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Life Cycle of the Phyline Plant Bug *Conostethus americanus* Knight, 1939 (Hemiptera: Heteroptera: Miridae) in Native Mixed-Grass Prairie in Wyoming, USA

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Abstract

The life cycle of the phyline plant bug *Conostethus americanus* Knight, 1939 (Hemiptera: Heteroptera: Miridae: Phylinae) is documented based on a population from native mixed-grass prairie in southeast Wyoming, USA. The bug is monophagous, univoltine, and overwinters as eggs in tufts of its host, Sandberg bluegrass (*Poa secunda* J. Presl, Poaceae). Eggs are laid in the host's leaf sheaths and occasionally along the rib of wilted leaves. The eggs hatch in April, coinciding with the host's first spring leaf growth. During the daytime, older nymphs (instars III–V) and recently molted adults are typically found on bare ground, adjacent to the host tuft crowns. After dark, the nymphs and recently molted adults climb onto the leaves to feed. The first adults appear in early May. Males outnumber females (1.5:1). Mating and oviposition occur during the latter half of May and early June. The distribution of *C. americanus* and its host are mapped. Seasonality is described. Host specificity and habitat affinity, which prevent competition with the ubiquitous *Labops hesperius* Uhler, 1872 (Hemiptera: Heteroptera: Miridae), are discussed. Photographs of adults, eggs, nymphs, host feeding damage, and habitat are provided.

Key words: *Poa secunda*, Sandberg bluegrass, nymph, oviposition, feeding damage, competition, *Labops hesperius*, sex ratio

Introduction

The small phyline genus *Conostethus* Fieber (Hemiptera: Heteroptera: Miridae: Phylinae) includes nine mostly western Palearctic species (Schuh 2002–2013; Schuh and Menard 2013). The single New World representative, *Conostethus americanus* Knight, 1939, was described from Colorado, Montana, and South Dakota (Knight 1939). It is poorly represented in collections and the few literature references are limited to location records or observations of feeding damage to rangeland grasses. Its life cycle is unknown and the nymphs have not been described. Although *C. americanus* is reported to develop on introduced crested wheatgrass (*Agropyron cristatum* (L.) Gaertn., Poaceae) (Spangler and MacMahon 1990), native hosts have not been identified.

Conostethus americanus is small (≈ 4 mm), mostly green and yellow with distinct black antennae, elongate, with long wings extending beyond the apex of the abdomen (Figs. 1, 2). It is easily recognized by the distinctly bowed front tibiae (Fig. 2), curved and densely pilose (on ventral side) third antennal segment in the male (Fig. 1), and large protruding red eyes. Pubescence is simple, short, and appressed. The Nymphs were reported to occur in early May in central Utah by Spangler and MacMahon (1990).

The literature and Symbiotic Collection of Arthropods Network (SCAN) online database (SCAN 2023) include approximately 130 occurrence records for *C. americanus* from 43 sites in Canada and the western United States (Fig. 3). The species is known from southeast Alberta to central Saskatchewan in Canada (Kelton 1980), south across Montana (Mills 1939, 1941) to South Dakota (Knight 1939), Nebraska (SCAN 2023), and southern Colorado (Polhemus 1994), and west to western Wyoming (Kondrateiff and Schmidt 2005) and central Utah (Knowlton 1954;

