

**RARE INVERTEBRATE SPECIES OF
KAIBAB NATIONAL FOREST,
NORTHERN ARIZONA:
FINAL REPORT
(FS AGREEMENT NO. 10-CS-11030420-038)**



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Prepared for Kaibab National Forest
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PROJECT OVERVIEW

Kaibab National Forest occupies three large tracts of primarily upland coniferous woodlands, forests, and meadows and some wetland habitats in northern Arizona. This vast, topographically diverse land area has been incompletely surveyed for insects and other invertebrate taxa. To assist the Forest Service with species and habitat management elements of its Kaibab National Forest Plan revision, we compiled information on the rare invertebrates known or suspected to occur within the boundaries of the Forest. We gathered information from numerous literature and both regional and national museums, including the Regional Forester's Sensitive Species list of species of management concern, NatureServe, the Arizona Game and Fish Department's Natural Heritage database, the Museum of Northern Arizona invertebrate database, and through written and oral communications with expert entomologists across the United States.

The above sources provided a wealth of information on 3 invertebrate species that the Forest Service recognized as potentially warranting management attention. The taxa described here include: 1 dragonfly (Odonata), 1 tiger beetle (Coleoptera; Carabidae – Cicindelinae), and one swallowtail butterfly (Lepidoptera: Papilionidae). The information gathered has been compiled into a management reference guide specifically for Kaibab National Forest. We provide an overview of the taxon to which each of the described species belongs. Guidance on Forest Service management actions is provided in a table for each species.

Along with the species described in this document, there are likely at least several dozen other rare invertebrates that have yet to be recognized as being rare in the Forest, and some have yet to be scientifically described (e.g., Physidae aquatic snails, Turbellaria flatworms, Plecoptera stoneflies, etc.; Stevens 2007). Such species also may warrant management attention. Therefore, uncertainty remains about the distribution and status of rare invertebrates in the Forest. Based on our review of the information and that of Stevens (2007), and given the challenges of understanding and monitoring invertebrate populations, continued attention to the distribution and status of rare invertebrates may be needed for the Forest Service to achieve its goals related to sustainability of native faunal populations and their habitats.

Reference Cited

Stevens, L.E. 2007. A review of invertebrate species of management concern on five northern Arizona forests: Final report. Museum of Northern Arizona, Flagstaff.

DRAGONFLIES (ODONATA) OF KAIBAB NATIONAL FOREST

Dragonflies and their smaller relatives the damselflies are colorful, conspicuous insects in the order Odonata and are important predatory invertebrates in aquatic, wetland, riparian, and terrestrial habitats throughout northern Arizona and the southern Colorado Plateau. Dragonflies (suborder Anisoptera) vary in size but are generally fairly large, and rest with their wings flat (unfolded); damselflies (suborder Zygoptera) are generally smaller and rest with their wings folded back. The larvae of both groups are aquatic sit-and-wait predators in springs, streams, and ponds, feeding on soft-bodied insects, tadpoles, and even fish. With at least 89 species documented thus far on and around the southern Colorado Plateau, their diversity, abundance, daring flight behavior, and ecological significance makes them conspicuous to the public, scientific, conservation, and management communities. Several major websites provide information on each species in the region, particularly the Arizona Odonates website (<http://www.azodes.com/main/default.asp>), and OdonataCentral. A bibliography on the region's taxa has been compiled by Stevens and Bailowitz (2009) and several journals on Odonata exist.

The Odonata of the southern Colorado Plateau include at least 89 species (35 genera, seven families), including 49 dragonfly (Anisoptera) species in 25 genera and four families, and 40 damselfly (Zygoptera) species in 10 genera and three families (Stevens and Bailowitz (2009)). The relatively high diversity of dragonflies in this region is related to: several factors. As with plants, the region is a mixing zone, including species from Mexico and Central America (35%), those from northern portions of North America (21%), and those that are locally derived (44%). There is a surprisingly strong influence of the Pacific Coast on the dragonflies of the southern Colorado Plateau. In general, the tropical species have lower elevation ranges than do boreal species. A total of 15 (17%) Odonata species on the southern Colorado Plateau are restricted to three or fewer localities, with four (5%) species found at only a single locality, and four high-elevation species may be at risk of extirpation though climate change impacts on their habitats. Among the four highly restricted species are the coenagrionid damselflies *Ishnura cervula* in central northern Arizona, and *Coenagrion resolutum* in perennial ponds on the North Kaibab. The latter species was not described in this report, but is relatively common and in good population health at several North Kaibab Forest natural ponds, as of 15 June 2012.

Persephone's Darner
Aeshnidae: *Aeshna persephone* Donnelly 1961



Taxonomy

Arthropoda

Hexapoda

Odonata

Aeshnidae

Aeshna persephone Donnelly 1961

This is one of the last large dragonflies in the United States to have been described, and clarifying its similarity to, and ecological overlap with *A. palmata* Hagen are the subject of on-going research.

Description (Needham et al. 2000)

Larvae: Large, elongate, buff-colored larvae with a conspicuous extendable lower mandible. They move by pumping water backwards through their abdomens, allowing them to jet through the pond and slow-moving stream habitats they inhabit.

Adult: Adult Persephone's Darners are large, robust dragonflies two wide, yellow-green lateral stripes on the thorax, and with lateral blue spotting very small to absent on abdominal segments 7-10. The cerci are palmate and wedge-like (Fig. 1). Persephone's Darner hindwing length varies from 48-52 mm, and their total body length varies from 72-75 mm.

Similar Species

Persephone's Darner larvae are easily confused with those of other darners in the region, particularly *Aeshna palmata* and the far more common *Rhionaeshna multicolor*. Both of those species have much narrower thoracic stripes and more blue on the abdomen.

Adult Persephone's Darner are most similar to the slightly smaller *Aeshna palmata* Hagen and within their range of overlap they can be difficult to separate. *A. palmata* has a hindwing length of 43-47 mm, a total body length of 67-70 mm. It has narrower yellow to blue-green stripes on the thorax and on the abdomen the lateral blue spots extend into segments 7-10. Also, its cerci are palmate.

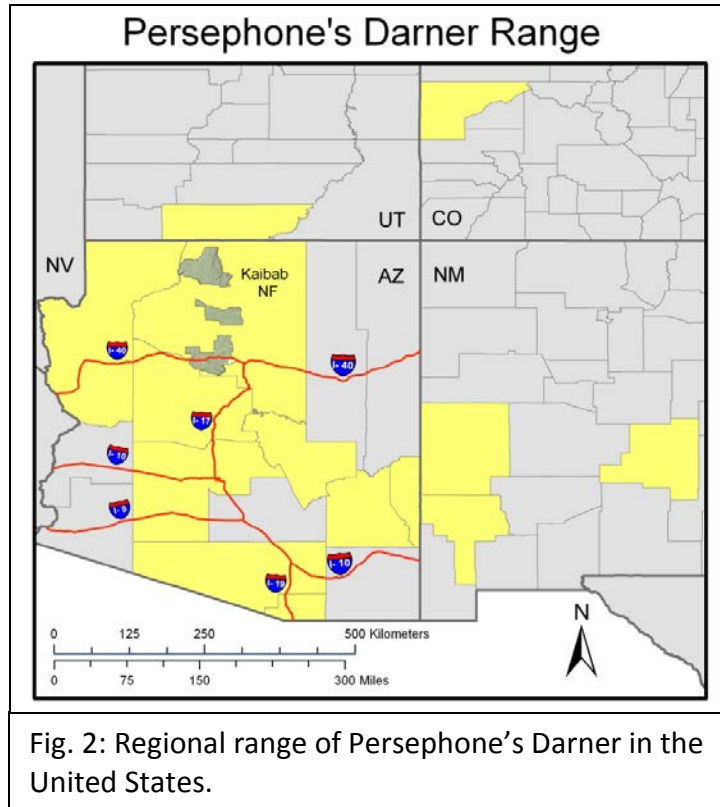
Range

Regional: Persephone's Darner is endemic to the American Southwest and northwestern Mexico (Fig. 2). It occurs from southwestern Utah to southwestern New Mexico and through much of southern and central Arizona, as well as through northwestern Mexico south to Nayarit. Isolated outlier specimens have been collected in western Colorado, central New Mexico, and western Texas. On the southern Colorado Plateau, it has been detected from 4000-7500 ft (1200-2300 m) elevation.

