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Source: Journal of Orthoptera Research, 24(2) : 49-54

Published By: Orthopterists' Society

URL: https://doi.org/10.1665/034.024.0202

Instars of narrow-winged saltbush grasshopper, *Aeoloplides tenuipennis* (Scudder, 1897) (Acrididae: Melanoplinae), with notes on habitat and identification

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Abstract

Early stages of narrow-winged saltbush grasshopper, *Aeoloplides tenuipennis*, have not been figured in the literature, hindering their separation from economically harmful or benign species of grasshoppers and hampering ecological or taxonomic investigations. During June and July 2015, five instars of *A. tenuipennis* were collected or photographed at two sites in Cochise County, Arizona, U.S.A. These are illustrated alongside a brief morphometric table. Notes on habitat, identification and polychromatism, and a comparison with 4th and 5th instars of the widespread snakeweed grasshopper, *Hesperotettix viridis viridis*, are included.

Key words

Nymph, Arizona, Chenopodiaceae, polychromatism, San Pedro Riparian National Conservation Area, Whitewater Draw, Cochise County, snakeweed, *Hesperotettix viridis viridis*

Introduction

Identifying and counting grasshopper nymphs is one of the first steps in making timely, economically sound, and environmentally safe decisions in pest management (Berry *et al.* 1996-2000 a, b). In the western United States, the instars (nymphal stages) of most grasshoppers harmful to crops or rangeland have been described (*e.g.*, Pfadt 1994, Johnson 2008, Brust *et al.* 2014, and see bibliography in Dysart 1996-2000). In contrast, species present in small numbers, occupying unusual habitats, or specializing on plants avoided by livestock generally do not pose an economic threat and their nymphs are less likely to attract attention. Nonetheless, early life history studies of "less important" species may yield ecological and systematic rewards, shedding light on poorly-known genera, highlighting behaviors, and fostering an understanding of specializations allowing numerous similar species to coexist.

The narrow-winged saltbush grasshopper, *Aeoloplides tenuipennis* (Fig. 1), is a common western species ranging from eastern California, Arizona and southwestern New Mexico north through Utah and southern Nevada to southern Idaho (Wallace 1955, Richman *et al.* 2014). Doubtless, it is present in the Mexican state of Sonora (one of my collecting sites is only 5 km north of the Mexican border), and perhaps in Chihuahua, but its range south of the U.S. border has not been clarified. It and its food plants inhabit Lower Sonoran life zone desert scrub, alkali flats, and grasslands. The nine similarly-appearing members of its genus (Eades *et al.* 2015) are recently derived, and largely allopatric (Fig. 2). They appear to have resulted from a Mexican progenitor that spread northward along three geographic fronts (Wallace 1955). All are stenophagous, specializing on saltbush and its relatives. In southeastern Arizona, *A. tenuipennis* is abundant on fourwing saltbush, *Atriplex canescens*; it also occurs on cattle saltbush, *Atriplex polycarpa*, seepweed or seabite, *Suaeda* spp., greasewood, *Sarcobatus vermiculatus*, and introduced prickly Russian thistle, *Salsola tragus* (Ball *et al.* 1942, Wallace 1955). Historically, these plants were considered members of the goosefoot family (Chenopodiaceae); however, current evidence places them with the amaranths (Amaranthaceae). The specialized chenopod diet includes noxious plants such as prickly Russian thistle (tumbleweed), and *A. tenuipennis* is generally considered innocuous to beneficial where cattle are grazed. Consequently, it has been ranked 368th out of 377 species in a pest-status scoring of western rangeland grasshoppers (Dysart 1996-2000). Little has been published on the nymphs of *A. tenuipennis*, and no illustrations have been presented, even on photo websites such as Flickr or BugGuide.Net that have a voracious appetite for images of Orthoptera.