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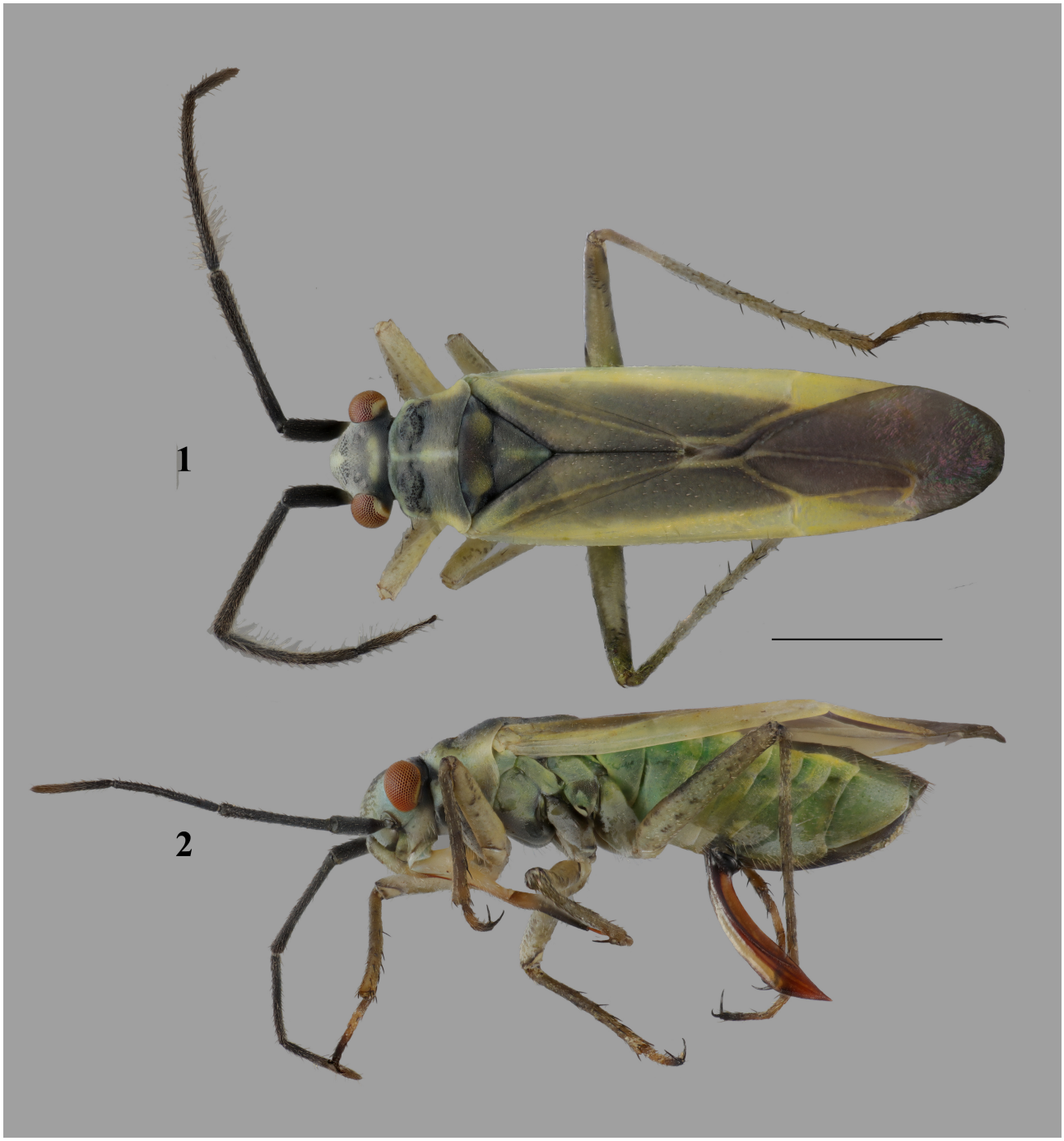
Spangler and MacMahon 1990) in the USA. In addition, apparently disjunct populations have been reported from northwestern Canada, including the Yukon (Scudder 2008) and the Tuktoyaktuk Peninsula at the northern boundary of the Northwest Territories (SCAN 2023). All the specimens reported in the literature and SCAN database were collected between early May and mid-July.

Kelton (1980) collected *C. americanus* from prairie grasses in Canada and Polhemus (1994) reported the species from short-grass prairie in Colorado. SCAN occurrence records from the western United States include collections from prairie grasses, mixed grasses, *Artemisia* L. (Asteraceae), *Quercus* L. (Fagaceae), Pacific madrone (*Arbutus menziesii* Pursh, Ericaceae), and Pacific dogwood (*Cornus nuttallii* Audubon ex Torr. & A. Gray, Cornaceae). The Canadian SCAN records include reported associations with alfalfa (*Medicago sativa* L., Fabaceae), *Melianthus* L. (Melianthaceae), and slender wheatgrass (*Elymus trachycaulus* (Link) Gould ex Shinners, Poaceae). However, many of the associations reported in the literature and SCAN database probably do not represent true hosts. Most of the specimens in the SCAN database were captured by sweep netting or beating vegetation.



FIGURES 1–2. Habitus photographs of *Conostethus americanus*. 1, Dorsal aspect ♂. 2, Lateral aspect ♀. Scale bar = 1 mm.

Wheeler (2001) and Schuh and Menard (2013) suggested *C. americanus* is probably a grass feeder and most of the early literature consists of reports of damage to native and cultivated livestock forage. In Montana, Mills (1939) reported *C. americanus* damage to numerous grasses (Poaceae) including cultivated winter wheat (*Triticum aestivum* L.), prairie Junegrass (*Koeleria macrantha* (Ledeb.) Schult.), Sandberg bluegrass (*Poa secunda* J. Presl), needle and thread grass (*Hesperostipa comata* (Trin. & Rupr.) Barkworth), and western needlegrass (*Achnatherum nelsonii* (Scribn.) Barkworth). Knowlton (1954) described "serious" feeding damage to grasses in Utah and the U.S. Department of Agriculture (1962) reported damage to "bluestem grass" in Wyoming.

The only bionomic information available for *C. americanus* appears to be research conducted by Spangler and MacMahon (1990) in a monoculture of introduced crested wheatgrass in a reseeded rangeland pasture in central Utah. *Conostethus americanus* was reported as one of three "major sap feeders" on crested wheatgrass and exhibited "strong relationships" to its phenology. It was most abundant during the leaf stage and declined as the grass began seed head development and occurred at only low densities during post-leaf stages. Crested wheatgrass is native to Russia and was introduced to North America in the late 1800s to improve range forage production (Vaness and Wilson 2007) and, according to Rogler and Lorenz (1983), is the most widely used introduced grass in the semiarid and arid regions of the western United States. It is present throughout most of western North America (Global Biodiversity Information Facility (GBIF) 2023).