Known Localities: Abbott (2007) reports Persephone's Darner from 13 localities within its range (Fig. 2). In addition, Stevens and Bailowitz (2009) background information report it from AZ: Apache Co., Canyon de Chellys National Monument – Pine Tree Canyon; Coconino Co., Coconino National Forest – Oak Creek; Grand Canyon National Park - Colo. R. Mi. 41R (1

Vaseys Paradise (Cr Mi 32R; 1); Greenlee Co., Apache Sitgreaves National Forest – Blue Crossing; UT: Kane Co., Grand Staircase-Escalante National Monument – Seamans Spring.

♂), Forster Ca



Kaibab National Forest – North Kaibab District: The potential range of Persephone's Darner on the North Kaibab District is indicated in Fig. 3a, and shows that only a small amount of potential habitat exists on the District. The rarity of this species is in large part due to the natural scarcity of suitable habitat, rather than human impacts on the landscape. Persephone's Darners have not been detected on the North Kaibab District, but it is found to the south in Grand Canyon and immediately to the north in Grand Staircase-Escalante National Monument in Kane County, Utah.

Kaibab National Forest – Tusayan District: The potential range of Persephone's Darner on the Tusayan District is indicated in Fig. 3b, and shows that only a small amount of potential habitat exists on the District. The rarity of this species is in large part due to the natural scarcity of suitable habitat, rather than human impacts on the landscape. Persephone's Darner has not been detected on the Tusayan District, but it is found to the south along the Mogollon Rim and to the north in Grand Canyon National Park.

Kaibab National Forest – Williams District: The potential range of Persephone's Darner on the Williams District is indicated in Fig. 3c, and shows that only a small amount of potential habitat exists on the District. The rarity of this species is in large part due to the natural scarcity of suitable habitat. Persephone's Darner has yet to be detected on the Williams District, but it is found to the southeast along the Mogollon Rim and to the north in Grand Canyon National Park.

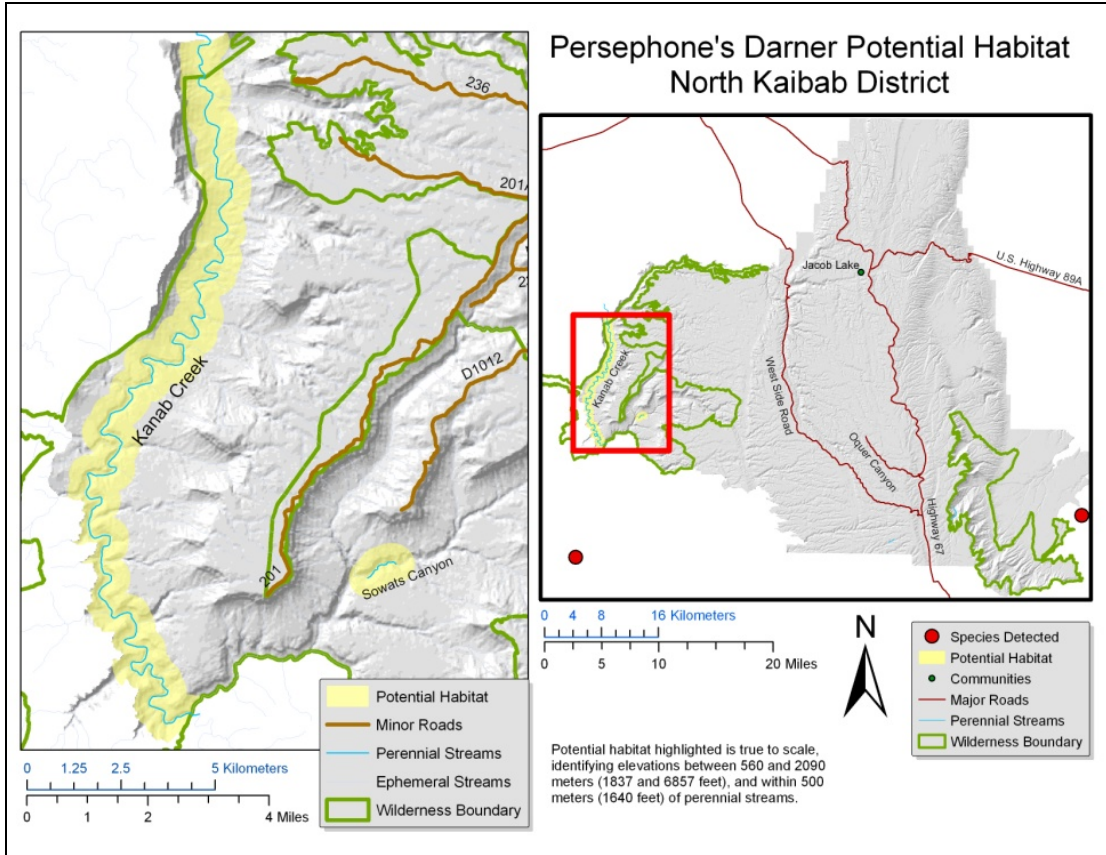


Fig. 3a: Potential range and localities of detection for Persephone's Darner on the North Kaibab District of Kaibab National Forest, Arizona.