Methods

On 11 and 19 June, and 22 July 2015, I visited the San Pedro Riparian National Conservation Area (SPRNCA), Palominas, Cochise County, Arizona (31.376956°N -110.106303°W) at an elevation of 1,292 m (4,238 ft.). On the June dates, various instars of *A. tenuipennis* were photographed during mid-morning. During the later date, instars and adults were observed and conspicuous plants were identified. The habitat is Chihuahuan Desert scrub on fine alluvium just above an old channel of the San Pedro River. Dominant shrubs were fourwing saltbush, rubber rabbitbrush, *Ericameria nauseosa* (Asteraceae), mesquite, *Prosopis juliflora* (Fabaceae), and littleleaf sumac, *Rhus microphylla* (Anacardiaceae). Ground cover included introduced Johnson grass, *Sorghum halepense* (Poaceae), lovegrass, *Eragrostis* sp. (Poaceae), prickly Russian thistle, pitseed goosefoot, *Chenopodium berlandieri* (Chenopodiaceae), buffalo gourd, *Cucurbita foetidissima* (Cucurbitaceae), Drummond's clematis, *Clematis drummondii* (Ranunculaceae), peppergrass, *Lepidium* sp. (Brassicaceae), Coulter's horseweed, *Laennecia coulteri* (Asteraceae), golden crownbeard, *Verbesina encelioides* (Asteraceae), scrambled eggs, *Corydalis aurea* (Papaveraceae), velvet weed, *Oenothera curtiflora* (Onagraceae), silverleaf nightshade, *Solanum elaeagnifolium* (Solanaceae), copper globemallow, *Sphaeralcea angustifolia* (Malvaceae), trailing windmills, *Allionia incarnata* (Nyctanginaceae), and Dakota mock vervain, *Glandularia bipinnatifida* (Verbenaceae). All visits were made during mid-late morning. Temperatures 11 and 19 June were *ca* 32° C (90°F) and 24°C (76°F) on 22 July.

On 22 and 28 June, and 9 July 2015, specimens were collected at Whitewater Draw State Wildlife Area (WDSWA) in the Sulphur Springs Valley, Cochise County, Arizona (31.559994°N -109.715943°W) at an elevation of 1,245 m (4,084 ft.). The draw, a

Fig. 1. Adult female *Aeoloplides tenuipennis* on fourwing saltbush, San Pedro Riparian National Conservation Area. Photographed 8 September 2015. (Photo Robert A. Behrstock/Naturewide Images).

basin surrounded by farmland and Chihuahuan Desert scrub/Desert grassland, receives *ca* 330 mm (13 in.) of rainfall/year (WeatherDB 2015) and collects runoff and sediments from surrounding North-South oriented mountain ranges. Alluvial soils adjacent to managed wetlands support extensive stands of fourwing saltbush. Other shrubs at the collecting site were a few small mesquites. Ground cover included plains bristlegrass, *Setaria macrostachya* (Poaceae), peppergrass, prickly Russian thistle, Coulter's horseweed, golden crownbeard, hairyseed bahia, *Bahia absinthifolia* (Asteraceae), burroweed, *Isocoma tenuisecta* (Asteraceae), silverleaf nightshade, copper globemallow, and trailing windmills. Specimens were collected by shaking foliage over the mouth of an insect net. The area sampled was *ca* 20 × 30 m and included both individual plants and clumps of fourwing saltbush. All visits to Whitewater Draw were made during mid-morning to mid-day and temperatures were *ca* 32°C (90°F).

On 11 July, three nymphs (one 4th instar and two 5th instars) of the snakeweed grasshopper, *Hesperotettix viridis viridis*, were collected for comparison with *A. tenuipennis*. They were netted from burroweed growing at roadside in dry, shrubby habitat along Middlemarch Road in the Dragoon Mountains, Cochise County, Arizona (31.852363°N -109.973765°W) at an elevation of 1,644 m (5,394 ft.).

Nymphs were held in a refrigerator for one day prior to being photographed. Individuals selected for photos were further relaxed in a freezer for *ca* 3 min. This additional short chill did not appear to alter their coloration. Chilled nymphs were then photographed live with a Nikon D7000 camera, Nikon strobe, and a Sigma 180mm lens. All nymphs were then preserved in 70% isopropyl alcohol.

