe habitat degradation, but trampling by large ungulates may cause direct mortality to firefly larvae and pupae, which reside at or below the soil

surface. Since many of the sites where the Southwest spring firefly occur are small in size, even a single large bull could cause severe damage to the larval population if it is present when larvae are active.

The presence of cattle may be a major driver in the decline of this species. While there are no published studies linking the presence of cattle to an absence of fireflies per se, anecdotally the relationship has been widely observed at western firefly sites (J. Cicero pers. comm. 2022; L. Buschman pers. comm. 2022; A. Walker pers. obs.). It is rare to find fireflies in places where cattle are present. Site degradation by cattle is even thought to be the primary reason for the loss of the *B. wickershamorum* type locality in the Babocomari River watershed (Fallon & Cicero 2021a). Furthermore, cattle have been observed trampling the wetlands and surrounding vegetation at both known *B. w. wickershamorum* sites on Las Cienegas National Conservation Area (NCA) in Pima County, and trespass cattle are a regular occurrence in the San Pedro NCA as well (C. Fallon pers. obs. 2022; C. Mollohan pers. comm. 2022; S. Killingsworth pers. comm. 2022). The Empire Gulch site, a wetland that has been monitored consistently for the past three years, is highly impacted by cattle; as recently as July of 2022, cattle were observed within the marsh, and their presence appeared to contribute to erosion and sedimentation of the site (Figure 5). Furthermore, firefly count estimates at the site have declined each year, with approximately 40 firefly individuals recorded in 2020, 20 in 2021, and only 10 observed in 2022, the same year a bull was observed at the site over multiple visits (C. Mollohan pers. comm. 2023). The wetland area at a second site, which was documented in 2022, is fenced and cattle are not permitted inside the fencing. However, several trespass cows were discovered within the exclusion area during survey efforts (C. Fallon pers. obs. 2022), indicating the fence had been breached. Cattle have also been observed in the canyon along Eagle Creek at the *B. w. piceum* type locality, where large portions of the habitat have been trampled (A. Walker pers. obs. 2021).

Of the many land management stressors affecting public land in the western United States, grazing is the most widespread. Managed ungulates utilize over 70% of land managed by the Bureau of Land Management (BLM) and U.S. Forest Service (Beschta et al. 2013). According to data released by the Bureau of Land Management, at least 54 million acres of land owned by the BLM fail to meet the agency's own land-health standards (Bureau of Land Management 2022a; Mohr 2022). The assessment only included 109 million acres out of the 246 million acres managed by the agency, so the actual amount of land failing to meet the land-health standards may be higher. These standards consider biological conditions, soil, health, water quality, plant species diversity and the quality of habitat for endangered and threatened species. Livestock grazing was considered a significant cause of failing health standards on 72% of the public land. There have also been several lawsuits filed by the Center for Biological Diversity against the US Forest Service, the Bureau of Land Management and the U.S. Fish and Wildlife Service for failing to keep cattle out of endangered species habitat in areas where the Southwest spring firefly can be found, including along the Verde River and its tributaries, in the San Pedro Riparian National Conservation Area, in Las Cienegas National Conservation Area, and in the Coronado National Forest (Bugbee 2020; Trudeau 2020; Center for Biological Diversity 2021). For example, livestock damage was found on 70% of areas surveyed along the Verde River, which may be potential habitat for the Gila Southwest Spring Firefly (Trudeau 2020).

Cattle often congregate in riparian areas where they can easily access water, the terrain and microclimate are more favorable, the soil is softer, and the vegetation is lush and palatable (Kovalchik & Elmore 1991; Figure 5a). While certain management practices can mitigate impacts, grazing by cattle in riparian areas is often exceedingly detrimental to the habitat. Overgrazing is associated with changes to riparian plant communities, which are crucial for maintaining water quality, soil health, channel morphology, and biotic diversity (Kauffman et al. 1983; Kondolf et al. 1996). As riparian vegetation is lost, stream temperatures rise, organic matter inputs lessen, and hydrologic processes are disrupted (Beschta 1997; Kauffman et al. 2004). For example, bank erosion (Figure 5b) becomes more likely when vegetation is grazed, contributing to higher sedimentation rates; over time, stream channels can become incised or widened. Incised rivers are disconnected from their floodplains, which reduces the exchange of water, nutrients, sediments, and organisms, and eliminates wetland habitats along the riparian corridor (Loos & Shader 2016). Hydrologic processes are also influenced by the soil compaction that results when cattle move through an area. Compaction reduces infiltration rates and hinders the ability of soil to hold water, leading to increased runoff and reduced base flows (Blackburn 1985; Belsky & Blumenthal 1997; Kauffman et al. 2004). Soil loss and compaction also reduce soil productivity, in turn making it more difficult for plants to re-establish (Beschta et al. 2013). Cattle may also reduce stream flows due to the diversions and water development projects that support livestock operations. In many cases, especially in the arid southwest, these disturbances may cause perennial streams to become intermittent (Beschta et al. 2013). For species that depend on permanent water, including the Southwest spring firefly, loss of any amount of perennial stream habitat can increase habitat fragmentation and localized extirpations.