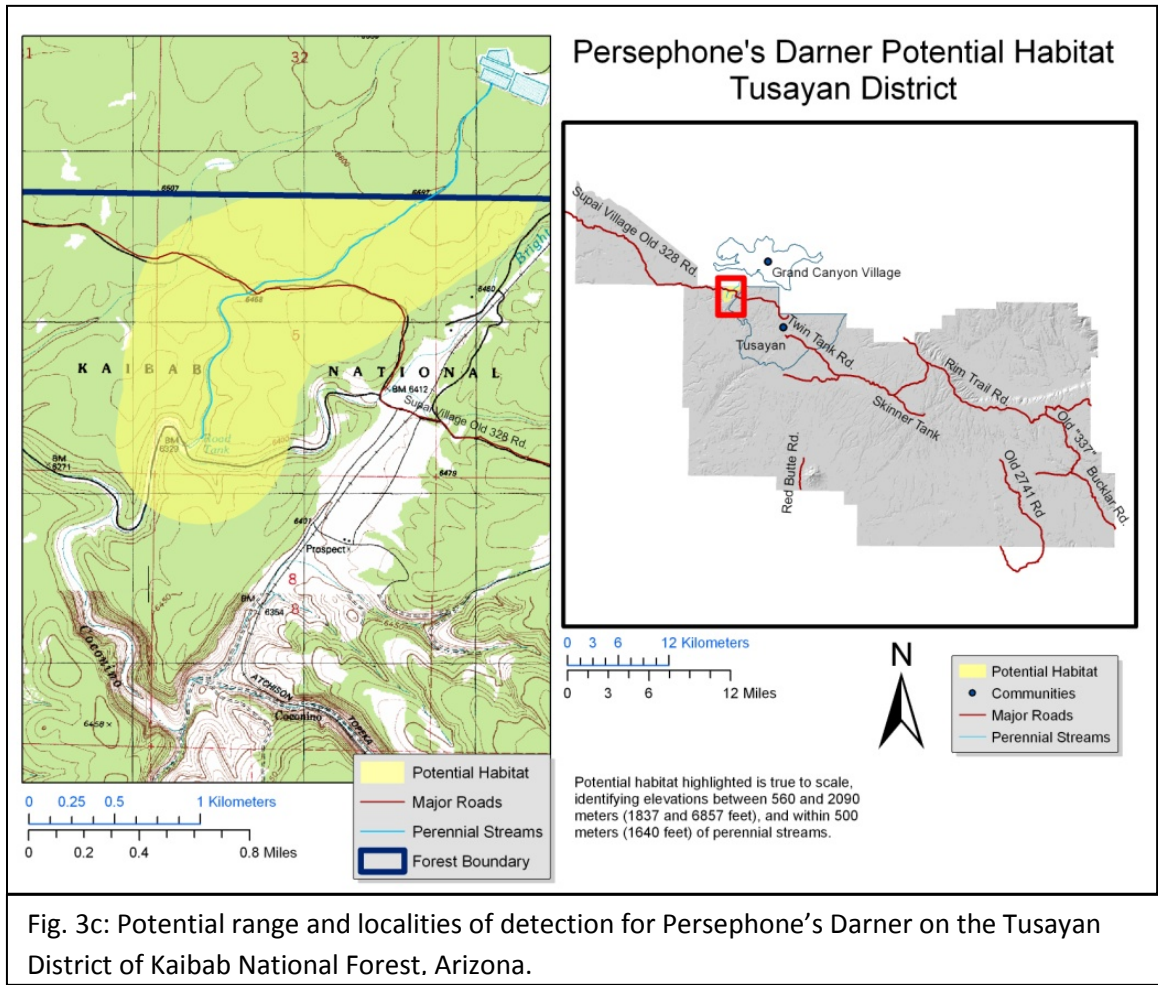


Fig. 3c: Potential range and localities of detection for Persephone's Darner on the Tusayan District of Kaibab National Forest, Arizona.

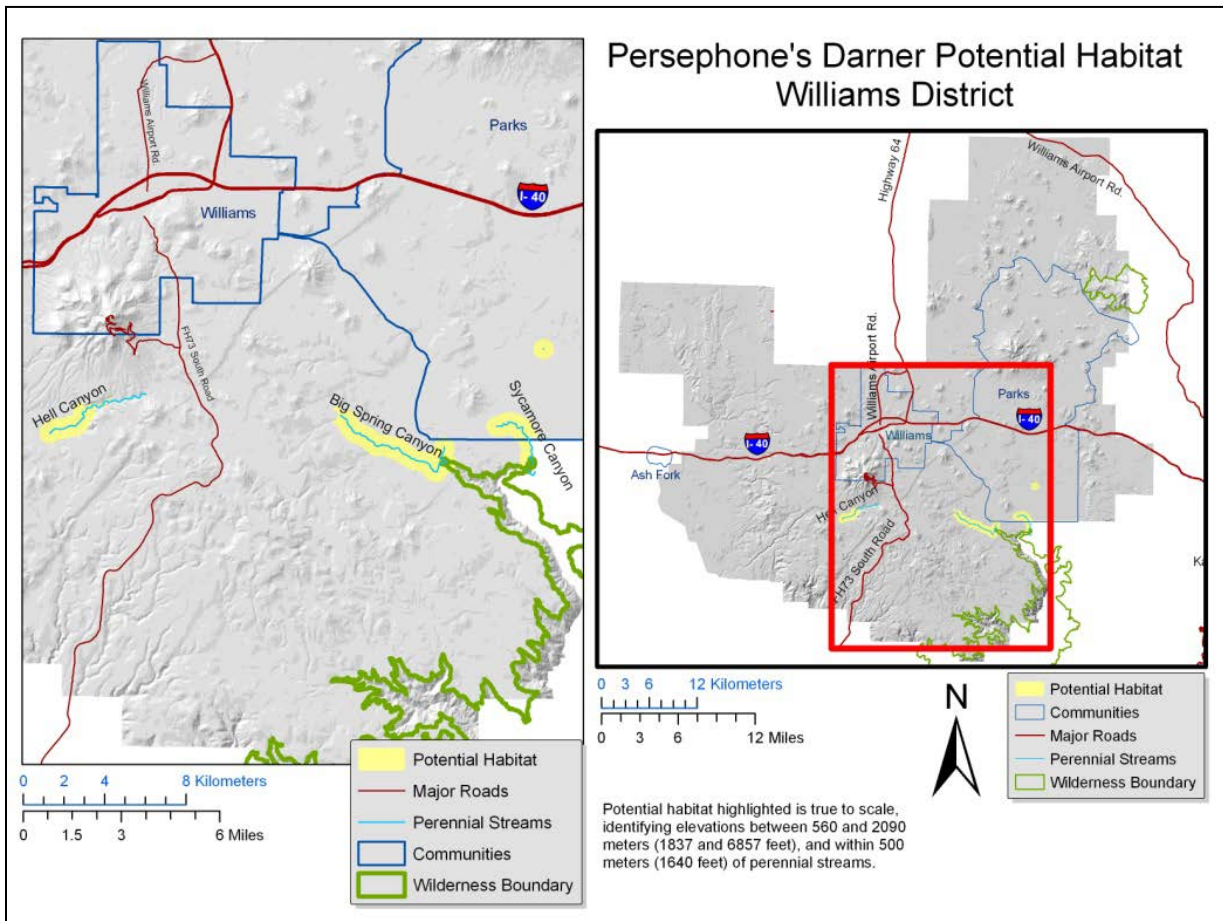


Fig. 3c: Potential range and localities of detection for Persephone's Darner on the Williams District of Kaibab National Forest, Arizona.

Habitat Requirements

This species is found in and along partially shaded desert mountain streams, and also has been documented in open riparian settings near perennial streams. It has rarely been reported away from water in this region. It is almost entirely confined to middle elevation canyons with permanent or semi-permanent flow.

Ecology and Life History

Adult Persephone's Darner fly mostly in the late summer and fall. Records extend from late July through mid-November. It is likely to have just one generation per year. Larvae are poorly studied, but are likely to exist in slow portions of desert mountain streams, where they prey on soft-bodied insects, tadpoles, and perhaps small fish.

Behavior

This species is generally regarded as being uncommon, but it is regularly encountered at low-moderate elevations. The adults are difficult to catch and difficult to distinguish from similar species, as they fly erratically, following shadow lines as they patrol, and sometimes climb to 10-15 meters above the ground.

Conservation Status

This is an uncommon species but is probably more common than the collection data reflect. Their late flight period and their restriction to more remote canyons suggest an exaggerated rarity. Donnelly (1961) commented on the conservation status of Persephone's Darner, providing additional information on its distribution and habitat requirements. As a result of improved information, its conservation status has changed from Rare (IUCN Conservation Monitoring Centre 1986; IUCN 1990) to Vulnerable (Baillie and Groombridge 1996), to its present status as an IUCN Species of Least Concern (Abbott 2007).

Threats

Persephone's Darner generally is not regarded as being threatened in natural and semi-natural habitats within its range, outside of Mexico (Bick 2003; Abbott 2007, Stevens and Bailowitz 2009). It is not known to be extremely sensitive to water quality changes, but more data are needed. However, the larvae are unlikely to persist in southwestern stream habitats that are subject to human-altered flooding, intensive grazing, water pollution, or urbanization. Occurrence of adults, which range rather widely, may not indicate that habitat is suitable for larval development. National Forest Service habitat modifying activities include an array of actions that may affect aquatic habitats in which larval Persephone's Darners develop (Table 1). Adults may be susceptible to roadkill when roads run immediately along or across wetland or stream habitats, and the species may be susceptible to pesticides applied to wetland and aquatic habitats.

This low-moderate elevation species may be expected to expand its range to higher elevations as the climate warms. Detecting such shifts will require monitoring of the Forest's lower-elevation stream segments.

Mitigation of Management Practices

Common Forest Service management activities include those listed in Table 1, and in general mitigation of erosion into perennial streams, and limiting impacts to perennial stream channels is recommended. Once the species color patterns are recognized, it is generally possible to conduct visual monitoring for it; however, developing a search image for it requires recognition of the several other common darner species in the region.