Spangler and MacMahon (1990) reported an average of four adult *C. americanus*/plant in the Utah crested wheatgrass monoculture. In a non-native "biculture", which included both crested and tall wheatgrass (*Thinopyrum elongatum* (Host) D.R. Dewey, Poaceae), a density of 0.26/plant was reported. Nymphs were present in the reseeded crested wheatgrass pasture in early May. Spangler and MacMahon (1990) released over 200 nymphs between two transplanted crested wheatgrass plants to test the effectiveness of big sagebrush (*Artemisia tridentata* Nutt., Asteraceae) in repelling mirids. After 10 hours, the nymphs had migrated from the release site to the adjacent crested wheatgrass plants.

In early May 2023, I encountered many small, green mirid nymphs active on the soil surface adjacent to tufts of Sandberg bluegrass in southeast Wyoming. Leaves were beginning to grow from the tufts, but other vegetation at the site was still dormant. Inspection revealed feeding damage on some of the emerging leaves. I reared these nymphs to adults and identified them as *C. americanus* based on Kelton's (1980) key and Knight's (1939) original description.

In this paper, I describe the life cycle of *C. americanus* in native mixed-grass prairie at the western extent of the North American Great Plains. I identify Sandberg bluegrass as the host and describe the development of nymphs and reproduction in relation to the host's phenology. I also describe microhabitat selection of *C. americanus* nymphs and recently molted adults that results in spatial segregation and reduced competition with the nymphs of the black grass bug, *Labops hesperius* Uhler, 1872 (Hemiptera: Heteroptera: Miridae), which occurs in the study area in large numbers on western wheatgrass (*Pascopyrum smithii* P. A. Love, Poaceae).

Materials and Methods

This study was conducted in a 100-ha rangeland pasture of native mixed-grass prairie on Rabbit Creek Ranch in the eastern foothills of the Laramie Mountain Range in northeast Platte County, Wyoming, USA (N42.2294, W-105.1832, 1,583 m a. s. l.). Common grasses (Poaceae) in the pasture include western wheatgrass, needle and thread grass, blue grama (*Bouteloua gracilis* (Kunth) Lag. ex Griffiths), Indian ricegrass (*Achnatherum hymenoides* (Roem. & Schult.) Barkworth), and Sandberg bluegrass. Invasive cheatgrass (*Bromus tectorum* L.) is spreading in the pasture. Dense stands of skunkbush (*Rhus aromatica* Aiton, Anacardiaceae) and prickly pear cactus (*Opuntia* Mill., Cactaceae) are common. The rangeland pasture is grazed in the spring and summer by cattle, in the fall and winter by deer and elk, and year-round by pronghorn.

The area is semiarid with pronounced seasonality and subject to strong fall and winter winds. Mean annual precipitation is less than 34 cm and drought is common (Knight *et al*. 2014). Most of Platte County, including the study area, has been under abnormally dry to severe drought conditions nearly continuously since June 2019 (Wyoming Water Resources Data System/State Climate Office 2023). However, above-average precipitation occurred in the study area during the spring of 2023.

Occurrence records for *C. americanus* and *P. secunda* shown in Fig. 3 were compiled from multiple sources including literature records and the SCAN (2023) and GBIF (2023) online databases. The GBIF database includes

records for both currently recognized subspecies of Sandberg bluegrass (*juncifolia* and *secunda*). GBIF subspecies records were merged and mapped as a combined *P. secunda* group in Fig. 3 and only the GBIF records outside the *P. secunda* range mapped by Soreng and Gillespie (2018) are shown. *Conostethus americanus* locations shown in Fig. 3 are based on SCAN occurrence records supplemented with additional records from the study area, Spangler and MacMahon (1990), U.S. Department of Agriculture (1962), Mills (1939, 1941), and a record for Elbert County, Colorado from Polhemus (1994), which appears to be missing from the SCAN database.

Nymphs collected from the study area were raised to adults in small (50 x 50 x 15 mm) rearing chambers at approximately 20˚C, 65–80% RH, and 14:10 L:D. The nymphs proved easy to rear on a diet of Sandberg bluegrass leaves. Supplemental water was not required as long as an elevated RH was maintained in the rearing chamber. Fresh leaves were provided every few days. Except for occasional losses during molting, nymph survival was 95+%.

I maintained adults in larger (70 x 80 x 100 mm) rearing chambers, under identical temperature, humidity, and light conditions, to observe feeding, mating behavior, and oviposition. The bottom of the adult rearing chambers was covered with a layer of dirt and sand with small gravel from the study site. Instead of loose leaves, small tufts of *P. secunda* were planted in the corners of the adult rearing chambers and replaced every few days.