Figure 5. Cattle are a major threat to Southwest spring firefly habitats. (a) At Empire Gulch on the Las Cienegas NCA, wallowing cattle have degraded the natural wetland where B. w. wickershamorum occurs (photo: Sarina Jepsen/Xerces Society). (b) Erosion of streamside walls as a result of cattle can lead to further sedimentation of fragile wetland areas (photo: Candace Fallon/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 2022b). 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 (Table 4). 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 (Table 4). 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.

The Morenci Mine—the largest copper producer in North America—is located along the eastern end of the Eagle Creek drainage where one of the two known locations for *B. w. piceum* occurs. The company that operates the Morenci Mine, Freeport McMoran, was ordered by the U.S. Department of Justice in 2012 to pay $6.8 million to settle charges by the Federal and State government regarding pollution of dangerous substances flowing from this mine, and the effect of that pollution on water quality, soil, other habitat, and birds (Hull 2012).

According to a 2012 report detailing unauthorized wastewater releases by this mine, "surface water has been, and most likely continues to be, exposed to hazardous substances released from the Morenci Mine through a variety of pathways" (United States and State of Arizona v. Freeport McMoran Corporation and Freeport McMoran Morenci Inc 2012, cited in Gestring 2019). These hazardous releases included sulfuric acid and metals which "injured, destroyed or led to the loss of surface waters, terrestrial habitat and wildlife, and migratory birds" (Gestring 2019). While the effects of water pollution from Morenci's mining operations on *B. w. piceum* populations and the snails they depend upon for food are largely unknown, they are likely to be unfavorable, given the documented destruction and degradation of aquatic and terrestrial habitat where this subspecies occurs.

Sources of contamination from active mines include mine pits, heap leach facilities, waste rock storage areas, dry stack tailing facilities, and chemical storage facilities. Seepage and acid mine drainage produced from dry stack tailing facilities, waste rock storage areas, and heap leach facilities can contaminate soil, surface, and groundwater downstream of mining activities. At legacy sites, where mines are no longer in operation, contaminants released from these facilities continue to exceed Arizona Aquifer Water Quality Standards (Arizona Department of Environmental Quality 2022). Although groundwater contamination may have indirect effects on firefly health, additional concerns for the Southwest spring firefly include the mechanical damage to the landscape (through physical removal of substrate), groundwater drawdowns to support mining activities (including refinement of copper ore, which requires more water than any other mined metal), and other waste products such as mine tailings

and rock waste. Each of these impacts have the potential to destroy or severely degrade the ephemeral and riparian habitats this species relies upon (Lewis & Burraychak 1979; Dudka & Adriano 1997; Zaimes 2007), and as such pose a significant threat to the continued existence of the Southwest spring firefly.

Table 4. Active mines in southern Arizona counties where B. wickershamorum is known to occur, as of 2021. Compiled from Arizona Geological Survey and the Arizona State Mine Inspector's Office (2022).

County	Mine name	Company	Mine type	Product(s)
Cochise	Johnson Camp Mine	Excelsior Mining JCM, Inc. fka Nord Resources Corp	SX-EW Plant	Copper
Graham	FMI Safford Operations	Freeport McMoran Copper and Gold Safford	Open pit mine	Copper
Greenlee	Morenci Mine	Freeport McMoran Copper and Gold Morenci	Open pit mine	Copper
Pima	Sierrita Open Pit (aka Duval-Sierrita Mine)	Freeport McMoran Copper and Gold Sierrita	Open pit mine	Copper
Pima	Rosemont Copper Project	HudBay Minerals dba Rosemont Copper Company	Advanced Stage Development Project	Copper
Pima	Mission, San Xavier, Eisenhower	ASARCO, Mission Mine Complex	Open pit mine	Copper
Pima	Oracle Ridge Mine	Silver Mountain Mining Operations Inc. fka Oracle Ridge Mining LLC	Underground mine	Copper
Pima	Silver Bell Mine	Asarco Silver Bell Mining LLC	Open pit mine	Copper
Pinal	Florence Copper	Florence Copper, Inc.	In-situ	Copper
Pinal	Ray Operations	ASARCO, Ray	Open pit mine	Copper
Pinal	Resolution	Resolution Copper Mining, LLC	Underground mine	Copper
Santa Cruz	Hermosa Taylor Deposit	Arizona Minerals (South 32)	Exploration	Lead, zinc, silver
Yavapai	Bagdad Mine	Freeport McMoran Copper and Gold Bagdad Operations	Open pit mine	Copper
Yavapai	Clarkdale Slag Project	Clarkdale Metals Corp	Exploration	Iron, gold
Yavapai	Drake Iron Ore	Drake Materials	Open pit mine	Iron ore