Restoration/Conservation Opportunities

Stream restoration at lower elevations on the National Forest may provide additional habitat for this species; and increased habitat area can increase large dragonfly species richness; however, additional distribution information is needed prior to using Persephone's Darner to justify such activities.

Table 1: Common general and specific Forest Service management practices, potential impacts, and mitigation actions.

General Activity	Management Action	Impacts	Mitigation Actions
Brush control	Mechanical cutting of juniper with lop and scatter to 18 to 24 inches from the ground	Wood chip cover of springs and streams	Avoid chipping near natural water sources; monitor
Brush control	Mechanical removal of emory oak, manzanita, and other brushy vegetation.	Exposure of aquatic habitats, heating water during daytime	Avoid removal of shade from shaded natural water bodies; monitor
Construction	Drainage or stream crossings by trails or roads with instertion of proper culverts to allow for water flow	Erosion, turbidity, water quality	Minimize road and trail impacts on aquatic habitats
Construction	Road construction	Erosion, turbidity, water quality impacts, dust, noise	Schedule road construction work to minimize wildlife population and habitat impacts, including larval emergence in early summer movements
Forest management	Prescribed burning	Increased temperature during fire, charcoal and sediment inflow into aquatic habitats; heavy equipment impacts	Conduct prescribed fires to minimize seasonal impacts on wildlife and habitats, especially spring and stream habitats
Forest management	Timber harvest using thinning in Ponderosa Pine	Increased temperature during fire, charcoal and sediment inflow into aquatic habitats; heavy equipment impacts	Conduct prescribed fires to minimize impacts on dragonfly habitats, especially springs and stream habitats
Forest management	Underburning using prescribed fire in Ponderosa Pine	Increased charcoal and sediment inflow into aquatic habitats; heavy equipment impacts	Conduct prescribed understory fires to minimize impacts on dragonfly habitats, especially springs and stream habitats

General Activity	Management Action	Impacts	Mitigation Actions
Livestock management	Fencing to exclude or concentrate livestock or wildlife	Fencing may exclude wildlife or concentrate livestock or wildlife into sensitive areas, such as springs and stream-riparian zones	Assess and manage fencing to minimize grazing impacts on dragonfly habitats, particularly springs and streams
Livestock management	Livestock grazing management	Erosion, turbidity, water quality	Manage livestock and game impacts on springs, streams, and wetlands habitats
Pest control	Non-native invasive plant species treatment (either mechanically or via herbicide)	Reduction or elimination of vegetation may increase erosion	Make sure herbicides are safely stored and handled, and tested to prevent unanticipated impacts on dragonflies and other aquatic resources
Pest control	Release of non-native invertebrates (e.g., crayfish) and vertebrates,(e.g., bullfrogs, tiger salamanders, and fish)	Predation, competition, disease transmission to native taxa	Control non-native fauna as feasible, using integrated pest control and long-term planning
Water resources management	Electroshocking fish as a monitoring activity	Electrical impacts on larger aquatic organisms, such as large aquatic invertebrates (e.g., hellgrammites) and fish	Ensure that electroshocking does not affect aquatic larval Odonata and other invertebrates.
Water resources management	Spring or stream capture and diversion	Reduction or elimination of surface flows	Reduced wildlife water supplies and habitat
Water supplies management	Spring and stream monitoring	Flow and water quality may dwindle or disappear without regular monitoring	Reduced wildlife water supplies and habitat

Information Gaps

The following information may help improve management of this dragonfly species.

- 1) What is the taxonomic relationship between *Aeshna persephone* and *A. palmata*?
- 2) What are *A. persephone* population dynamics, particularly in relation to fire frequency and other major anthropogenic impacts?
- 3) What is the spatial and elevational distribution of *A. persephone* larvae?
- 4) What are the water quality limitations on larval development?
- 5) What are the implications of global climate change on this species?

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TIGER BEETLES (COLEOPTERA: CARABIDAE) OF KAIBAB NATIONAL FOREST

Tiger beetles are medium-sized (3/8-1 in, 12-25 mm) ground-dwelling beetles that are active and often colorful predators. Tiger beetles recently have become much better known, due to the publication of Pearson et al's. (2006) *Field Guide to the Tiger Beetles of the United States and Canada* (Oxford University Press, Oxford). There are four genera of tiger beetles in North America north of Mexico: giant tiger beetles (*Amblycheila*), night-stalking tiger beetles (*Omus*), big-headed tiger beetles (*Tetracha*), and common tiger beetles (*Cicindela*), of which all but *Omus* occur in northern Arizona (Stevens and Huber 2004). The genus *Cicindela* has been subdivided into 11 subgenera, including *Cicindela*, *Tribonia*, *Cicindelidia*, *Habroscelidomopha*, *Eunota*, *Microthylax*, *Opilidia*, *Brasilia*, *Cylindera*, *Dromochorus*, and *Ellipsomorpha*.

Adult tiger beetles are commonly bronze, green, or blue, with cream colored maculations (markings) on their elytra (first pair of wings), and have large mandibles. Most adult tiger beetles are diurnal, but some, such as *Amblycheila* and *Tetracha* are nocturnal. Diurnal species fly up or chase down soft-bodied invertebrate prey, and often are strongly territorial. While many species have 1-2 generation per year, quite a few species have 2-3 yr life cycles.

Larval tiger beetles also are predatory, and have massive head and mandibles, and a distinctive dorsal hump on the top of the abdomen. The larvae dig a sometimes deep (>1 ft, 35 cm) vertical burrow. They rest at the top of the burrow with their heads flat to the ground, lunging out to grab passing invertebrate prey. They are sensitive to vibrations of large animals and quickly retreat deep into their burrows. Unfortunately, the larvae have not received as much scientific attention as the adults, and often have not been described.

Kaibab Variable Tiger Beetle
Carabidae: *Cicindela terricola kaibabensis* Johnson 1990



Fig. 1: Kaibab Variable Tiger Beetle *Cicindela terricola kaibabensis* Johnson 1990. Collected by A. Hadley in North Canyon Meadow on the North Kaibab District on 6/29/2002.

Taxonomy

Arthropoda

Hexapoda

Coleoptera

Carabidae - Cicindelinae

Cicindela (Cylindera) terricola

C. t. kaibabensis W.N. Johnson 1990

Description

Larvae: Larvae of the Kaibab Variable Tiger Beetle (KVTB) have not been described but are likely similar to those of other members of the subgenus *Cylindera*. They are characterized by a large, flattened head, massive mandibles, and a pronounced dorsal hump on the thorax. They construct vertical burrows from in which they wait for passing prey (primarily other invertebrates).

Adults: Adult KVTB are relatively small (less than 5/8", 15 mm long), green-bronze to blue-green tiger beetles, with narrow cream-colored maculations (colored patterns) on the elytra (first pair of wings; Fig. 1). The head has two long setae along the front edge of the eyes, and large mandibles, relatively long filiform antennae. The adults are very active during warm days in early-middle summer, and maintain an upright, "alert" posture when resting. They are easily alarmed and fly when approached within about 6 ft (2 m).

Similar Taxa

Adult KVTB are distinct from other tiger beetles in their range, being slightly larger and more metallic blue-green, and with more conspicuous maculations than either *Cicindela marutha* or *Cicindela punctulata chihuahuae*, which KVTB somewhat resembles; however, neither of these similar species occurs above 7100 ft (2150 m) elevation (Stevens and Huber 2004). The only other species that commonly co-occur with KVTB are *Cicindela longilabris* and *C. purpurea*, both of which are relatively large species.

Range

Regional: *Cicindela terricola* is widely distributed across the western United States, from Arizona northward into Canada (Fig. 2); however, the KVTB is restricted to a few meadows on the North Kaibab District.

