

A New Species of *Catocala* (Lepidoptera: Noctuidae) from Florida

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ABSTRACT

A new species of underwing moth, *Catocala aestivalia* sp. nov., is described from northern Florida, USA. Genitalic and Cytochrome Oxidase Subunit I 5' mitochondrial DNA characters differentiate *C. aestivalia* from related species with similar wing pattern and structure. In contrast to these other related *Catocala* species, *C. aestivalia* appears to specialize on *Crataegus aestivalis* growing in or near hydric hardwood forests along streams and rivers.

KEYWORDS

Rosaceae, genitalia, mitochondrial DNA, new species, host specialization, underwing moth

Introduction

In the Nearctic region there is a morphologically well-defined group of 13 species of *Catocala* Schrank whose larvae feed on rosaceous plants. We term this the “*Catocala grynea* species group,” with our usage being largely concordant to Barnes and McDunnough’s (1918) “Group XVII” (we exclude *C. clintonii* Grote, which had been placed in Group XVII only tentatively). The 13 species in the *C. grynea* species group are: *C. crataegi* Saunders, *C. dulciola* Grote, *C. pretiosa* Lintner, *C. grisatra* Brower, *C. lincolnana* Brower, *C. grynea* (Cramer), *C. blandula* Hulst, *C. ultronia* Hubner, *C. mira* Grote, *C. miranda* Henry Edwards, *C. orba* Kusnezov, *C. praeclara* Grote and Robinson and *C. alabamae* Grote. These 13 species share high structural homogeneity, and most lack diagnostic genitalic characters. However, the group itself is readily separable within the genus *Catocala* as a whole, due in part to the following unique synapomorphies: a disjunct short apical chord on the ventral phallus hood between the left outer and left middle chords; a band of sclerotization on the inner-lateral side of the anal papillae, overlapping the ventral band but narrower and contrastingly darker; a ventral band of sclerotization on the

anal papillae (Figure 2T); and a coiled stalk of the utriculus.

The species *C. crataegi* is widely distributed in North America, and separable on wing pattern from the other 12 members of the *C. grynea* species group. Our recent molecular analysis also shows that *C. crataegi* forms two Cytochrome Oxidase Subunit I (COI) 5' clusters: one clade occurring in the Canadian and Transition Life Zones of eastern North America, extending south along the Appalachians to North Carolina; and another clade represented from eastern Texas and Mississippi, which we refer to here as the “southern *crataegi* complex.” In Florida, there are geographically disjunct populations of a widely collected taxon similar in wing pattern to *C. crataegi*, but studies of COI 5', genitalic morphology and host biology reveal that it has its own unique combination of character states differentiating it from all other members of the *C. grynea* species group. From wing pattern, specimens from these Floridian populations can be separated from specimens of the northern *C. crataegi* clade, but cannot reliably be separated from all specimens of the southern *crataegi* complex. Because the names in the *C. grynea* species group have recently been typified (see Gall 2002; Gall and Hawks 2002, 2010; ICZN 2004), it is now estab-

lished that there is no available name applicable to the Floridian taxon. We describe it below as a new species, and discuss aspects of its life history.

Materials and Methods

The 5' region of the mitochondrial gene COI (658 base pairs [bp]) was sequenced by Paul Hebert's lab at the University of Guelph as described in Hebert et al. (2003), with sequences aligned by eye in Mesquite version 2.75 (Maddison and Maddison 2011). Unique combinations of diagnostic characters were identified from the map characters function in WinClada (Nixon 2002) in combination with Mesquite. Dissection and imaging techniques are as described in Kons and Borth (2015), genitalic terminology follows "Genitalic Structural Terminology for *Catocala* and Related Genera" (Kons and Borth [2014]) and collateral gland complex terminology follows Mitter (1987). For photographing the anterior rosette of diverticula on the everted male vesica, a groove was made in a plastic cylinder and the aedeagus positioned as shown. Adults were collected at various localities using bait, mercury vapor/ultraviolet sheets, and ultraviolet light traps (Kons and Borth [2007]). Detailed information on the habitats present at the collecting localities is in Kons and Borth (2006). Collection acronyms (following Arnett et al. 1993) are as follows: HLK, Hugo L. Kons Jr. personal collection, Gainesville, Florida, and Appleton, Wisconsin, USA; MGC, McGuire Center for Lepidoptera Research, University of Florida, Gainesville, Florida, USA; RJB, Robert J. Borth personal collection, Milwaukee, Wisconsin, USA; YPM ENT, Yale Peabody Museum of Natural History, Division of Entomology, New Haven, Connecticut, USA.