Factor 3: Disease or predation

Many firefly species produce or ingest toxic defense chemicals called lucibufagins to protect themselves from predators, particularly vertebrate predators such as birds (Eisner et al. 1978, 1997). However, despite the presence of these compounds and ability to flash as a warning to predators, fireflies make up the diet of many animals (Lewis et al. 2012; Faust 2017). Spiders are a well-known predator of fireflies (Lloyd 1973; Long et al. 2012; De Cock et al. 2014), along with other invertebrates including harvestmen and assassin bugs (Lewis et al. 2012; Faust 2017).

Fireflies are known to suffer from reproductive bacterial parasites (*Wolbachia*, *Spiroplasma*, *Mesoplasma*, *Serratia*, and *Entomoplasma*) that can alter sex ratios by causing an increase in female eggs being produced or by killing male eggs (Faust 2017). Fireflies can also be afflicted by nematodes that can kill both larvae and adults (Faust 2017). For example, agricultural biocontrol agents can include the use of roundworms to control unwanted pest populations (e.g. *Steinernema* nematodes to control mole crickets), however this can have the unintended consequence of killing fireflies (Faust 2017). Various fungi, mites, and multiple species of parasitic fly (including phorid flies) also threaten firefly health (Brown 1994; Faust 2017).

While it is unknown if the Southwest spring firefly is threatened by natural or introduced pathogens or predators, predation and disease caused by pathogen infection can compound existing threats for this and other species that are already experiencing declines within highly localized ranges.

Factor 4: Inadequacy of existing regulatory mechanisms

There are no existing regulatory mechanisms that adequately protect the Southwest spring firefly at the federal, state, or local level. Furthermore, no known conservation actions or management plans are in place to protect this species. Although some sites do occur on federal lands, including the Coronado National Forest and Gila BLM District, permitted grazing allotments within these areas do little to protect this firefly from habitat degradation. Furthermore, while the species is known from at least eight protected areas (Aravaipa Canyon, Canelo, Las Cienegas, Miller Peak, Muleshoe Ranch, Patagonia-Sonoita Creek, Redfield Canyon, and San Pedro Riparian), cattle are still permitted in several of these locations, and existing regulations do little to protect firefly populations from growing threats due to drought and water drawdowns and modifications.

Federal regulatory mechanisms

There are no existing federal mechanisms which are adequate to ensure the Southwest spring firefly's long-term survival and recovery. The Service is required to consider other federal agencies' actions when considering the adequacy of existing regulatory mechanisms.

Bureau of Land Management

Some of the largest known populations of this species occur on BLM lands. Though the species shares some habitats with species included on the Bureau of Land Management, Arizona Sensitive Species List, the Southwest spring firefly is not itself on this list, and therefore is not afforded specific protections or management considerations from the BLM (Bureau of Land Management 2017). Furthermore, active grazing allotments on BLM lands where this firefly occurs–including protected areas such as Las

Cienegas National Conservation Area–present ongoing threats to the firefly through direct trampling and degradation of its habitat.

U.S. Forest Service

Several populations of the Southwest spring firefly occur on Forest Service lands on the Coronado National Forest. National Forest management plans provide guidelines for species' protections, but these guidelines are generally discretionary, and no plans are specifically in place for this firefly or its habitat (U.S. Forest Service 2018). The firefly is not currently listed as a USFS sensitive species, nor is it considered during any environmental assessments.

Overlap with critical habitat of other listed species

Arizona has been ranked first among U.S. states in the proportion of native freshwater species at risk of extinction (Stein 2002). Although not specifically mentioned in Stein's 2002 study, the Southwest spring firefly could be considered similarly imperiled since it is one of the many species dependent on riparian habitats in southern Arizona. This firefly shares habitat with numerous federally protected threatened and endangered riparian dependent species including the yellow billed cuckoo (*Coccyzus americanus*), Southwestern willow flycatcher (*Empidonax traillii extimus*), Gila chub (*Gila intermedia*), Loach minnow (*Tiaroga cobitis*), spikedace (*Meda fulgida*), Gila/Yaqui topminnow (*Poeciliopsis occidentalis*), razorback sucker (*Xyrauchen texanus*), jaguar (*Panthera onca*), lesser long nosed bat (*Leptonycteris curasoae yerbabuenae*), northern Mexican gartersnake (*Thamnophis eques megalops*), Chiricahua leopard frog (*Lithobates chiricahuensis*), and Canelo Hills ladies-tresses (*Spiranthes delitescens*) (Turner & List 2007). However, given ongoing habitat degradation in the designated critical habitat of these listed species, due to continued grazing of cattle, for example (Bugbee 2020), ESA protection of other species within the range of the Southwest spring firefly is unlikely to safeguard this firefly species.