Kaibab National Forest – North Kaibab District: Despite the wide range of *C. terricola* in western North America, the KVTB is one of the most narrowly endemic invertebrate taxa in northern Arizona (Fig. 3). The KVTB is restricted to a few variably interconnected, grass-dominated meadows on the North Kaibab District from 8 miles (13 km) north of North Kaibab Lodge eastward to the East Rim. The actual distribution of KVTB within DeMotte Park remains unknown, and this taxon does not appear to exist south of the North Rim of Grand Canyon. It has yet to be detected in Grand Canyon National Park. The potential range of KVTB on the North Kaibab District is inadequately indicated in Fig. 3 because of the limited availability of habitat mapping data. Nonetheless, the restriction of this taxon to a few mixed conifer meadows remains enigmatic because grass-dominated meadows are relatively common throughout the North Kaibab District.

The range of sites at which KVTB has been detected include: 8 miles (13 km) north of North Kaibab Lodge in DeMotte Park, and in the small meadow at the top of the North Canyon Wilderness Area.

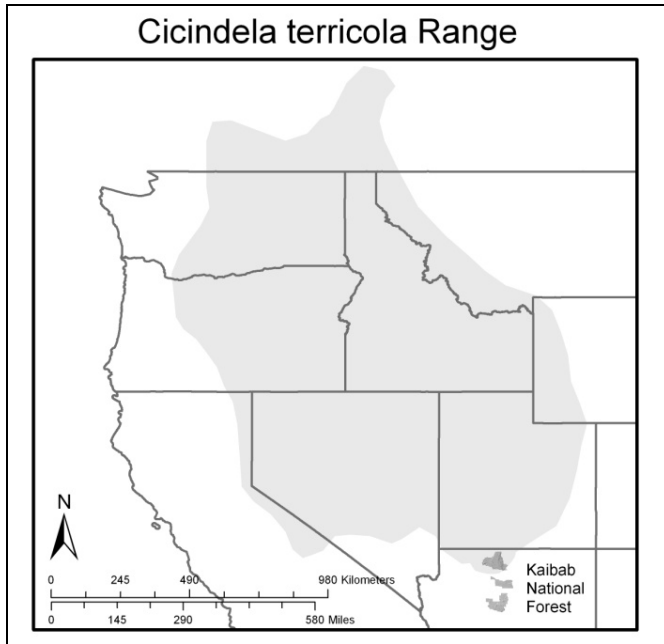


Fig. 2: Regional range map of *Cicindela terricola* in western North America.

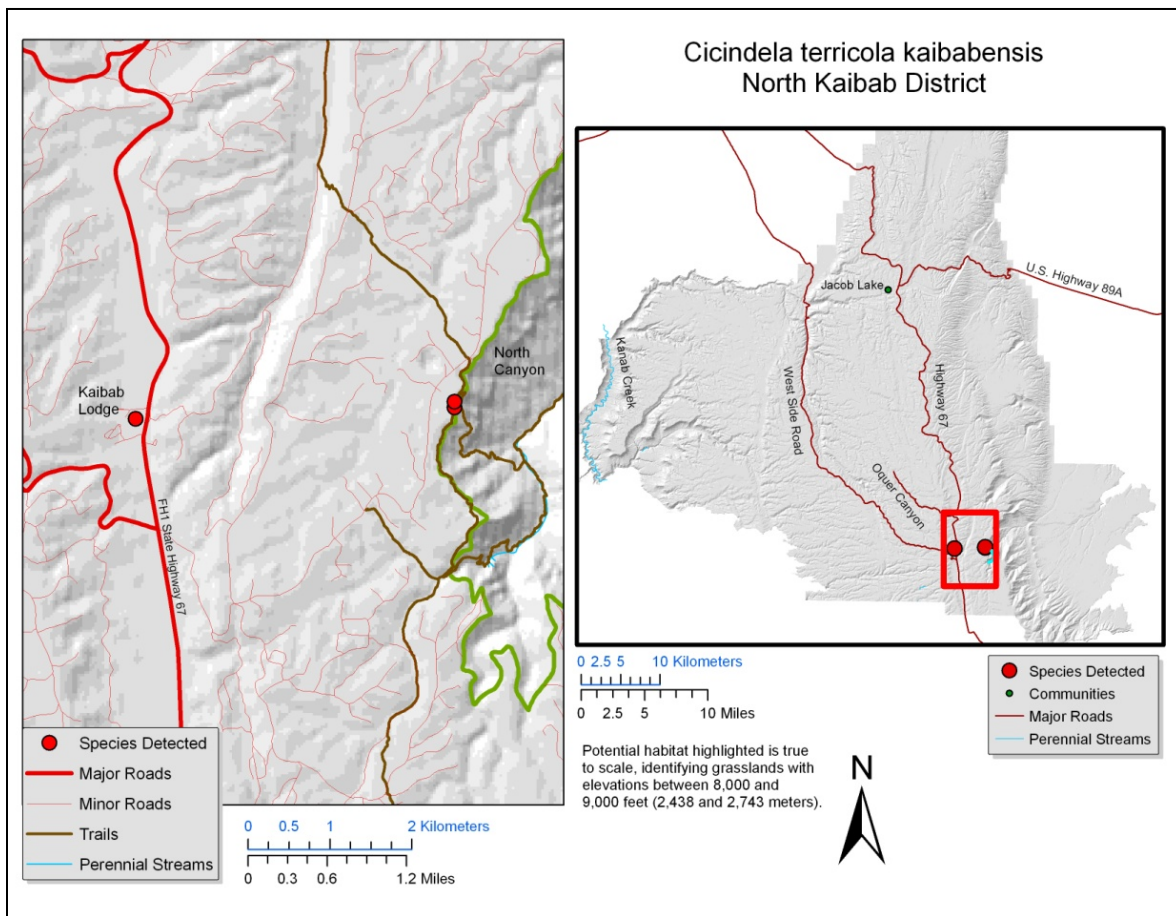


Fig. 3: Map of *Cicindela terricola kaibabensis* occurrence in the North Kaibab District of Kaibab National Forest.

Kaibab National Forest – Tusayan District: KVTB has not been collected south of the Colorado River and is not known to occur in the Tusayan District, which is likely too low in elevation to support this boreal species. Although the habitat in the White Mountains of Arizona appears to be suitable, it has not been detected there, and North Kaibab meadows appear to be its only habitat in Arizona.

Kaibab National Forest – Williams District: KVTB has not been collected south of the Colorado River and is not known to occur in the Williams District, which also is likely to be too low in elevation to support this species.

Habitat Requirements

KVTB occupies upper elevation, open grass-dominated meadows in mixed conifer forests, specifically those near the North and East rims of Grand Canyon on the North Kaibab National Forest. Perennial grass cover is approximately 20-60% in KVTB habitat, and the species appears to use small (ca 0.5 ft² – 0.05 m²) patches of open soil in which to sun and, likely, court. Larval habitats remain unstudied.

Ecology and Life History

Both larvae and adults are predaceous, and feed on soft-bodied insects. Larvae sit and wait for prey to approach their burrows, sensing vibrations in the soil. They quickly lunge out grab the unsuspecting prey with their heavy mandibles, subdue the prey and eat it. Adults sit in open patches among perennial grass clumps during sunny portions of the day, scouting for prey, intruding neighbors, and potential predators. They maintain a “ready-for-action” posture, with their heads up and abdomens lowered. Other adult tiger beetle species leap out and grapple terrestrial or slow-flying prey, but adult KVTB foraging behavior has not been studied.

From the limited amount of collection and observation information available, KVTB appears to be a pre-monsoon species, emerging in late May, and with adult activity in June and early July. Eggs are likely laid in the soil, and larvae are likely active during mid-late summer, and pupate over winter, emerging when soil temperatures warm in late springtime.

Behavior

Based on other members of the subgenus, KVTB larvae likely live in vertical burrows that are 2.5 – 8 in (6-20 cm) deep, where they rest with their heads at the top of the burrow, flat against the ground. There they wait for soft-bodied prey. They are likely extremely sensitive to vibration, and probably withdraw into the ground when they detect large animals approaching (e.g., livestock, large game, and insect collectors).