Photographs were taken with a Dun Inc. BK Plus Lab System using a Canon 5DS camera with 5 and 10X LD Mitutoyo objective lenses. Image stacks were montaged using Zerene Stacker. Photographs were edited using Adobe Photoshop CS6. Measurements were made on digital images using scales calibrated for each Mitutoyo lens. Voucher specimens have been deposited in the National Museum of Natural History, Smithsonian Museum, Washington, D.C.; the American Museum of Natural History, New York; and the Canadian National Collection of Insects and Arachnids, Ottawa. Plant names are consistent with the U.S. Department of Agriculture's Plant Database (https://plants.usda.gov/home).

Results and Discussion

Host Plant. Sandberg bluegrass was the host for *C. americanus* in the study area. Nymphs collected in early May were reared from instars II–V to adults on a diet of only Sandberg bluegrass leaves. After the final molt, adults from these rearing experiments were relocated to larger rearing chambers with tufts of Sandberg bluegrass with culms. The adults readily fed on the host, mated, and the females oviposited. Mills (1939) had previously reported *C. americanus* feeding on Sandberg bluegrass in Montana.

Sandberg bluegrass is a widely-distributed, highly variable complex of cool-season, perennial bunchgrasses that are common in the foothills and lower elevations of eastern Wyoming (Skinner 2010; Rocky Mountain Herbarium 2023). Its taxonomy is complex with 40 published names in the group (Kellogg 1985). Most of the separate taxa have been synonymized into a single species in recent years, although some current treatments continue to recognize two morphologically different subspecies. Halvorson (2011) summarized the current taxonomy of the group as "a *Poa* by any other name is *secunda*, and some of us are thankful."

Sandberg bluegrass is common in western North American rangelands from northern Mexico to southern Alaska and across much of the Northern Great Plains. Fig. 3 shows an estimate of the range of *P. secunda* north of Mexico developed by Soreng and Gillespie (2018) compared with SCAN (2023) and literature occurrence records of *C. americanus*. Additional occurrence records of Sandberg bluegrass included in the GBIF database (GBIF 2023), and outside Soreng and Gillespie's estimated range, are also shown in the figure. All but two of the currently known *C. americanus* occurrence locations are within the Sandberg bluegrass range mapped by Soreng and Gillespie (2018). Both of these sites are in close proximity to Sandberg bluegrass occurrence records in the GBIF database (Fig. 3) including on the Tuktoyaktuk Peninsula in the Northwest Territories.

In the study area, Sandberg bluegrass is often the dominant grass on windblown ridges with shallow, gravelly soils. Sandberg bluegrass is one of the first grasses to green up in the early spring, but cures quickly and is usually dormant by early summer (U.S. Department of Agriculture 2009). In the study area, many of the plants are completely dried by mid-June. Howard (1997) summarized the plant's phenology in southern Idaho as follows: start of growth at the end of March; first flower stalks at the end of April; seed heads fully developed in mid-May; plants begin drying in late May; flowers in bloom in early June; seeds ripe at the end of June; seed dissemination begins at the end of June; seed dissemination complete at the end of July; plants completely dried by early July. These dates undoubtedly vary considerably over the species' range.