State regulatory mechanisms

Similarly, there are no existing state mechanisms or protective measures in place to protect this firefly. The Arizona Fish and Game Department lacks management authority over all insects, and as such they are unable to address the conservation needs of the Southwest spring firefly, representing a major gap in regulatory mechanisms that leaves this animal vulnerable. In Arizona, management authority of insects lies with the state's Department of Agriculture, whose mission focuses on crop production not biodiversity conservation. Arizona's State Wildlife Action Plan states "Although the Department recognizes the conservation needs of a number of plants and insects, lack of authority, resources and expertise limits the Department's ability to respond to those needs" (Arizona Game and Fish Department 2012). Arizona's Natural Heritage Program maintains the Heritage Data Management System (HDMS), which identifies plants, animals, and habitats of concern in the state and consolidates information about their distribution and status (Arizona Game and Fish Department 2022). While the Southwest spring firefly was recently added to the HDMS as a tracked species (M. Barbour pers. comm. 2023), Natural Heritage Programs do not have any regulatory or management authority. Their designations of tracked species may call attention to the plight of imperiled species and habitats, but they do not convey any protection for the species they track. Therefore, even though the Southwest spring firefly has been added to the HDMS, it does not receive any protections through the state. Given that no state agency in Arizona with expertise in the conservation and recovery of wildlife populations

has management authority over insects, there is an urgent need to protect this species under the federal Endangered Species Act.

Local regulatory mechanisms

Local mechanisms that could benefit this species include outdoor lighting ordinances to minimize light pollution from glare, light trespass, and sky glow, such as the City of Tucson Lighting Code. While these ordinances do not have the explicit goal of protecting *B. wickershamorum* or other nocturnal insects from harmful artificial light at night, they could nonetheless help to mitigate light pollution impacts on firefly populations. However, the majority of locations where this species occurs are outside of the jurisdictions that have these ordinances, and hence they do not provide any protections to this species where they are most needed, such as at the Morenci Mine type locality or in areas along the U.S.-Mexico border wall in Santa Cruz and Cochise Counties where some populations of the Southwest spring firefly occur within 1-5 km of the border and where brighter lights have been installed in recent years to detect and deter illegal border crossings. To the best of the petitioners' knowledge, no other local regulations are in place to protect the Southwest spring firefly.

Factor 5: Other natural or manmade factors affecting this firefly's continued existence

Additional factors threaten the Southwest spring firefly's continued existence, including declines in the species' primary food source and habitat degradation due to light pollution, climate change, invasive species encroachment, and pesticide use, as described in detail below.

The Southwest spring firefly is vulnerable to extinction because just over two dozen populations have been documented range-wide, 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 population (the species' type locality) has likely been extirpated, due to cattle grazing. Small population sizes make this species vulnerable to site-disturbing activities and stochastic events including drought, fire, flooding, and climate change.

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). These changes can impact insects in many ways, from causing shifts in phenology or species ranges to affecting a wide range of other factors including fitness, fertility, food sources, and pathogen loads (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.

Climate change has also been linked to an increase in the severity and frequency of wildfire (Garfin et al. 2018; U.S. EPA 2023), which can eliminate habitat and cause direct firefly mortality. Past fire suppression activities in the Huachuca Mountains and other sky island mountain ranges have led to the buildup of dense fuels, especially in wooded riparian areas where the Southwest spring firefly is known to occur (Coronado Planning Partnership 2008). This increases the chances for high-intensity, stand-replacing fires. These types of fires can impact local hydrology and watershed function, and may lead to increased soil erosion, sedimentation, and poor water infiltration (Coronado Planning Partnership 2008), all of which can degrade the ephemeral spring, seep, and marsh habitats with which *B. wickershamorum* is associated.

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, Aravaipa Canyon, and Guadalupe 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.

Climate models for the region predict additional habitat loss and isolation for montane areas of the Madrean Archipelago, with cascading effects on biodiversity (Yanahan & Moore 2019). For *B. wickershamorum* populations that occur at higher elevations within the region's sky island complexes, this may further impact gene flow, diversity, and population fitness, particularly in light of ongoing drought and increasing frequency and severity of stand-replacing wildfires.