Adult KVTB are extremely active and sensitive to the approach of large animals, usually taking flight when large animals are within about 6 ft of them. When alarmed, the fly a short distance and land in perennial grass clumps, immediately burying themselves in the shallow cover. This makes it exceptionally difficult for researchers to observe, collect, or monitor them. Several species of the subgenus *Cylindera* have multi-year life cycles, and it may be that KVTB have a 2-year life cycle. This would influence the scheduling of monitoring activities.

Conservation Status

The KVTB is not regarded as rare and is listed as a G5 and S5 species (secure—common; widespread and abundant); however, it is of concern because of its naturally extremely restricted range in several North Kaibab District meadows. KVTB presently is not a federally listed species.

Threats

General threats: Threats to KVTB are primarily related to the quality and status of their habitat. However, the relationship between population dynamics of this beetle and grazing impacts has not been examined. Long-term invasion of meadow/prairie habitat by shrubs or trees would be detrimental to this species. Low grazing intensity and the activities of soil disturbing rodents (such as pocket gophers – particularly *Thomomys talpoides*, and voles - *Microtus*) are likely needed to ensure open ground among perennial grass clumps. The responses of the KVTB to grassland fire is not known, and deserves research attention. Similarly, KVTB association with the burrows of ground-disturbing rodents may deserve attention. Lastly, vegetation changes associated with global climate change may threaten meadow habitat composition.

National Forest Service Habitat- modifying Activities: National Forest Service habitat modifying activities include an array of actions that may affect meadow habitats in which larval and adult KVTB occur (Table 1). Adults may be susceptible to pesticide treatment and wildfire, but more information is needed on the sensitivity of this species.

Mitigation of Management Practices

Forest Service management practices may affect KVTB and its habitat on the North Kaibab District (Table 1), but more detailed information is needed on this beetle's ecology before such management actions can be effectively mitigated. Prior to acquisition of such information, contemporary low- to moderate livestock and non-native wildlife grazing intensity likely continue to permit the species to exist. Because it is unknown whether KVTB is sensitive to fire, it may not be advisable to burn the North Canyon Trail Meadow and the central and southern portions of DeMotte Park at the same time. Road construction and permitting off-road access across meadows in the habitat area also may warrant careful attention.

Restoration/Conservation Opportunities

KVTB is one of the most restricted taxa on the North Kaibab District, and occurs nowhere else. However, restoration and improved conservation of this taxon will likely require more detailed ecological information than presently exists, including population dynamics. It may not be advisable to expand either the beetle's present distribution or the population size of this tiger beetle, but rather to practice effective habitat management that is informed by credible inventory, research, and monitoring information. Such information should seek to provide data to answer the key research and monitoring questions. Monitoring approaches for tiger beetles vary, but most refer to recommendations about

how to non-destructively observe and report tiger beetles, with suggestions provided by Pearson et al. (2006).

If evidence of significant habitat disruption or eminent threat of extinction emerges, emergency conservation strategies may include translocation of KVTB to other appropriate habitats on the Forest, in Grand Canyon National Park, and/or propagation of this species in captivity. A good, nearby model for informed conservation of narrowly endemic tiger beetles is that of the endangered Coral Pink Sand Dune Tiger Beetle (*Cicindela albissima*), which has been thoroughly studied and is now protected by the U.S. Bureau of Land Management and the Utah State Parks system (Kinsley and Hill 2001). Lessons learned from those conservation efforts may be applicable to KVTB.

Table 1: General and specific Forest Service management activities, potential impacts, and mitigation strategies.

General Activity	Management Action	Impacts	Mitigation Actions
Brush control	Mechanical cutting of juniper with lop and scatter to 18 to 24 inches from the ground,	Wood chip cover of meadow habitats	Avoid brush removal in meadows unless it improves KVTB habitat
Brush control	Mechanical removal of emory oak, manzanita, and other brushy vegetation as a fuel reduction project near WUI	Exposure of aquatic habitats, heating water during daytime	Avoid brush removal in meadows, as soil disturbance may negatively affect larvae and adult habitat.
Brush control	Mechanical treatment of chaparral (mastication)	Exposure of meadow habitats	Avoid concentrating slash in meadows or near meadow margins, as KVTB require open soil as perching sites
Construction	Drainage or stream crossings by trails or roads with insertion of proper culverts to allow for water flow	Erosion, soil compaction	Minimize road and trail impacts on meadow habitats that may affect KVTB habitat and activity
Construction	Road construction	soil compaction, dust	Schedule road construction work to minimize KVTB population and habitat impacts, including potential dispersal
Forest management	Prescribed burning	Increased soil temperature during fire, charcoal and sediment inflow into meadow habitats; heavy equipment impacts	Conduct prescribed fires to minimize seasonal impacts on KVTB in its habitats
Forest management	Timber harvest using thinning in Ponderosa Pine	Increased soil temperature during fire, charcoal and sediment inflow into meadow habitats; heavy equipment impacts	Conduct prescribed fires to minimize seasonal impacts on KVTB in its habitats

General Activity	Management Action	Impacts	Mitigation Actions
Forest management	Underburning using prescribed fire in Ponderosa Pine	Increased soil temperature during fire, charcoal and sediment inflow into meadow habitats; heavy equipment impacts	Conduct prescribed fires to minimize seasonal impacts on KVTB and its habitats
Livestock management	Fencing to exclude or concentrate livestock or wildlife	Fencing may exclude wildlife or concentrate livestock or wildlife into sensitive areas, such as springs and stream-riparian zones	Assess and manage fencing needs to meet desired goals
Livestock management	Livestock grazing management	Erosion, dust, vegetation removal, increased soil temperature	Keep livestock away from stream margins and aquatic habitats
Pest control	Non-native invasive plant species treatment (either mechanically or via herbicide)	Reduction or elimination of vegetation may increase erosion, dust	Make sure herbicides are safely stored and handled, and apply appropriately to KVTB habitats
Pest control	Release of non-native invertebrates and vertebrates	Predation, competition, disease transmission to native taxa	Control non-native fauna as feasible, using integrated pest control and long-term planning
Water resources management	Electroshocking fish as a monitoring activity	Electrical impacts on larger aquatic organisms, such as large aquatic invertebrates (e.g., hellgrammites) and fish. No effect on KVTB.	Not applicable to KVTB
Water resources management	Spring or stream capture and diversion	Reduction or elimination of surface flows	Not applicable to KVTB
Water supplies management	Spring and stream monitoring	Resource conditions may dwindle or disappear without regular monitoring	Reduced KVTB habitat and potential population size

Research Questions

- 1) What are the genetic and taxonomic relationship between *Cicindela terricola kaibabensis* and other subspecies of *C. terricola*?
- 2) What are the specific habitat requirements of all life stages of KVTB - why do nearby mixed conifer meadow habitats not support KVTB?
- 3) What are KVTB population dynamics, particularly in relation to fire frequency, grazing, and other major anthropogenic impacts, and can those population dynamics be modeled?
- 4) What are the implications of global climate change impacts on KVTB?

Monitoring Questions

- 1) What methods are most appropriate for monitoring KVTB?
- 2) What are the population trends of KVTB within and among years?
- 3) How variable is KVTB habitat preference and use?

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SWALLOWTAIL BUTTERFLIES (LEPIDOPTERA: PAPILIONIDAE) OF THE KAIBAB NATIONAL FOREST REGION

Swallowtail butterflies include the largest butterflies in the nation, of which the many-tailed swallowtail (*Papilio multicaudata*) was recently designated as Arizona's state butterfly. This family contains at least 7 taxa in northern Arizona, including the well-known yellow tiger swallowtails (*Papilio multicaudatus* and *P. rutulus*), and several black species, including the common Baird's Old World Swallowtail (*Papilio machaon bairdii*) and the Kaibab Indra Swallowtail (*P. indra kaibabensis*). Garth (1950) provided an early review of the butterfly fauna of northern Arizona.