First through 5th instars were identified by wing bud (wingpad) characteristics (Brust *et al.* 2014, Capinera *et al.* 2001). Measurements of instars included: body length taken from the anterior-most point of the head rearward and parallel with the body axis to the rearmost point of the body (terminal abdominal appendages or the tip of the subanal plate); length of the hind femur measured from the anterior-most point of the femur (dorsal to the articulation with the coxa) to the tip of the dorsal lobe of the hind knee; and head depth measured from the highest point on the occiput to the lowest point on the labrum. Antennal segments of the flagellum (*i.e.*, beyond the pedicel) were counted. These proved very difficult to discern on early instars before the segments are differentiated and more heavily pigmented; thus, rather broad ranges are presented. Measurements were made with a Wild M5 microscope fitted with an optical reticle.

Adult grasshoppers often appear strikingly different from their fifth instars, both in form and coloration. In order to confirm the nymphal series with a known adult, eleven 5th instar nymphs were collected on 9 July 2015, at WDSWA and placed in a fine mesh butterfly rearing cage with a supply of fourwing saltbush.

Results

By 16 July, three adult male *A. tenuipennis* had eclosed in the rearing cage, confirming the identity of the 5th instar nymphs collected at WDSWA.

During all visits to WDSWA, nymphs of *A. tenuipennis* were present in large numbers, individual bushes harboring perhaps 20-40/m^2. Approaching any saltbush elicited an explosive, popcorn-like spectacle as adults and various instars reacted to shadows or movement, launching toward cover in the center of the bush, a behavior reported by Wallace (1955) and Barnum (1964). On 9 July, nymphs and adults were noted on saltbush, prickly Russian thistle, and on open ground where they were resting or basking. Disturbed adults abandoned prickly Russian thistle and jumped or flew to cover in taller fourwing saltbush. By 9 July, most nymphs appeared to be 4th and 5th instars; only a few smaller nymphs were present. On