Recreation

Several of the known *B. w. wickershamorum* populations occur within recreation areas, including the Coronado National Forest. Hiking, wildlife viewing, horseback riding, mountain biking, and off-road vehicle (ORV) use are all popular activities within these areas. Because the Southwest spring firefly is vulnerable to trampling and habitat degradation, off-trail hiking and ORV use can be particularly damaging to its populations. For example, surveyors have observed high ORV traffic in the Huachuca Mountains' Scotia Canyon, which hosts a large firefly population (C. Mollohan pers. comm. 2023.), as well as at the type locality for *B. w. piceum* (A. Walker pers. obs. 2021, C. Mollohan pers. comm. 2022). The negative impacts of off-road vehicle use on public lands are well documented and growing, and include soil erosion, stream sedimentation, alteration of hydrological flows, vegetation destruction, wildlife mortality, spread of invasive species via seeds stuck on tire treads and undercarriages, fragmentation of habitat, pollution, and other disturbances (Trombulak & Frissell 2000).

Hiking is a popular activity throughout the firefly's range, and in particular in the Huachuca-Patagonia mountain complex. Numerous trails wind through these mountains, with more hikers using the trail systems every year. The Scotia Canyon Trail, which primarily follows the creek within this canyon where *B. wickershamorum* occurs, was recently designated as a segment of the much longer Arizona Trail (U.S. Forest Service 2022), which spans the state from the Mexican border to the Utah state line. It is possible this designation will increase foot traffic and dispersed camping in the area, which could lead to trampling of firefly larvae and microhabitats.

Light pollution

Artificial light at night (also known as light pollution or ALAN) negatively affects the reproductive success of nocturnal firefly species that require darkness for their courtship displays (Owens & Lewis 2018; Lewis et al. 2020). Artificial light at night can interfere with the behavior of nocturnal fireflies in a multitude of ways, including temporal disorientation (courtship behavior failure to be triggered because the ambient light levels never reach necessary thresholds), phototaxis (fireflies being drawn to lights), and disruption of light signal reception (fireflies failing to respond to the signaling of potential mates because the signal is drowned by artificial light, or because sudden exposure to artificial light saturates their dark-adapted photoreceptors, effectively blinding them to other signals) (Owens & Lewis 2018, 2022). Because the Southwest synchronous firefly begins its courtship displays in early evening and it is largely present in remote areas removed from population centers, this threat may not be as extreme as it is for other species that flash in full darkness or are located in urban areas. However, extremely bright lights at several locations could be interfering with reproductive success. For example, the type locality of *B. w. piceum* is near the Lower Eagle Creek Pump House, which takes water 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; Figure 6). 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. It is also possible this species used to persist in areas with high levels of ALAN, and those populations have now been wiped out because of it.