Swallowtail larvae are large, brightly colored and smooth, and some expose false eye spots or foul-smelling organs to deter predators. Larvae feed on an array of herbs, shrubs and small trees, mostly in the orange (Rutaceae), willow (Salicaceae), pipevines (Aristolochiaceae), and other plants.

Swallowtails undergo 1-2 generation per year, depending on the species, and are encountered throughout the growing season. The adults fly with graceful, slow wingbeats, and nectar at thistles and other flowers, and visit mud, likely for salt. Grand Canyon Wildlands Council (2004) reported that butterfly species richness was 3-fold greater and abundance was >100-fold greater at springs and water sources as compared to dry uplands in northern Arizona.

Although none of the swallowtail butterflies in northern Arizona are federally listed, and only the Kaibab Indra Swallowtail is state listed, some land units protected butterflies from collecting (e.g., the National Park Service, Indian Tribes, etc.). The sale of butterflies to private collectors around the world is a large industry, and several cases of butterfly poaching have been prosecuted (e.g., <http://www1.american.edu/TED/poachbut.htm>).

Kaibab Indra Swallowtail
***Papilio indra kaibabensis* Bauer 1955**



Fig. 1: Kaibab Indra Swallowtail – *Papilio indra kaibabensis* Bauer 1955

Taxonomy

Arthropoda

Hexapoda

Lepidoptera

Papilionidae

Papilio indra

Papilio indra kaibabensis Bauer

Description

Larvae: When first laid, Kaibab Indra Swallowtail (KIS) eggs are yellow-green and turn black before hatching. First instar larvae are black with a light to white patch mid-dorsally. As the larvae mature they are pink and black striped and have orange-colored dots.

Adult: KIS is a medium-sized swallowtail, mostly black with narrow to absent yellow bands on all wings ventrally and on the forewings dorsally. It has obvious blue patches on the

dorsal hindwings, and has moderately long narrow tails on the hindwings. The pupil on the hindwing eyespot is centered and the abdomen usually lacks yellow spotting.

Similar Species

KIS is most similar to the *Papilio indra minori*, which occurs north of the KIS range in southern Utah. Another similar taxon is the female *Papilio machaon bairdii*, which may co-occur with KIS. Morphological, phenological, and host plant association differences help to distinguish KIS from female *P. m. bairdii*. *P. m. bairdii* has a line of thick yellow dots on the hindwing. It flies in early spring and autumn, while KIS flies in early-mid summer. The pupil of the eyespot tends to be smaller and closer to the hind margin of the wing in *P. m. bairdii* and the abdomen is spotted with yellow. *P.m. bairdii* larvae are restricted to members of the Rutaceae (orange family), such as *Thamnausma montanum*, a lower- to mid-elevation shrub species in northern Arizona, and possibly also to hoptree (*Ptelea* sp.) at higher elevations.

Range – Regional: While *P. indra* is widespread throughout the southern United States, KIS is regionally scarce and only locally common (Fig. 2). Thus far, KIS has only been detected in Coconino County in Arizona (Fig. 3a), mostly between 5100 and 8200 ft (1500 and 2500 m) elevation (Fig. 3). KIS is restricted to the region in and immediately around the eastern basin of Grand Canyon near the Kaibab Uplift, but the KIS population on Cedar Ridge, south of Page, Arizona may be included in this taxon. KIS appears to intergrade or hybridize with *P. indra minori* from western Colorado and southern Utah.

Kaibab National Forest – North Kaibab District: The potential range of KIS includes the southern and eastern boundary areas of the North Kaibab District. KIS primarily occurs around the edges of the eastern basin of Grand Canyon mostly along and below the North Rim. While KIS is primarily occurs in Grand Canyon National Park, individuals are likely to be found on adjacent North Kaibab District lands.

Kaibab National Forest – Tusayan District: The potential range of KIS on the Tusayan District is indicated in Fig. 2, and shows that KIS has been detected near the boundaries of the Tusayan District, but has not yet been detected on this District. The absence of this species in the Tusayan District is due to the natural scarcity of suitable host plants and habitat.

The range of points at which KIS has been detected near the Tusayan District boundaries include: AZ: Coconino Co., Navajo Indian Reservation (Cedar Ridge area); AZ: Coconino Co., Bureau of Land Management (13 miles W of Cameron); AZ: Coconino Co., Grand Canyon National Park (Yavapai Point). These or closely related populations also have been documented from 13 miles west Cameron, Arizona. Thus, KIS may occasionally occur along the northern boundary of the Tusayan District.

North Kaibab National Forest – Williams District: KIS has not been detected from the Williams District, due to the absence of host plants and suitable habitat.

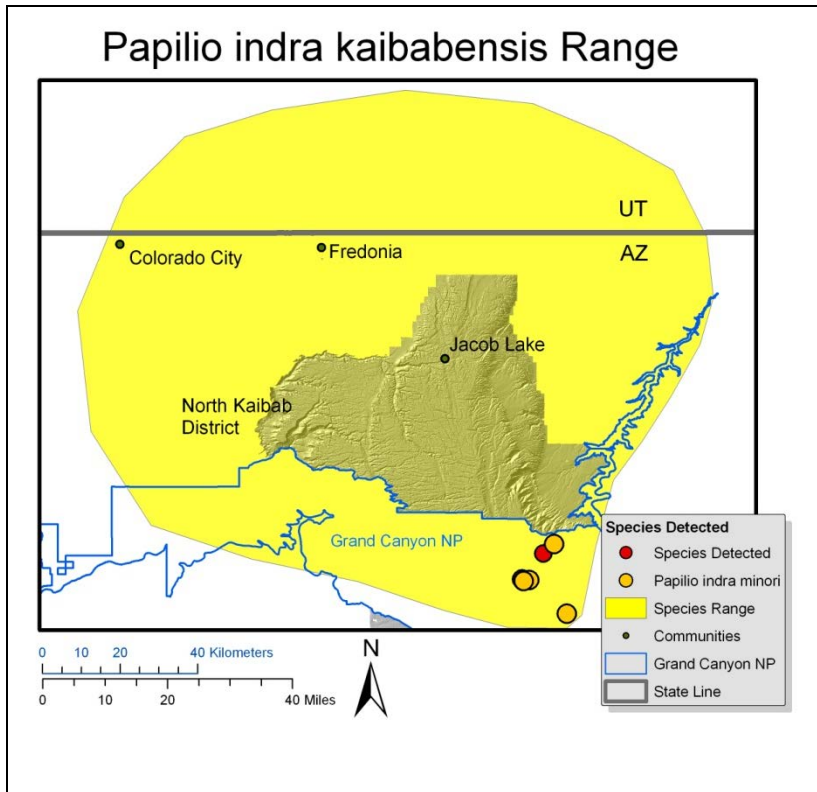


Fig. 2: Regional map of *Papilio indra kaibabensis* on the southern Colorado Plateau.

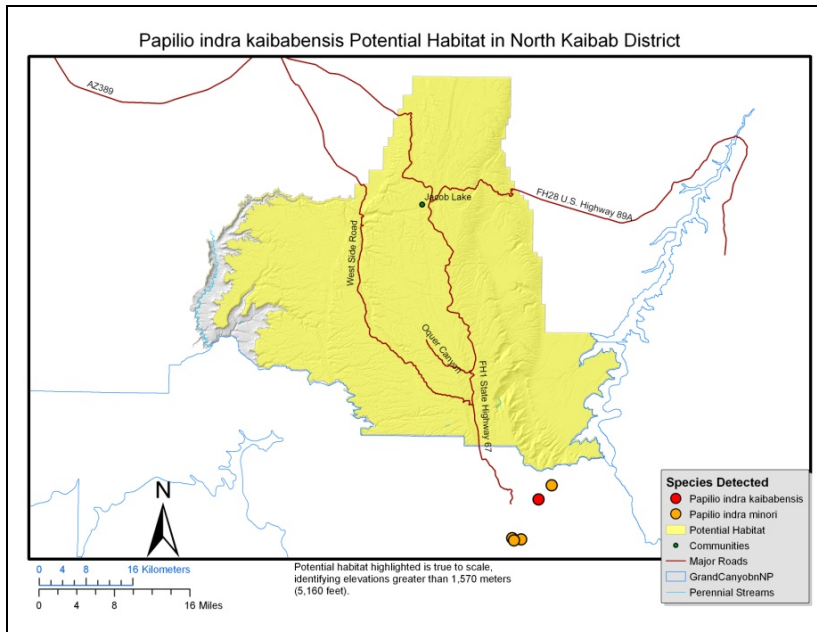


Fig. 3: Distribution of *Papilio indra kaibabensis* on the North Kaibab District.