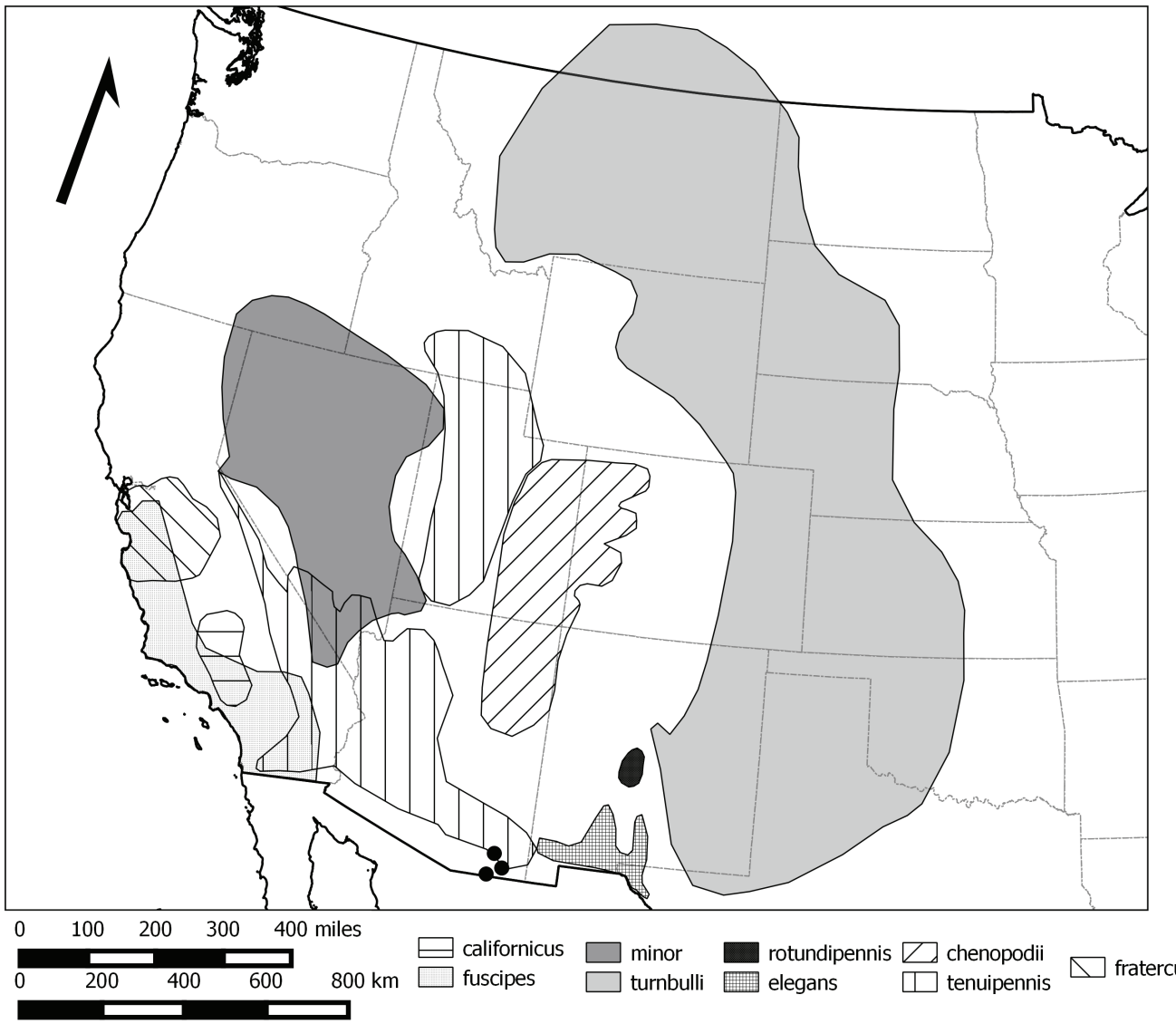

Fig. 2. Distribution of all *Aeoloplides* species (from Wallace 1955, Barnum 1964, and Strohecker *et al.* 1968). Black dots indicate collection localities of the present study.

22 July, fourwing saltbush and prickly Russian thistle at SPRNCA held smaller numbers of nymphs, mostly 5th instars, and a very few younger ones.

Discussion

Aeoloplides tenuipennis overwinters in the egg stage. Eggs hatch perhaps as early as April, certainly during May and June. I encountered one 1st instar nymph on 22 June. Other records of nymphs include: ARIZONA, May and June (Ball *et al.* 1942); 27-28 July, Yuma County (Rehn & Hebard 1908); 18 August, Coconino County (Wallace 1955); and 11 July, Pima County (Wallace 1955); CALIFORNIA, 19 July, Riverside County and 27 July, Mono County (Wallace 1955); NEVADA, nymphs on various Chenopodiaceae as late as 22 August at the Nevada Test Site, primarily Nye County (Barnum 1964).

An internet search yielded four or five *Aeoloplides* nymphs photographed in habitat, and five more posed for keys. These included Russian thistle grasshopper, *A. turnbulli*, California saltbush grasshopper, *A. californicus*, and Southern Coast bush grasshopper, *A. fuscipes* (Pfadt 1994, Brust *et al.* 2014, BugGuide.Net 2015, flickriver.com 2015, flickrhivemind.net 2015). Based on these photos, nymphs of *A. turnbulli* and *A. californicus* are especially similar to *A. tenuipennis* which is not surprising as Wallace (1955) considered *turnbulli*, *californicus*, *tenuipennis*, and little saltbush grasshopper, *A. minor*, to constitute a subgroup within the genus. Barnum (1964, p. 38) stated it was "impractical" to attempt to separate nymphs of *A. tenuipennis*, from those of little saltbush grasshopper, *A. minor*, which was sympatric in his Nevada study area. A male nymph of *A. fuscipes* of southern and southwestern California (Strohecker *et al.* 1968), photographed 6 April 2011, by Alice Abela in San Luis Obispo County, California, differed markedly from its photographed congeners in possessing a dark stripe that began in the rear portion of the eye, and continued rearward across the head and pronotum into the wing pads. It also exhibited three dark brown bands on the outer, inner, and upper surfaces of the hind femur, black lateral stripes on the abdominal segments, generally dark hind tibia, and much dark pigmentation on the tarsi of the front and middle legs. It lacked a wedge at the base of the hind femur, a feature present on some other members of the genus.