Catocala aestivalia Kons and Borth, sp. nov.

Figure 1A–H (specimens),

Figure 2A–U, W–X (structures, immatures),

Figures 3A–F and 4A–C (vesica)

Type material. Limited to specimens from Florida, USA, having COI 5' sequences and/or male genitalia dissections.

Holotype. Male, Dissection No.: 2014HLK:2017, DNA No.: 20448-COI-14, Alachua Co., Hogtown Creek by Southwest 20th Avenue, 29.63830°N, 82.39193°W, hydric hardwood

floodplain forest along creek, bait trap, 5 May 2006, Hugo L. Kons Jr (YPM; Catalog No. YPM ENT 778775; the holotype has a comprehensive set of genitalia images, 658-bp COI 5' sequence and the most typical wing pattern phenotype).

Paratypes. Alachua Co., Hogtown Creek by SW 20th Avenue, hydric hardwood floodplain forest along creek, 29.63830°N, 82.39193°W, bait trap, H. Kons Jr. (HLK): 1 female, 398-COI-06/2010HLK:1110, 26 April 2006; 1 female, 391-COI-06, 27 April 2006; 1 male, 401-COI-06, 28 April 2006; 1 female, 400-COI-06/2010HLK:1108, 29 April 2006; 2 males, 1 female, 386-COI-06/2010HLK:111, 384-COI-06/2010HLK:1112, 385-COI-06, 30 April–1 May 2006; 5 males, 378-COI-06, 379-COI-06/2010HLK:1107, 380-COI-06, 382-COI-06, 381-COI-06, 3 May 2006; 3 males, 2014HLK:2032, 20457-COI-14/2014HLK:2033, 2014HLK:2045, 5 May 2006; 1 male, 3337-COI-08, 12 April 2007; 1 female, 3333-COI-08/2011HLK:1137, 13–14 April 2007; 1 female, 3335-COI-08, 19 April 2007; 1 male, 3336-COI-08, 22 April 2007; 1 female, 3334-COI-08/2010HLK:783, 7 June 2007. Dixie Co., N of Hwy 358, hydric hardwood floodplain forest along Boat Creek, 29.68577°N, 83.3368°W: 1 male, 2321-260407-FL, bait trap, 26 April 2007, H. Kons Jr. and R. Borth (HLK). Liberty Co., Apalachicola National Forest: 1 male, 2320-130507-FL/2010HLK:753, NF Road 111 just E of Bay Creek, herb bog near cypress-titi swamp, 30.16550°N, 84.83227°W, bait trap 2, 13 May 2007, H. Kons Jr. and R. Borth (RJB); 1 male, 2322-140507-FL, Hwy 67 by Revell Branch, hydric forested corridor along stream through pine-palmetto flatwoods, 30.10368°N, 84.67177°W, bait trap 1, 14 May 2007, H. Kons Jr. and R. Borth (HLK). Liberty Co., Apalachicola Bluffs and Ravines Preserve: 1 female, 2323-150507-FL, hydric hardwood floodplain forest along Apalachicola River, 30.47392°N, 84.98387°W, bait trap G, 15 May 2007, H. Kons Jr. and R. Borth (HLK); 1 male, 2014-100507-FL, same locality, 10 May 2007, H. Kons Jr. and R. Borth (RJB); 1 female, edge of steephead ravine with mesic hardwood forest, near hydric hardwood forest, 30.46273°N, 84.98608°W, UV Trap 1, 11 May 2007, H. Kons Jr. and R. Borth (HLK). Gadsden Co., Aspalaga Road, hydric hardwood floodplain forest where Flat Creek flows into Apalachicola River, vicinity of 30.62698°N, 82.90057°W: 1 male, 2011HLK: 1178/3372-COI-08, baited tree trunk, 11 May 2005, H. Kons Jr. and R. Borth (HLK); 1 male, 9600-COI-11, rearing code RJB08L17, reared on *Crataegus aestivalis* from wild larva found on *C. aestivalis*, pupated 1 April 2008, emerged 17 April 2008, R. Borth (HLK). Gadsden Co., Clyde Hopkins Municipal Park, hydric hardwood floodplain forest near Apalachicola River: 1 female, 275-010506-FL, bait trap, 1 May 2006, H. Kons Jr. and R. Borth (RJB). Jackson Co., hydric hardwood forest opening with *Crataegus aestivalis* along Hwy 271: 1 male, 2014HLK:2084, 30.93305°N, 84.99978°W, bait trap 1, 1 May 2007, H. Kons Jr. and R. Borth (HLK).