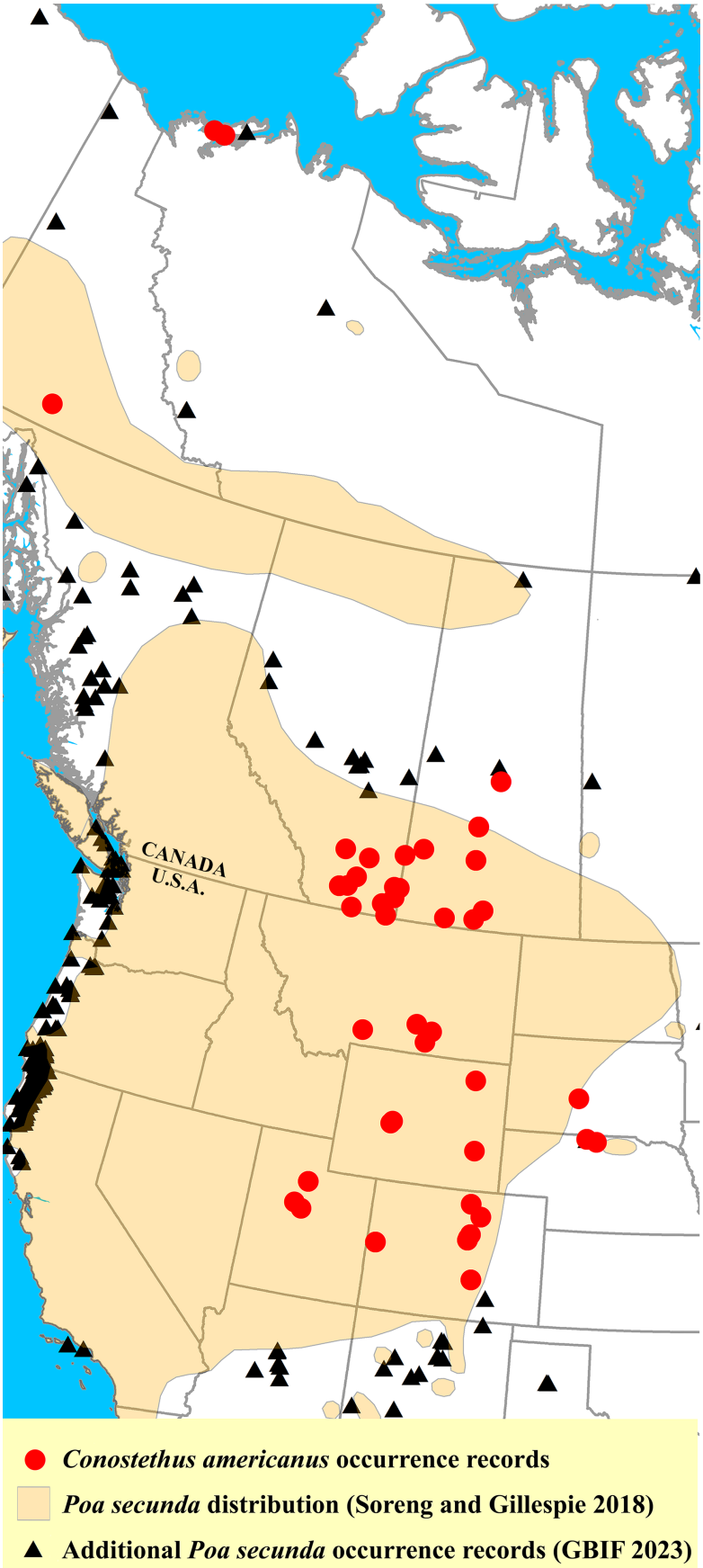


FIGURE 3. Distribution of *Conostethus americanus* and its host *Poa secunda* in western North America.

Microhabitat Selection. *Conostethus americanus* nymphs and adults occupied a narrow band (1–5 x 20 m) of dry, sandy to gravelly soil with little or no grass litter and sparse (≈ 120/m^2) tufts of Sandberg bluegrass (Fig. 4). The widely-spaced tufts were between 20 and 70 cm in diameter and produced one or two short (usually about 10 cm) culms beginning in mid-May. Adult *C. americanus* appeared simultaneously with the development of the first culms. The narrow band of sandy to gravelly soil occupied by *C. americanus* also had a few cheatgrass and western wheatgrass seedlings interspersed among the dominant Sandberg bluegrass tufts.

The Euro-Siberian *Conostethus roseus* Fallén also appears to be associated with dry, sandy soil sites with sparse vegetation. In Surry England, Woodroeffe (1959) reported large aggregations of *C. roseus* adults and nymphs from dry sandy soils covered "only by a thin growth" of vegetation. Stehlík (1977) reported *C. roseus* from "sterile" ground in Moravia. Information is currently unavailable to determine whether other members of the genus share a similar habitat preference.

At the study site, *C. americanus* nymphs and recently molted adults were found on the ground surface during the day, most often in small shallow wind-scoured depressions in the bare dirt at the base of the tufts. They were rarely observed on the host during the day but occasionally older nymphs and recently molted adults were observed wandering across open areas between tufts. The nymphs appeared to seek shade during the late afternoon. Older adults were found during the day on the culms and leaves of the host or flying between plants.

Seasonality. Collection dates in the literature and in the SCAN (2023) database suggest *C. americanus* is univoltine across its range. Most SCAN and literature collection dates occur between mid-May and the end of June. July records are limited to specimens from Saskatchewan, the Yukon (Scudder 2008), the Tuktoyaktuk Peninsula in the Northwest Territories, and a few specimens from central Colorado. The earliest seasonal report of the species is for nymphs collected in Utah on 4 May (Spangler and MacMahon 1990). The earliest adult record is Knight's (1939) paratype from Capa, South Dakota collected on 12 May.

During this study, instar I nymphs were not found. Large numbers of instar II–V nymphs were present on 2 May 2023, coinciding with active host leaf growth. By 6 May, most of the nymphs collected from the site were instar IV and no instar II and only a single instar III nymph were found. On 10 May, when culms were observed on some of the tufts, the population consisted entirely of instar IV and V nymphs and a few adults. By 15 May, adults were common. The last nymphs were observed at the site on 19 May. Adults persisted at the site until 14 June. The number of adults at the site decreased steadily after the end of May and adults were difficult to locate after early June when the host plants began to dry.

The phenology of the host precludes a second generation of *C. americanus* in the study area. Sandberg bluegrass cures early. In Idaho, Howard (1997) reported the grass begins drying in late May. In the study area, completely dry tufts were observed in early June. The dry hosts would not sustain a second generation of nymphs or provide suitable oviposition sites.