Using the Lucid nymph grasshopper key (Brust *et al.* 2014),

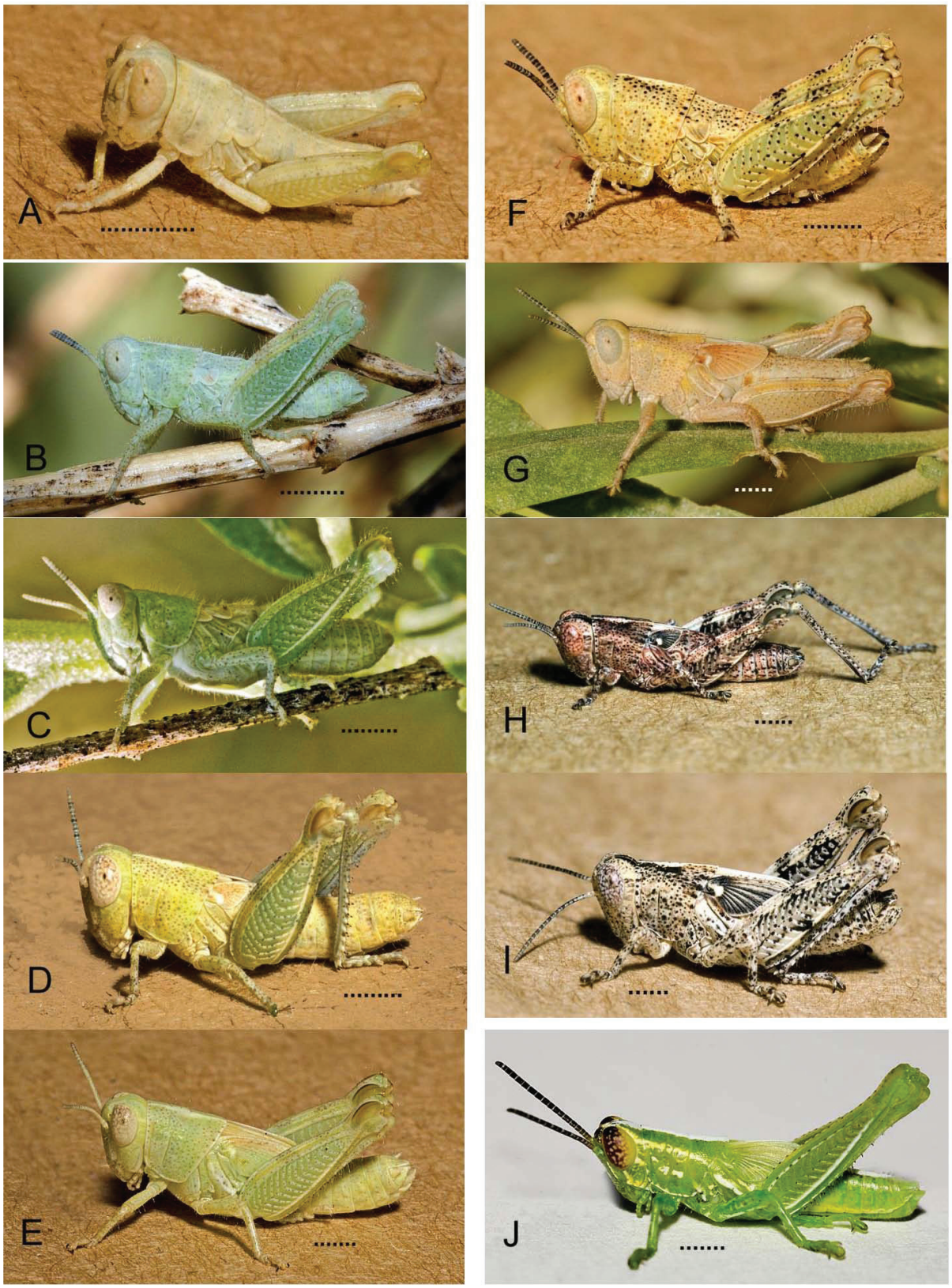

Fig. 3. A-I *Aeoloplides tenuipennis* nymphs. A: 1st instar, Whitewater Draw State Wildlife Area (WDSWA), 22 June 2015; B: 2nd instar, San Pedro Riparian National Conservation Area (SPRNCA), 19 June 2015; C: 3rd instar, SPRNCA, 19 June 2015; D: 4th instar, WDSWA, 22 June 2015; E: 5th instar, WDSWA, 22 June 2015; F: 3rd instar, heavily pigmented yellow morph, WDSWA, 28 June 2015; G: 5th instar, pink morph, SPRNCA, 22 June 2015; H: 4th instar, heavily pigmented, WDSWA, 22 June 2015; I: 5th instar, heavily pigmented, WDSWA, 22 June 2015; J: *Hesperotettix viridis* 5th instar, Dragoon Mountains, 11 July 2015. For all photos, dashed scale bar represents *ca* 2 mm. (Photos Robert A. Behrstock/Naturewide Images). For color version, see Plate I.