Diagnosis.

Wing pattern. At present, specimens of *Catocala aestivalia* cannot always be reliably separated from the southern *Catocala crataegi* complex based on wing pattern, despite marked differences in the most typical phenotypes between the two species. *Catocala aestivalia* specimens usually have more extensive whitish scaling on the dorsal forewings and encircling

the reniform, whereas southern *crataegi* complex specimens are usually more plainly colored, but there is overlap (e.g., Figure 1A versus I), and some *C. aestivalia* specimens have as little whitish scaling as typical southern *crataegi* complex specimens (e.g., Figure 1F versus J). The prominent marginal shade present in nearly all specimens in the northern *C. crataegi* clade occurs in less than 10% of *C. aestivalia* specimens, although intermediates occur with a partial or diffuse marginal shade. Most *C. aestivalia* specimens with a prominent marginal shade (Figure 1G) lack the contrasting whitish median area characteristic of the northern *C. crataegi* clade (Figure 1K and L); in the occasional exceptions (Figure 1B), *C. aestivalia* lack the contrasting brown patch on the anterior side of vein CuA2 present in northern *C. crataegi* specimens in good condition. Some *C. aestivalia* possess a prominent white ring around the reniform, as is true in *C. pretiosa* (except for some eastern Kentucky individuals). However, in *C. pretiosa* this ring is wider, brighter and the white contrasts more with the white scales in the ground color, whereas in *C. aestivalia* the white in the ring is of similar color to white scales in the ground color. Some *C. mira* are similar to plainly marked individuals of *C. aestivalia*, and the differences in shading and color between the two species is subtle: *C. mira* generally has a richer and more contrasting brown between the postmedial and subterminal lines compared to *C. aestivalia*, and also tends to have more contrast between the gray and brown on the dorsal forewings. Compared to *C. aestivalia*, *C. blandula* has thicker areas of black along the antemedial line and postmedial line posterior of vein CuA2. In addition, *C. blandula* has two contrasting whitish bands in the median area, one between the antemedial line and the reniform, and a narrower one along the inner side of the postmedial line distal to the reniform and anterior to vein M1; these bands are absent or less contrasting in *C. aestivalia*.

Male genitalia. In *C. aestivalia*, vesica diverticula 5a and 5b are of comparable size and basal width, with 5b at most slightly smaller and narrower at the base relative to 5a (Figure 4A–C and M). In both *C. crataegi* clades (Figure 4D–I and N), *C. pretiosa* (Figure 4K) and *C. blandula* (Figure 4L), 5b is distinctly smaller and narrower than 5a (Figure 4); these characters are only visible in anterior aspect (Figure 4J). Note the lengths of diverticula 5a and 5b will appear to vary based on the angle of the specimen, but the relative proportions and widths of the bases are visible from a range of angles as long as the anterior rosette of diverticula is viewed head on (such that diverticula 2 to 5 and 1a are visible). In slide-mounted genitalia, these characters are not examinable because the anterior rosette of diverticula (2 to 5) will be laterally folded over and destroyed.

Female genitalia. The papillae anales of *C. aestivalia* (Figure 2S and T) are narrower and more abruptly tapering in dorsal or ventral aspect than in *C. mira* and *C. blandula* (Figure 2V), but the female genitalia of *C. aestivalia* and *C. crataegi* are not separable.

COI 5'. *Catocala aestivalia* is diagnosed from all other sequenced *Catocala* species by the following combination of 13 character states: 205(A), 212(C), 220(C), 283(C), 304(C), 346(T), 352(A), 451(C), 514(C), 548(T), 548(T), 562(C) and 652(T). Character state 205(A) has not been found in any other

Rosaceae-feeding *Catocala* species, and among the Nearctic *Catocala* has been recorded only from *C. illecta* Walker.