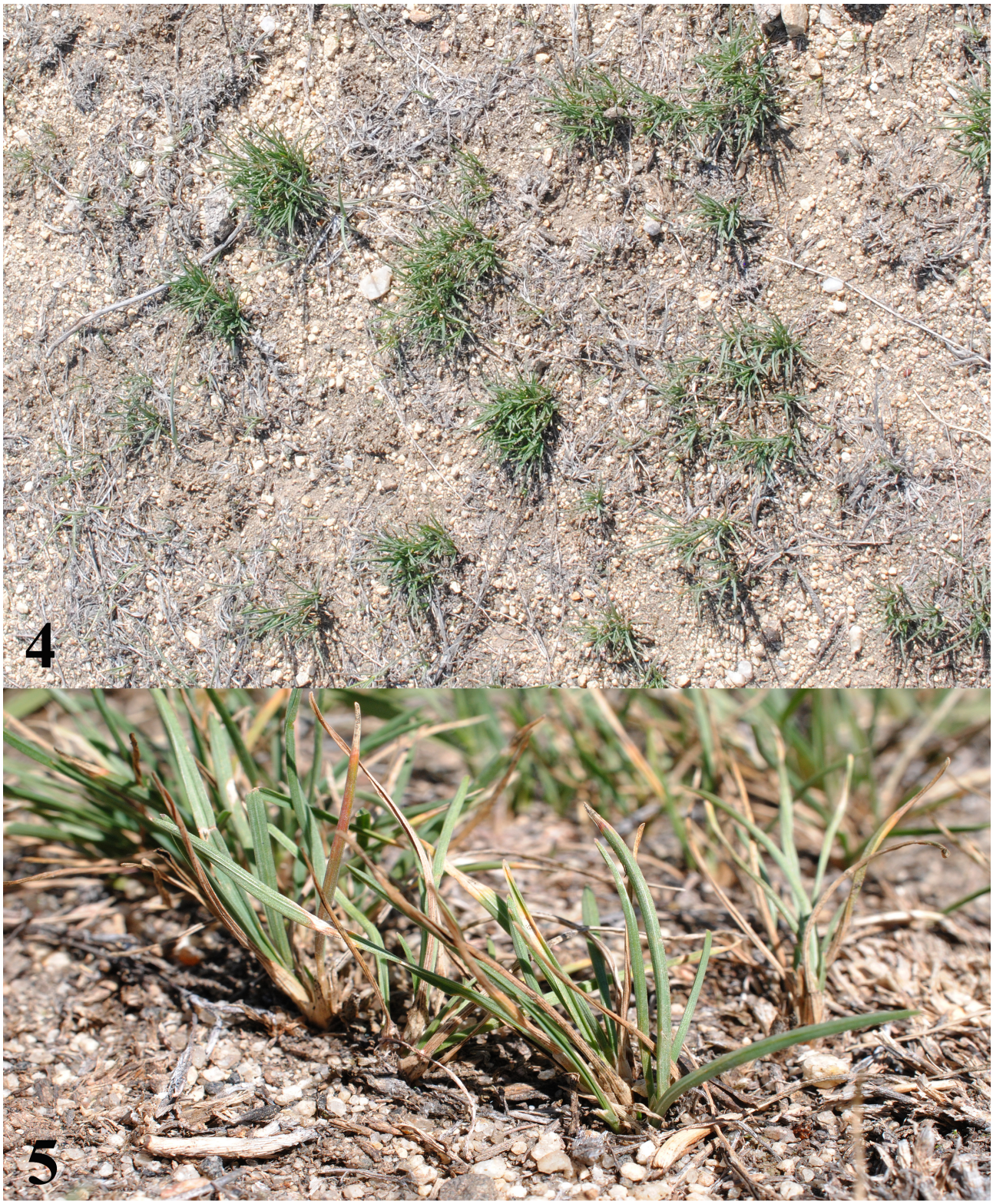
Feeding. Nymph and recently molted adults fed only at night. Typically, the nymph climbs to the end of a leaf, turns around, and slowly descends toward the base of the leaf, stopping to feed at numerous locations along the blade. In rearing chambers, a few nymphs were observed attempting to feed on culms and inflorescence. On tufts where nymphs were abundant, it was typical to observe brown and withered leaves. In many cases, feeding damage occurred to half of the tuft leaves (Fig. 5). However, over the entire site, feeding damage did not appear excessive and probably had little impact on the grass. Impacts from the feeding of *L. hesperius* nymphs on adjacent western wheatgrass appeared much more severe. I did not observe damage to culms or inflorescence from *C. americanus* feeding.

Adults were capable of flight within a few days after the final molt and were observed feeding on the host during the day. Females feed nonstop during egg production and after mating. Adult males appeared to spend most of the time seeking receptive females and considerably less time feeding.