Table 1. Collection date, instar number, number of individuals measured (n), body length (BL) range and mean, hind femur length (HF) and mean, ratio of mean FL to mean BL, head depth (HD) range and mean, and antennomere counts (ANT) for instars of *Aeoloplides tenuipennis* collected at Whitewater Draw Wildlife Area and *Hesperotettix v. viridis* collected in the Dragoon Mountains.

Date	Instar	n	BL ($\bar{x}$)	FL ($\bar{x}$)	$\bar{x}$ FL/$\bar{x}$ BL	HD ($\bar{x}$)	ANT
Aeoloplides tenuipennis							
22 June	1	1	7.30 (7.30)	3.46 (3.46)	0.47	2.38 (2.38)	c. 12
22-28 June	2	7	7.69-9.53 (8.30)	3.84-5.23 (4.65)	0.56	2.53-3.23 (2.87)	c. 17-19
28 June-9 July	3	4	11.07-12.00 (11.45)	5.38-5.84 (5.61)	0.48	3.23-3.46 (3.32)	c. 16-19
28 June	4	6	10.92-14.00 (12.68)	6.30-7.07 (6.86)	0.54	3.69-3.92 (3.82)	c. 18-20
22-28 June	5	5	15.07-17.53 (15.81)	7.38-8.46 (8.02)	0.50	4.40-4.92 (4.53)	20-23
Hesperotettix v. viridis							
11 July	4	1	11.23 (11.23)	7.07 (7.07)	0.63	3.38 (3.38)	c. 19
11 July	5	2	15.38-15.53 (15.45)	8.00-8.30 (8.15)	0.52	3.69-3.76 (3.72)	c. 20-21

the nymphs used in this study (whose range is outside the key's coverage) are identified as, or being close to, *A. turnbulli*. Character states yielding a near identification for green *A. tenuipennis* I collected are: instar number = 4, presence of spine on throat = yes, portion of month collected = late June, body length = 12.68 mm, hind femur length = 6.86 mm, outer femur face pattern = *either* mottled or spotted *or* light or dark bands, hind tibia color = blue, head - face angle = near vertical, predominant head color = tan or green, compound eye appearance = lighter spots within eye, antennae shape = filiform. Ignoring the 'head profile pattern' character yielded an identification of *A. turnbulli*. On pale green specimens, the choice '= mottled or blotchy' would have been correct. However, the key required the response 'horizontal stripe or patch behind or below eye,' a variable character on *A. turnbulli* and *A. tenuipennis* and lacking in some nymphs. Brust *et al.* (2014) note that certain characters may be selected or skipped while working through the key. By selecting the most significant characteristics, I was able to distinguish various color morphs of *Aeoloplides* nymphs from the other sixty or so nymphal species included using only seven character states.

Hebard (1935, p. 300) referred to the adults of *A. tenuipennis*, which exhibit striking ranges in wing and body length, and pigmentation, as "one of the most plastic species found in the arid southwest," attributing the variety of topomorphs to their feeding on certain plants. Even within the small geographic area sampled at WDSWA, nymphs of *A. tenuipennis* were notably polychromatic, occurring side-by-side on fourwing saltbush in green, pink, pale yellow, ivory, and rusty morphs that exhibited sparse to heavy maculation.

First instars of *A. tenuipennis* are pale yellowish-greenish with a near vertical face, sparse minute fuscous speckles over much of the body, a pale stripe on the midline of the pronotum, short, filiform antennae, no stripe on the hind femur, and milky white spots separated by pale reddish spaces on the surface of the compound eye (Fig. 3A); their presence on chenopods is a useful characteristic.