Description. The description is augmented with a more extensive series of figures available online (Lepidoptera Biodiversity, LLC 2015); these are referenced below as “Supp. fig.”

Head (Figure 2X). Vertex with variable mix of dark and light gray scales, and some individuals have a variable amount of pale whitish tan scales. Frons with predominately light and dark gray scales, sometimes variably mottled with pale whitish tan, paired lateral blackish patches bordering eyes. Labial palp basal segment pale whitish tan with some darker gray scales distally; middle segment with a dark blackish gray medial band mottled with pale tan, a thin white band apically and white mottled with light gray and pale tan basally; terminal segment mottled shades of gray, tan and white (Figure 2X). Chaetosema pale whitish tan. Patch of scales behind the eye pale whitish tan dorsally, dark brownish gray mottled with white laterally and ventrally.

Thorax. Patagia predominately gray with a scattering of dark gray and white scales. Tegulae with black border, often broken and diffused on inner side, usually solid on outer and anterior side, area within mixed shades of gray with scattered black and white scales. Anterior thoracic collar often with a transverse black band, rimmed with a thin band of whitish scales dorsally, tan or gray elsewhere, a broad transverse band of blackish scales on the inner side (often not visible, unless head is bent forward). Paired tufts of hair on dorsal-posterior side of thorax tan to light gray. Ventral thorax densely covered with pale whitish tan hairs.

Wings

WINGSPAN: Forewing length (base to apex) of holotype 19 mm; males 16 to 21 mm, females 17 to 22 mm.

FOREWING UPPER SIDE (Figure 1A–G): Extremely variable, background color usually predominately gray with a variable amount of white and brown mottling, predominately white in some females (rarer phenotypes, Figure 1C and D), rarely predominately blackish brown (Figure 1E). Holotype (Figure 1A) is a typical phenotype. We estimate less than 10% of individuals have a well-developed contrasting dark marginal shade (see Diagnosis and Figure 1B and G). Individuals with marginal shade usually lacking a white medial area (Figure 1G), but exceptions occur (Figure 1B). Scaling inside reniform variable, various combinations of gray, white, brown and/or blackish scales, sometimes with a small contrastingly lighter colored patch in the center. Reniform usually at least partially encircled with white band of variable width, solid or broken, sharp or diffuse. Basal dash sharp, thin, black and conspicuous in both sexes, extends one-third to two-thirds of the distance from the wing base to the antemedial line. Basal line distinct, black, often thick but sometimes broken, with two shallow distally protruding loops, the more anterior loop much larger than the second loop. Antemedial line variable in width, single, black distally, sharp to diffuse white basally; line sometimes diffused and inconspicuous anterior to discal cell in specimens with a prominent marginal shade (Figure 1G),