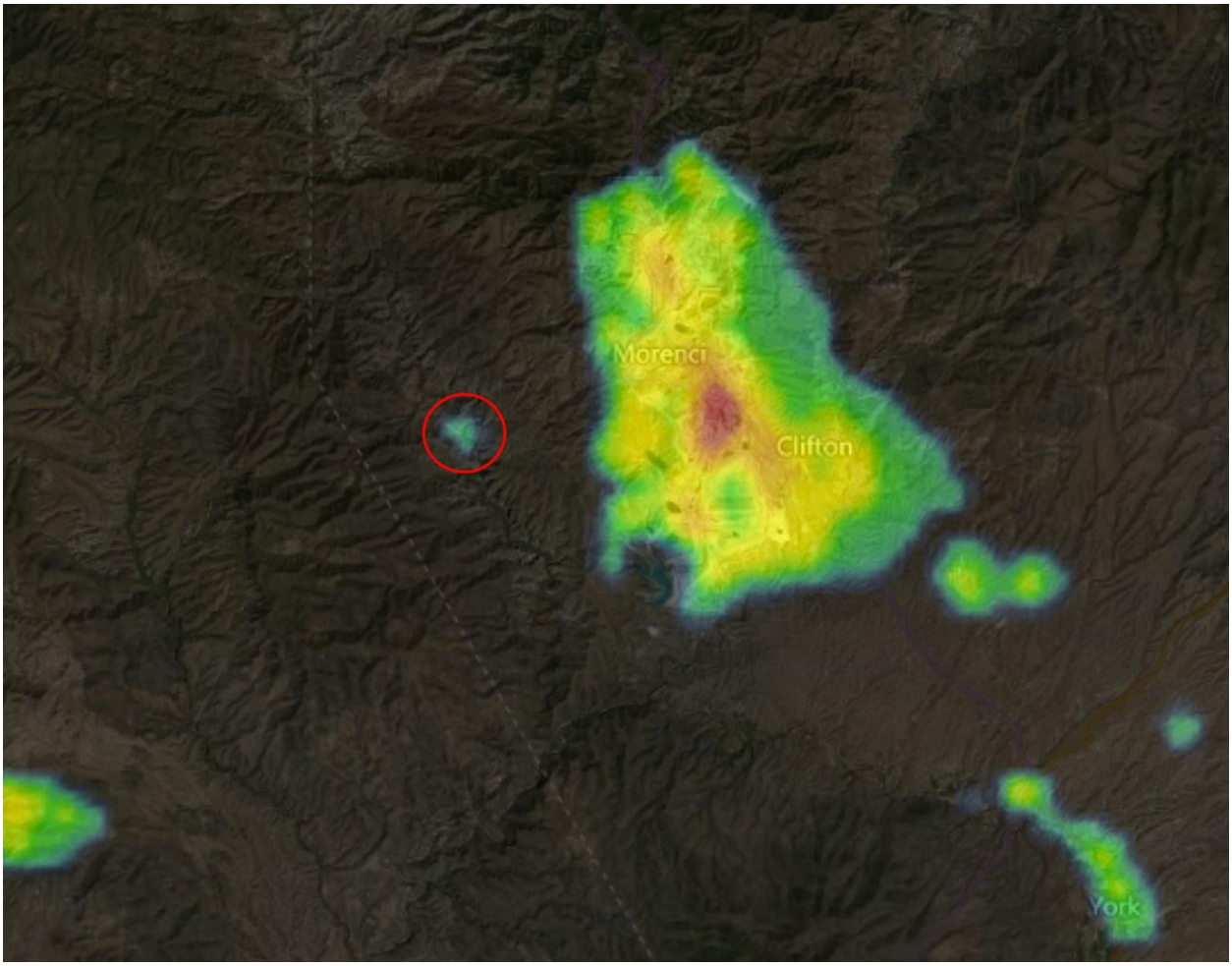

Figure 6. Light pollution in the vicinity of the B. w. piceum type locality (red circle), collected by the Visible Infrared Imaging Radiometer Suite (VIIRS). Also visible on the map are the Morenci Mine and the town of Clifton. Colors represent increasing amounts of artificial light ranging from blue and green (low amounts of artificial light) to yellow and red (high amounts of artificial light). Light is measured in radiance (10-9 Watts/cm2/steradian). Radiance imagery from the Earth Observation Group, Payne Institute for Public Policy (www.lightpollutionmap.info).

Artificial light at night is also a growing threat to nocturnal wildlife like the Southwest spring firefly that occur along Arizona's southern border. In July 2022, the Department of Homeland Security announced plans to install or complete stadium-style floodlights along 455 miles of existing sections of the U.S.-Mexico border wall, including the San Pedro Riparian National Conservation Area and Coronado National Forest (Department of Homeland Security 2022). Although Southwest spring fireflies have not yet been recorded from these border wall sites, they are known to occur within the San Pedro River Basin and the Coronado National Forest, and could potentially be impacted.

Firefly tourism

Firefly tourism is an increasing industry globally (Faust 2017; Lewis et al. 2021). As one of only two flashing firefly species in the Southwest, the Southwest spring firefly could easily become the focus of tourism activities in the state. Already, tourists will travel many miles to specific areas to observe the lighting displays of firefly species (Faust 2017; Lewis et al. 2021). Increased tourism comes with direct threats to fireflies such as habitat degradation due to soil and leaf litter disturbance and increased water, soil, and light pollution (Lewis et al. 2021). Additionally, if infrastructure is needed to support tourists, further habitat destruction may occur for the construction of such structures (Lewis et al. 2021). Furthermore, as firefly tourism is a relatively new and emerging industry in the U.S., there exists little regulation and protection of species, despite the fact that some sites in the eastern U.S. are now drawing in over 12,000 visitors per year in just an eight day span (Faust 2017; Lewis et al. 2021). This lack of regulation often means that the increased foot traffic by tourists can cause trampling of firefly larvae in the soil, trampling of adult fireflies on the ground, or disruption of mating fireflies resting low on vegetation (Lewis et al. 2021). While firefly tourism is not currently a threat to this species, it has the potential to become one if sites are not managed to accommodate growing local interest.

Loss of prey

Declines in soft-bodied prey such as snails and slugs may further threaten the Southwest spring firefly's existence. Firefly larvae are dependent on earthworms, terrestrial mollusks, and other soft-bodied invertebrates for food (Lewis 2016; Faust 2017). The Southwest spring firefly has been directly observed to feed on snails, and is thought to specialize on them (J. Cicero pers. comm. 2022). Terrestrial mollusks, which are considered some of the most imperiled animals in the world, face many of the same threats as this firefly, including habitat degradation and drought (Lydeard et al. 2004). While the extent to which prey population trends are impacting firefly populations is unknown, it is clear that declines in local prey populations could have severe impacts on larval fireflies.

Invasive species

Riparian areas in the western U.S. have some of the most aggressive invasive species. While there are some examples of invasive animals contributing to declines in native aquatic vertebrates and invertebrates, through competition and predation, to our knowledge, the Southwest spring firefly is primarily impacted by exotic invasive plant species, which heavily degrade riparian habitats.