Habitat Requirements

KIS exists in pinyon-juniper and dry mixed coniferous forest habitats - rugged terrains with great topographic relief. In part this is related to the distribution of larval host plants. The larvae feed on various species of desert Apiaceae, including parsleys and umbels, of which *Pteryxia petraea* and *Lomatium* spp. occur on and along the North Rim. However, inventory data on host-plant population distribution are few, and development of a host-plant management plan will require basic inventory.

Ecology and Life History

KIS is double brooded, with the stronger brood flying in May and June, and the second, less predictable flight in August. The larvae are described in detail by Scott (1986) and are sometimes conspicuous on its Apiaceae host plants, but additional information is needed on KIS host plant preferences on Kaibab National Forest. Adult KIS nectar at several flower species and also come to damp soils. Adult males congregate on hilltops, a behavior that distinguishes KIS from other similar black swallowtails in the region. The larvae pupate attached to protected hard substrata.

Behavior

Larvae are conspicuously colored, but remain in the host plant foliage. The chrysalis is attached to firm substrata. Adults fly with slow, erratic wingbeats.

Conservation Status

KIS are listed by NatureServe as a G5 species, demonstrably secure globally, although it may be rare in parts of its range, especially at the periphery. However, it is of conservation concern because of its restricted range around the eastern basin of Grand Canyon, and because of poaching threats. KIS presently is not a federally listed species, but is additional study may warrant such a designation.

KIS is uncommon, but the treacherous terrain it inhabits makes the study of adult behavior challenging. Although the larvae are easily visible on host plants, they are not easily reared. The NPS limits collecting in Grand Canyon, restraints that are likely sufficient to maintain viable butterfly populations if host plant populations are healthy. Butterfly collecting is not restricted on the Kaibab National Forest.

Threats

General threats: Because of the close relationship between butterflies and their host plants, a decline in host plant population often results in decline of associated butterflies. However, the status of KIS host plants is not known, and merits further study. Host plant surveys are needed prior to management project implementation.

A substantial industry exists in the sale of butterflies to private collectors around the world and a now-classic case of butterfly poaching involved KIS (<http://www1.american.edu/TED/poachbut.htm>). In that case., Richard Skalski, Thomas Kral, and Marc Grinnell were convicted in 1995 of illegally capturing thousands of butterflies from U.S. National Parks and Wildlife Refuges, including taking KIS from Grand Canyon National Park without National Park Service permission. Specimens were offered for sale over the internet. This crime was vigorously and successfully prosecuted by the U.S.

Fish and Wildlife Service. Poaching and over-collecting of larvae remain a conservation concern for such rare butterflies and other showy invertebrate species.

National Forest Service Habitat- modifying Activities: National Forest Service habitat modifying activities include an array of actions that may affect habitats in which larval and adult KIS occur (Table 1).

Table 1: General and specific Forest Service management activities, potential impacts, and mitigation strategies.

General Activity	Management Action	Impacts	Mitigation Actions
Brush control	Mechanical cutting of juniper with lop and scatter to 18 to 24 inches from the ground	Wood chip cover of meadow habitats	Avoid chipping near meadows
Brush control	Mechanical removal of emory oak, manzanita, and other brushy vegetation as a fuel reduction project near WUI	Exposure of aquatic habitats, heating water during daytime	Avoid concentrating slash; monitor
Brush control	Mechanical treatment of chaparral (mastication)	Exposure of meadow habitats	Avoid concentrating slash; monitor
Construction	Drainage or stream crossings by trails or roads with instertion of proper culverts to allow for water flow	Erosion, soil compaction	Minimize road and trail impacts on meadow habitats
Construction	Road construction	soil compaction, dust	Schedule road construction work to minimize KVTB population and habitat impacts, including potential dispersal
Forest management	Prescribed burning	Increased soil temperature during fire, charcoal and sediment inflow into meadow habitats; heavy equipment impacts	Conduct prescribed fires to minimize seasonal impacts on KVTB an its habitats
Forest management	Timber harvest using thinning in Ponderosa Pine	Increased soil temperature during fire, charcoal and sediment inflow into meadow habitats; heavy equipment impacts	Conduct prescribed fires to minimize seasonal impacts on KVTB an its habitats

General Activity	Management Action	Impacts	Mitigation Actions
Forest management	Underburning using prescribed fire in Ponderosa Pine	Increased soil temperature during fire, charcoal and sediment inflow into meadow habitats; heavy equipment impacts	Conduct prescribed fires to minimize seasonal impacts on KVTB and its habitats
Livestock management	Fencing to exclude or concentrate livestock or wildlife	Fencing may exclude wildlife or concentrate livestock or wildlife into sensitive areas, such as springs and stream-riparian zones	Assess and manage fencing needs to meet desired goals
Livestock management	Livestock grazing management	Erosion, dust, vegetation removal, increased soil temperature	Keep livestock away from stream margins and aquatic habitats
Pest control	Non-native invasive plant species treatment (either mechanically or via herbicide)	Reduction or elimination of vegetation may increase erosion, dust	Make sure herbicides are safely stored and handled, and apply appropriately to KVTB habitats
Pest control	Release of non-native invertebrates and vertebrates	Predation, competition, disease transmission to native taxa	Control non-native fauna as feasible, using integrated pest control and long-term planning
Water resources management	Electroshocking fish as a monitoring activity	Electrical impacts on larger aquatic organisms, such as large aquatic invertebrates (e.g., hellgrammites) and fish. No effect on KVTB.	Not applicable to KVTB
Water resources management	Spring or stream capture and diversion	Reduction or elimination of surface flows	Not applicable to KVTB
Water supplies management	Spring and stream monitoring	Resource conditions may dwindle or disappear without regular monitoring	Reduced KVTB habitat and potential population size

Mitigation of Management Practices

Forest Service management practices may affect KIS, its host plants, and its food plants and habitat (Table 1), but more detailed information is needed on KIS ecology before such management actions can be effectively mitigated. Host plants, caterpillars and adult KIS may be susceptible to rim fire management. Prescription burning of canyon rim areas should be localized, at least until host plant distributions are better understood. However, the steep terrain in which this species exists makes it difficult to mitigate indirect impacts. Road and trail construction through habitat should be carefully considered or avoided if possible. KIS and its host plants may be susceptible to pesticide treatments, and such treatments should be reviewed for potential impacts on this butterfly.

Restoration/Conservation Opportunities

The scant information on KIS host plant use and population dynamics, and the extreme topographic relief of their habitats, limit the potential for direct conservation. General conservation of the habitat should be pursued by reducing road and trail impacts, limiting non-native plant introductions, and through appropriate fire management.

Research Questions

- 1) What are the genetic and taxonomic relationship between the several populations of *Papilio indra kaibabensis* and *P.i. minori*?
- 2) What are KIS population dynamics, and particularly in relation to anthropogenic impacts?
- 3) What are KIS host plants and what is the distribution and status of those host plants?
- 4) What is the extent of trade in KIS larvae and adults?
- 5) What are the implications of global climate change impacts on KIS?

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