On progressively older instars (Table 1), the density of the maculation may or may not increase. Figs 3B-E depict 2nd-5th instars of the pale green morph, the most common form at SPRNCA and WDSWA. With age, there is a general increase in the fuscous spotting on all parts of the body, but not sufficient to obscure the pale ground color. On some individuals, the antennules are more heavily pigmented, as are the spines on the hind tibiae. The hind tibiae may be pale green, pale blue or pale yellow. The white stripe on the midline of the pronotum (that may continue rearward onto the abdomen) is contrastingly paler and not defined at its margins by denser maculation. The face of the hind femur remains pale with tiny darker flecks within the pale bands between chevron-like ridges. Some individuals may have darker pigmentation on the semilunar process of the hind knee. On 4th and 5th instars there is often a white spot on the wing bud of the tegmen (*e.g.*, Figs 3D, E, G, H, I). Other pale morphs may be yellow or pink, as is a 5th instar (Fig. 3G). All stages lack prominent lateral pronotal carinae, and an elevated mid-pronotal ridge that is or is not deeply cut by sulci. These features, along with the filiform antennae, unbanded head, pronotum, and hind femur, prosternal spine, near vertical face, and affinity for Chenopodiaceae help separate *A. tenuipennis* from the 80 or so other grasshopper species found near WDSWA and SPRNCA.

Pfadt (1994) noted differences in maculation among color forms of *A. turnbulli*. Tan or gray nymphs usually had three dark marks on the exterior face and marginal areas of the hind femur but these marks were faint or absent in green forms. Similarly, green forms of *A. tenuipennis* exhibited lightly or unpatterned hind femora. Forms I would characterize as yellow, ivory, or rufous exhibited denser and more widely spread maculation on all parts of the body, including crisply annulated antennules, dense pigmentation outlining the dorsal pronotal stripe, and denser and darker speckling on the head, pronotum, abdomen, and hind tarsi (Figs 3F, H, I.).

Barnum (1964) mentioned the difficulty in distinguishing green or tan nymphs of *A. tenuipennis* (which may or may not possess a pronotal stripe), from the very similar nymphs of the snakeweed grasshopper, *Hesperotettix viridis*, a widespread species found in much of the U.S.A. In southeastern Arizona and southwestern New Mexico, green nymphs of *A. tenuipennis* and the subspecies *H. v. viridis* of the western U.S.A. are likely to occur sympatrically where their host plants (chenopods and bushy asters, respectively) coexist on silty flats, fallow fields, or Chihuahuan Desert scrub. Separation of the two in southeastern Arizona appears straightforward, as *H. v. viridis* exhibits (at least in the last four instars), a gleaming white dorsal stripe from the occiput toward or reaching the base of the supra-anal plate, various white lines and maculations on the margins and lateral fields of the of the pronotum, white diagonal bands on the meso- and metathorax, and white longitudinal carinae on the face of the hind femora (Fig. 3J., Brust *et al.* 2014). *A. tenuipennis* is a pale pastel green and *H. v. viridis* is closer to emerald green. Yellow, pink, or heavily maculated individuals of *A. tenuipennis* are not likely to be confused with *H. v. viridis*.

Adults of *A. tenuipennis*, *A. turnbulli*, *A. californicus* and *A. minor* are very similar, as are their nymphs, whose subtle differences may be overshadowed by variation in color or maculation. Except in limited zones of sympatry, their various instars are perhaps best identified by noting their distribution. In zones of sympatry, identification may depend on rearing a sample of nymphs.

Acknowledgements

Thanks to W. Eugene Hall (Collections Manager, Entomology Collection, University of Arizona, Tucson) for providing a microscope and lab space, and Jim Garrett (Manager, Arizona Game and Fish Dept., Whitewater Draw Wildlife Area, Elfrida) for courtesies extended to me. Thanks also to David Ferguson (Belen, New Mexico) and Sidney W. Dunkle (Tucson, Arizona) for providing copies of important references, and to Mimi Kamp (Bisbee, Arizona) and Elizabeth Makings (Arizona State University Herbarium, Tempe) for identifying several plants. Special thanks to Aileen Thompson (Stellenbosch University, South Africa) for preparing the distribution map.

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