Invasive plants are a consistent factor in habitat modification throughout riparian areas in Arizona. Invasive plant species outcompete native plants, leading to a change in plant communities which ultimately impacts entire species assemblages. In Arizona, the most harmful invasive plant species impacting riparian areas include salt cedar (*Tamarix* spp.), Russian olive (*Elaeagnus angustifolia*), tree of heaven (*Ailanthus altissima*), vinca (*Vinca major*), silktree (*Albizia julibrissin*), purple loosestrife (*Lythrum salicaria*), Bermudagrass (*Cynodon dactylon*), Johnsongrass (*Sorghum halepense*), buffelgrass (*Pennisetum ciliare*), Russian knapweed (*Acroptilon repens*), Lehmann lovegrass (*Eragrostis lehmanniana*), Eurasian watermilfoil (*Myriophyllum spicatum*), water hyacinth (*Eichhornia crassipes*), cheatgrass (*Bromus tectorum*), African sumac (*Rhus lancea*), softfeather pappusgrass (*Enneapogon cenchroides*), and purple fountain grass (*Pennisetum setaceum*) (Zaimes 2007; Arizona Native Plant Society 2023). Of these, salt cedar is likely the most destructive and pervasive.

Salt cedar has spread vigorously across waterways of the western U.S. because it is tolerant of alkaline, saline soils and periods of drought (Zaimes 2007). It was originally introduced in the early 1800s as an ornamental tree and a tool for preventing soil erosion. Other human impacts on waterways, including groundwater pumping, which lowers the water table, overgrazing of cottonwood and willow seedlings, and alteration of flow regimes due to damming, have created conditions that favor the establishment and survival of salt cedar (Zaimes 2007). Other impacts of salt cedar invasion in riparian areas include increases in soil salinity, alteration of soil composition, and increased uptake of water when compared to native riparian vegetation (Ladenburger et al. 2006; Pattison et al. 2011). Invasive tamarisk also has an impact on fire regimes and has increased both the frequency and severity of fires in riparian ecosystems in the western United States (Drus et al. 2013). Due to its flammability and size, salt cedar acts as a bridge between understory vegetation and forest canopies, increasing the likelihood of crown fires which are fatal to cottonwood trees (*Populus deltoides wislizeni*). The species is also quick to recover following fires, aiding in its capacity to convert riparian forests.

Pesticides

Pesticides are identified as a serious threat to firefly conservation in North America, second only to habitat loss and fragmentation, according to a survey of firefly experts (Lewis et al. 2020). The habitats occupied by *B. wickershamorum* may experience contamination from pesticides used within its occupied habitats, or potentially from drift or runoff from adjacent treated sites. Fireflies may absorb pesticide through direct contact with airborne pesticides, or through contact with contaminated surfaces, sediments, surface water and/or groundwater. Consumption of contaminated prey by firefly larvae is another potential route of exposure.

The majority of locations where *B. wickershamorum* has been identified are administered by the U.S. Forest Service, the Nature Conservancy, and Bureau of Land Management. Predominant land uses include grazing, fuelwood harvesting, and recreation (DeBano et al. 1995). Pesticides in such environments are not usually applied intensively, compared to agricultural and developed areas. However, *B. wickershamorum* individuals may occasionally come into contact with insecticides, fungicides and/or herbicides. Pesticides may be applied within their habitat deliberately, for example to deal with forest health problems or invasive weeds. Pesticides may also enter firefly habitat inadvertently, from cattle manure or drift from mosquito applications.

Forest health problems are widespread in Arizona. While recent reports suggest that the Sky Islands are less affected than other areas of Arizona, some infestations of insects (especially bark beetles and wood borers) and disease—either of which can cause tree mortality—are present nearby (U.S. Forest Service 2013; McAlexander 2021). For example, within southeastern Arizona, 14,000 acres with insect damage were observed in 2021, mostly on federal lands (McAlexander 2021). Insecticides are one option available for land managers to control bark beetles (Fettig et al. 2022), and treatments could introduce insecticides into *B. wickershamorum* habitat, threatening exposure to this firefly. However, information about the extent of applied insecticides and fungicides are not easily accessible to the public. Calls to the Coronado National Forest and The Nature Conservancy were not returned as of the time of this writing.

Invasive weeds, including vinca (*Vinca major*) and buffelgrass (*Pennisetum ciliare*) are common in parts of the Sky Islands region. Vinca is found in canyons, and treatment areas could be co-located or situated

above occupied firefly habitat. Buffelgrass is widespread along roadsides and rangeland. Local efforts to eliminate these weeds include herbicides as one tactic; sometimes herbicides are applied aerially (Bethel 2019; U.S. National Park Service 2022). The herbicides that are usually used to control buffelgrass include glyphosate and imazapyr. These herbicides are non-selective and impact non-target plants (U.S. Forest Service 2014) that may be consumed by firefly prey, such as snails or slugs. Some herbicides, including atrazine, simazine, glyphosate, and paraquat, also can have a repellent effect on predatory ground beetles. Brust (1990) found that beetles were repelled from treated fields for a month after application of glyphosate or paraquat.