Sex Ratio. In the field and in the rearing chambers, males were more common than females. A ♂:♀ sex ratio of 1.5:1 (n = 70) was observed in recently molted adults collected from rearing chambers at the end of May.

Oviposition Sites. The protracted blade-like ovipositor is shown in Fig. 2. All observations of oviposition were made in the rearing chambers where most oviposition occurred at night. Typically, eggs were inserted into the host's leaf sheath below the collar and ligule. Small white swellings on the outside of the sheath indicated the presence of eggs. Usually, two eggs were deposited under a single surface swelling and I observed up to five swellings along a single flag leaf. Occasionally, the female ovipositor penetrated the sheath, and eggs were deposited between the sheath and the stem. A few females inserted eggs perpendicular to the midrib of wilting leaves affected by feeding. The eggs were typically deposited in pairs parallel to the midrib in the longitudinally curled portion of the leaf.

Habitat Segregation from *L. hesperius*. The area directly adjacent to the narrow band of Sandberg bluegrass occupied by *C. americanus* is dominated by western wheatgrass and most of the ground surface is covered with litter composed of several-year-old western wheatgrass leaves, culms, and seed heads. A large number of *L. hesperius* nymphs occupied the western wheatgrass litter and developed concurrently with the adjacent *C. americanus* nymphs. Nymphs of both species were present in large numbers throughout May.



FIGURES 4–5. Habitat and feeding damage from *Conostethus americanus*. 4, Typical habitat occupied by *Conostethus americanus.* 5, Feeding damage to *Poa secunda* leaves.

It appears that litter is necessary for *L. hesperius* nymphal development (Todd and Kamm 1974). The lack of litter at the *C. americanus* site keeps the nymphs of the two species spatially isolated, reducing inter-specific competition. In addition, *L. hesperius* typically uses one or more year-old straw for oviposition and avoids green culms and broken stubble (Todd and Kamm 1974). *Conostethus americanus* oviposits directly on its host's green sheaths and wilting leaves, reducing competition for oviposition sites. Although the literature includes several reports of *C. americanus* feeding on wheatgrasses (Mills 1939; Spangler and MacMahon 1990), this was not the case for nymphs or adults in the study area. It was apparent that the two mirids were developing on different hosts. Despite repeated surveys, I was unable to locate nymphs or adults of *C. americanus* in areas dominated by western wheatgrass.

Description of Eggs and Nymphs. The egg and nymphs of *C. americanus* are shown in Figs. 6–10. I was unsuccessful in collecting instar I nymphs. The eggs probably hatched in mid-April when snow prohibited access to the site. By the time the nymphs were found, only instar II–V nymphs were present. The abbreviated descriptions below, combined with Figs. 7–10, should aid in identifying *C. americanus* nymphs.

The small, yellowish-green nymphs of *C. americanus* are easily recognized. The nymphs have a single distinct black dorsal abdominal gland opening between abdominal tergites 3 and 4 and a row of black setae along the anterior margin of abdominal tergite 8 (Figs. 7–10). When viewed dorsally, the anterior margin of the head is broadly rounded. The eyes are large and red and the nymphs are somewhat elongated.

Eggs (Fig. 6). 0.80–0.90 mm long, 0.20 mm wide; elongate; posterior end broadly rounded; sharply tapering anterior end; white, opaque.

Instar II (Fig. 7). Total length 1.66 mm; width across eyes 0.53 mm; distance between eyes 0.33 mm; pronotum width 0.42 mm; mesonotum width 0.51 mm. Instar II can be distinguished from instar III nymphs based on the width across the eyes exceeding the width of the pronotum. Head, thorax, and abdomen dorsally yellowish green; antennae light brown with black, semi-erect setae; legs light brown with long erect brown tibial setae; claws and distal portion of tarsi black; eyes red; anterior and lateral portion of head posterior of eyes brownish; orange spot on abdominal tergite 1 and 2 evident in live specimens; row of black erect setae across the posterior margins of abdominal tergites; setae on posterior margin of abdominal tergite 8 longer, distinct; small wing pads beginning to develop on posterolateral margins of meso- and metanotum; black dorsal abdominal gland opening between abdominal tergites 3 and 4 distinct, constricted medially.

Instar III (Fig 8). Total length 1.70 mm; width across eyes 0.53 mm; distance between eyes 0.4 mm; pronotum width 0.63 mm; mesonotum width 0.58 mm. Similar to instar II except width of pronotum subequal to width across eyes and mesonotum width greater than width across eyes; wing pads more developed with mesonotal wing pads extending onto the metanotum laterally; anterior margin of the mesonotum distinctly concave.

Instar IV (Fig. 9). Total length 2.36 mm; width across eyes 0.70 mm; distance between eyes 0.46 mm; pronotum width 0.50 mm; mesonotum width 0.84 mm. Instar IV is distinguished from instar III by the well-developed meso- and metanotal wing pads. Mesonotal wing pads extend nearly to apex of metanotal wing pads and both extend to posterior margin of abdominal tergite 1 or onto abdominal tergite 2. Width of mesonotal wing pad much greater than width across eyes.