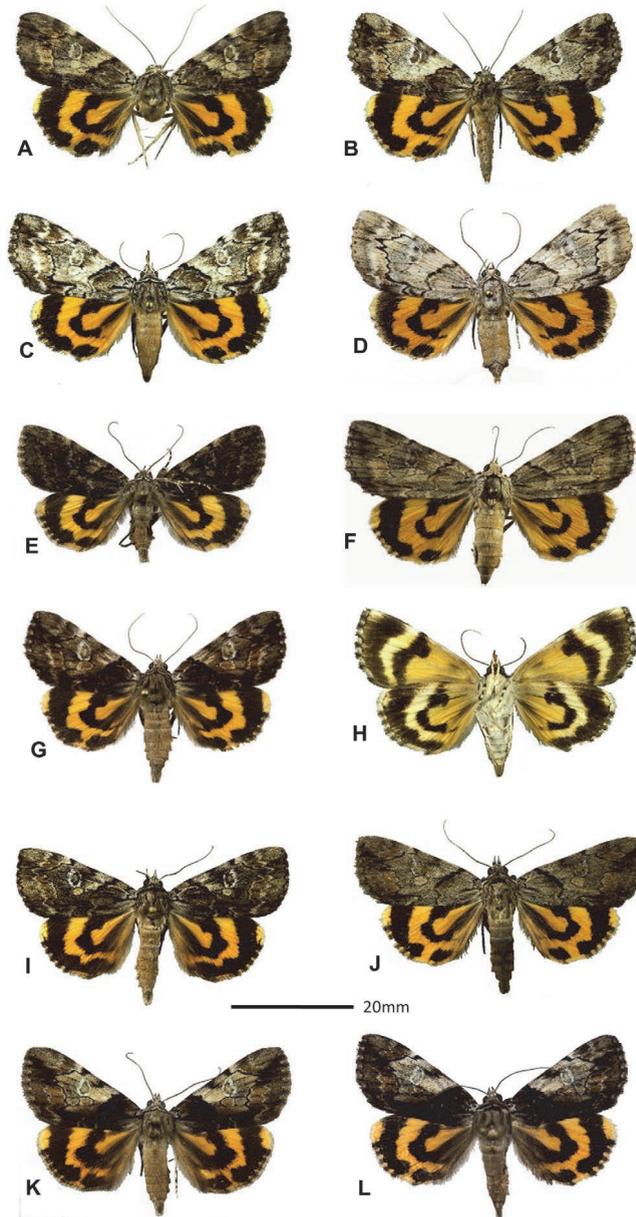


FIGURE 1. **A**, *Catocala aestivalia* holotype male (Dissection No. 2014HLK:2017, DNA No. 20448-COI-14), Alachua Co., Florida, USA, Hogtown Creek, 5 May 2006. **B**, *C. aestivalia* male (DNA No. 079-58-080490-FL), Alachua Co., Florida, USA, 8 April 1990. **C**, *C. aestivalia* female (DNA No. 3335-COI-08), Alachua Co., Florida, USA, Hogtown Creek, 19 April 2007. **D**, *C. aestivalia* female (DNA No. 3333-COI-08, Dissection No. 2011HLK:1137), Alachua Co., Florida, USA, Hogtown Creek, 13–14 April 2007. **E**, *C. aestivalia* male (DNA No. 9600-COI-11), Gadsden Co., Florida, USA, Aspalaga Road, emerged 17 April 2008, reared from wild larva taken feeding on *Crataegus aestivalis*. **F**, *C. aestivalia* female (Dissection No. 2011HLK:1178, DNA No. 3372-COI-08), Gadsden Co., Florida, USA, Aspalaga Road, 11 May 2005. **G**, *C. aestivalia* male (DNA No. 3337-COI-08), Alachua Co., Florida, USA, Hogtown Creek, 12 April 2007. **H**, *C. aestivalia* male (ventral, same as C) (DNA No. 3335-COI-08). **I**, Southern *C. crataegi* complex male (DNA No. 5039-060508-TX), Sabine Co., Texas, USA, 6 May 2008. **J**, Southern *C. crataegi* complex male (80-58-140504-TX), Sabine Co., Texas, USA, 14 May 2004. **K**, *C. crataegi* male (DNA No. 77-58-020798-MI), Cass Co., Michigan, USA, 2 July 1998. **L**, *C. crataegi* male, Wauteaga Co., North Carolina, USA, 1 July 2011.