Pesticide residues in slug bodies can be transmitted to their predators (Douglas et al. 2015). Similar pathways could occur with snails, which have been shown to become contaminated with certain pesticides (Druart et al. 2011). Hence, invasive weed treatment may pose an indirect threat to *B. wickershamorum* by affecting the food chain below it, or by repelling predatory beetles such as the fireflies themselves.

Cattle and other livestock are susceptible to a number of parasites that are often treated with internal or topical applications of insecticides. For example, ivermectin and similar macrocyclic lactone compounds, administered as injectable or “pour-on” formulations, are used to treat cattle for worms, flukes, and external parasites. Ticks, lice, and biting flies may also be treated with pour-on applications of pyrethroids (a class of insecticides considered highly toxic to a broad spectrum of insects). Beetles as a group are sensitive to the effects of pyrethroids and may experience mortality when exposed (Silcox et al. 1985; Beachley 2008; Babendreier et al. 2015; Peterson et al. 2016), suggesting fireflies may be killed if present during pour-on applications in the field.

Once eliminated from the body, residues of ivermectin are commonly found in cattle dung, and can also be detected below dung pats in the uppermost soil layer (Römbke et al. 2010a). Ivermectin is considered slightly to moderately persistent in soil (half-lives ranging from 14-56 days), but can demonstrate longer persistence in soil mixed with manure (Liebig et al. 2010).

Ivermectin residues in manure have been demonstrated to result in impacts ranging from mortality to delayed reproduction on dung-dwelling and feeding insects, particularly dung beetles and flies (Madsen et al. 1990; Sommer et al. 1992; Floate 1998; Römbke et al. 2010b; Verdú et al. 2018; Sands & Wall 2018). The prevalence of cattle within and near known locations of *B. wickershamorum* suggests that firefly larvae developing in soil or moving on or near dung locations may be exposed to ivermectin and other insecticides, and may be susceptible to their toxic effects.

Although Arizona is an arid state, dozens of species of mosquitoes do occur there, with activity peaking between May and October each year. Some Arizona mosquitoes transmit diseases of concern, including West Nile virus (most documented cases have occurred within Maricopa County, outside the known range of this species) and St. Louis encephalitis (cases have been reported from Cochise and Pinal counties, both of which fall within the range of this species). Cochise County reports that they conduct no public abatement activities and only make recommendations to private landowners about abatement options when they receive complaints (N. Johnson, pers. comm 2022). Pinal County uses biological control and other abatement measures. Should any of the counties start applying aerial

insecticides to water bodies where this species occurs, this would pose a threat to the continued existence of *B. wickershamorum*.

Request for critical habitat designation

We request that the Service designate critical habitat for the Southwest spring firefly in concurrence with its listing. Critical habitat is defined in Section 3 of the ESA as (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 1533 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species (16 U.S.C. § 1532 (5)).

A fundamental goal of the ESA is to ensure that "the ecosystems upon which endangered species and threatened species depend may be conserved" (16 U.S.C. § 1531 (b)). Thus, critical habitat is an effective and important component of the ESA, without which the Southwest spring firefly's chance for survival significantly diminishes. Petitioners therefore request that the Service propose critical habitat in concurrence with the species listing.

Conclusion

Fireflies are highly regarded among the public due to significant cultural, biological, and economic importance. The petitioners have carefully assessed the most current and accurate scientific information available for the Southwest spring firefly and its subspecies regarding the threats this taxon has faced historically, faces presently, and will face in the future, and have determined that the species is in imminent danger of extinction throughout its range. The Southwest spring firefly is a rare habitat specialist found in only 27 localities in southern Arizona, at least one of which has likely been extirpated. The petitioners urge the listing of this imperiled species. The ESA requires that the Service promptly issue an initial finding as to whether this petition "presents substantial scientific or commercial information indication that the petitioned action may be warranted" (16 U.S.C. § 1533 (b)(3)(A)).

The petitioners suggest that listing the Southwest spring firefly is warranted under the ESA as it is imperiled by four of the five listing criteria: 1) the present or threatened destruction, modification, or curtailment of its habitat or range; 3) disease or predation ; 4) the inadequacy of existing regulatory mechanisms; and 5) other natural or manmade factors affecting its continued existence. There are no existing regulatory mechanisms which are adequate to protect the Southwest spring firefly from extinction, and listing this species is the only way to ensure its continued existence in the face of habitat loss and degradation, climate change, and light pollution, among other threats. Conserving this firefly and its habitats would in addition help protect riparian and ephemeral wetland habitats in southern Arizona, which are themselves an extremely imperiled resource. A prompt decision is required to save this species from extinction.

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