Instar V (Fig. 10). Total length 2.67 mm; width across eyes 0.78 mm; distance between eyes 0.33 mm; pronotum width 0.76 mm; mesonotum width 1.00 mm. Except for the shorter wings and the presence of the dorsal abdominal gland opening, instar V nymphs closely resembles adults. The meso- and metanotal wing pads extend beyond the dorsal abdominal gland opening, typically reaching the anterior margin of abdominal tergite 5. Width across wing pads and abdomen much greater than width across eyes. Medial projection of dorsal abdominal gland opening overlapping posterior margin of opening. Genital capsule usually developed sufficiently to determine sex.

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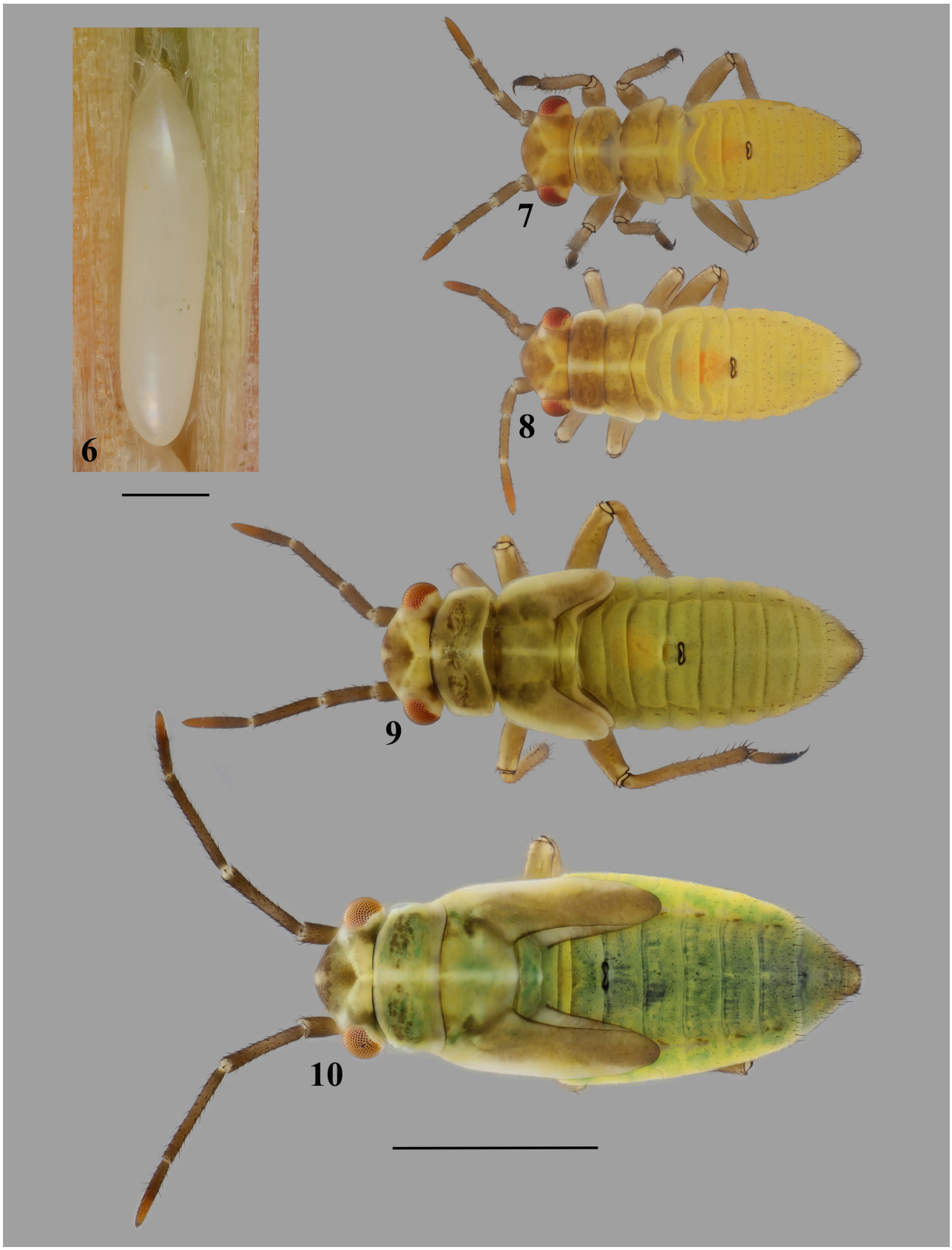

FIGURES 6–10. Eggs and nymphs of *Conostethus americanus*. 6, Egg. Scale bar = 0.2 mm. 7, Instar II. 8, Instar III. 9, Instar IV. 10, Instar V. Scale bar for Figs. 7–10 = 1 mm.

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