black outer border occasionally absent posterior to vein CuA2 (Figure 1F). Antemedial line comprised of up to five distally protruding loops, loops anterior to vein CuA2 may be largely fused together into a large, distally protruding loop with some or all of the partitions indistinct or indiscernible (Figure 1C), or each partition may be conspicuous (Figure 1B). Posterior loop smoothly curved between vein 2A and inner margin; second (medial) loop largest, spanning between veins 2A and the lower margin of the distal cell; third loop smoothly curved, spanning discal cell; fourth loop short and triangular on posterior side followed by a longer straight line on the posterior side; fifth loop small, smoothly curved to straight, anterior to radial vein. Area basal to the antemedial line variable, often with a greater concentration of brown scaling relative to area between antemedial and postmedial line, but sometimes pattern similar on both sides of antemedial line. Median line black and diffuse, usually conspicuous between anterior edge of reniform and costa, sometimes discernible as a diffuse band on the basal side of the reniform spot, not discernible posterior to the reniform. Postmedial line thin, black, sometimes bordered distally by a discontinuous thin whitish edge. Postmedial line undulations protrude distally as curved loops or teeth: below 2A smoothly curved, sometimes extending basally at vein 2A; between Cu2 and A2 a single to very shallowly double curved loop, much farther distal at vein Cu2 than vein 2A; variable between veins Cu1 and Cu2, usually a shallow loop or tooth but sometimes nearly straight, never extending basally to form an open reniform spot; shallow curved or pointed loop between veins Cu1 and M3; two large distally protruding pointed teeth between veins M1 and M3, shallow curved loop, tooth or nearly straight line between veins R5 and M1; shallow loop or tooth between veins R5 and R4 and sharply turned basally along vein R4; between vein R4 and costa varies from thin and shallowly curved-dentate to thick and fairly straight. Subterminal line white, highly variable, ranges from sharp to diffuse, broad to thin and broken, undulations vary from distinct to indistinct, dentate to smoothly curved. Area between postmedial and subterminal line a mix of gray and brown scaling, sometimes with white or blackish brown scaling in the more extreme phenotypes, usually contrastingly browner and darker relative to background color, except in the darkest specimens (Figure 1E). Outer margin often with a terminal line comprising a series of thin black basally protruding loops between the veins (Figure 1A–C), but this line can be broken and reduced to small black dots or lines between the veins (Figure 1D); sometimes terminal line with white patches on the distal side between the veins (Figure 1C). Some veins accented with a variable amount of diffuse black scaling distal to subterminal line (see Figure 1F). Diffuse black to dark brown band sometimes present from intersection of vein M1 and subterminal line to outer margin and vein R4 (Figure 1A–C). Fringe predominately gray, sometimes diffused with black or white, with darker gray or blackish patches at the veins.

HIND WING UPPER SIDE: Background color yellowish orange. Apical patch prominent with yellow-orange background color. Marginal band black, usually broken in cell CuA2 (Figure 1A, B, D, F and G), sometimes narrowly joined across cell Cu2 (Figure 1E), protruding basally as curve or tooth at vein CuA2, fairly smoothly curved anterior to this vein but some-

times with shallow basal undulations or extension of black scaling along the veins. Medial band sharp, black, abruptly changing direction on basal and distal sides along vein M2, curved distally anterior of vein CuA2, curved basally in cell CuA2, sometimes with a basally oriented line (Figure 1B–D) or patch (Figure 1A) in the anal cell. Basal area with band of black scales extending from hind wing base to basal apex of medial band in cell CuA2, such that medial band appears to form a complete loop. Fringe orange variably diffused with black, with black patches at the ends of veins CuA2 to M1, predominately diffused black basal to vein 2A.

FOREWING UNDERSIDE (Figure 1H): Background color pale orange basal to medial band, pale cream color distal to medial band. Marginal and medial bands sharp and black; basal band very diffuse. Marginal band lighter black with sparse diffuse pale cream scaling along outer margin, with the pale scaling widening posterior to anterior, and a cream-colored apical patch with diffuse borders. Diffuse black along inner margin posterior of anal vein between medial and marginal bands. Discal spot oblong black patch, usually mostly or completely fused with the basal side of the marginal band. Fringe undulated, cream with black patches between veins 2A and M1.

HIND WING UNDERSIDE: Background pale orange basal to the medial band and posterior to the veinlet in the discal cell, pale cream colored distal to the medial band, except basal to vein 2A where pale orange. Marginal and median bands sharp and black, of similar shape to upper side, marginal band more often and more broadly connected across cell CuA2. Discal spot black and crescent shaped, usually partially fused with median band. Fringe pattern same as upper side except with pale cream scales rather than yellowish orange.

Legs (Supp. fig. 2A–Q). Spination and shape similar for both sexes except male profemur with dorsal subapical flattened spine (Supp. fig. 2N), female profemur lacking spine.

FORELEG (Supp. fig. 2C, H, I and L–O): Protibia lacking spines (Supp. fig. 2C, L and M), with a small convex sulcus with radiating spines near basal extremity on the inner side (Supp. fig. 2C and L). Protarsomeres 1 to 4 with three ventral rows of large triangular spines, and two rows of minute hairlike curved spines between them. Protarsomere 5 with four ventral rows of large triangular spines, with a row of minute hairlike spines in-between each inner and outer row. Scattered minute hairlike spines present along dorsal midline of tarsomeres and along sides.

MIDLEG (Supp. fig. 4A, B, E, F, J and K): Mesofemur unspined. Mesotibia with one row of spines on outer side, with 0 to 3 additional smaller spines dorsal or ventral of the main row (Supp. fig. 2A and J); inner side often unspined (Supp. fig. 2K) but sometimes with a single spine near the midpoint along the ventral edge (Supp. fig. 2B). Mesotibia without hair pencil or groove on inner side. Mesotarsi ventral spination as in protarsi (Supp. fig. 2E and F).

HIND LEG (Supp. fig. 2D, G, P and Q): Metafemur and metatibia unspined (Supp. fig. 2D). Metatarsal ventral spination as in meso- and protarsi (Supp. fig. 2G, P and Q).



FIGURE 2. *Catocala aestivalia* adult and immature structures. *C. aestivalia* holotype male (Dissection No. 2014HLK:2017): A–H, J–O; *C. aestivalia* female genitalia (Dissection No. 2011HLK:1178): R–T; *C. aestivalia* ovum, deposited 20 May 2007, photographed 4 March 2008, female from Jackson Co., Florida, USA: U and W; *C. aestivalia* larva in prepupal phase (reared adult shown in Figure 1E): P and Q; voucher codes for specimens with a single plated photograph are noted below. **A**, Male genitalic capsule (ventral). **B**, Male genitalic capsule (dorsal). **C**, Male genitalic capsule (lateral, before hairs and scales removed). **D**, Male genitalic capsule (lateral). **E**, Valvae (inner). **F**, Uncus, tegumen and tuba analis (lateral). **G**, Male abdominal segment 8 (tergite [left], sternite [right]). **H**, Uncus (lateral). **I**, Female tergite 7 (Dissection No. 2011HLK:1137). **J**, Aedeagus (sensu lato). **K**, Juxta and anellus (flattened). **L**, Uncus (posterior). **M**, Ductus ejaculatorius. **N**, Male abdominal tergites 1 to 7. **O**, Male abdominal sternites 3 to 7. **P**, Cocoon between two leaves after one leaf removed, with prepupal larva inside. **Q**, Larval head capsule. **R**, Ductus seminalis and collateral gland complex. **S**, Female genitalia (ventral). **T**, Female genitalia (lateral). **U**, Ovum (lateral). **V**, *C. blandula* papillae anales [Letcher County, Kentucky, USA] (Dissection No. 2011HLK:1190). **W**, Ovum (dorsal). **X**, Head (lateral) (Voucher No. 2011HLK:1587). *Abbreviations*: ac, adjoining canals of receptacle duct; cg, collateral gland; ds, ductus seminalis; l, lagena; oc, oviductus communalis; sr, simple region of receptacle duct; u, utriculus; v, vesicle; vg, vagina.

Abdomen. Predominately brownish gray with some hind wing background colored orange-yellow hairs and scales over tergites (Figure 1A–G), white scaling over sternites (Figure 1H). Cuticle (Figure 2G, N and O [male], Supp. fig. 2C–E [female]) as shown in figures, with minor variation in the shape of the anterior margins of the segments. Female tergite 7 anterior side with deep concave gouges on each side and convex at midline, whereas posterior side concave at midline and convex on each side; lateral sides strongly concave (Figure 2I).

Male genitalia ($n = 9$). **CAPSULE** (Figure 2A–D): Vinculum strongly fused with valvae, juxta less strongly fused with vinculum than typical of most *Catocala*, vinculum weakly fused with tegumen, vinculum arms laterally expanded and weakly fused midventrally, diaphragma membranous except for juxta/anellus.

VALVAE (Figure 2E, Supp. figs. 3E and 4G–I): Outer surfaces densely covered with elongate tan-colored hairs and scales except for anterior portion of sacculus (Figure 2C; image taken in alcohol and hairs appear darker than the natural color); inner surface of “cucullus” with shorter scales and hairs along ventral margin. Sacculus with short posterior extension at fusion with cucullus, of similar length and width (Supp. fig. 4G and H). Elongate setae scattered along posterior margin of sacculus on inner side, but sparse except on the above extension (Supp. fig. 4G and H). Ventral inner sides of sacculus with concave indentation along margin of clasper base (Supp. fig. 4I). Right and left cucullus clear and membranous (Figure 2E). Cucullus with scattered elongate setae on inner surface along ventral margin (Supp. fig. 3E). Left and right costa heavily sclerotized and widest medially, tapering to a blunt or sharp point posteriorly, posterior extent of costa nearly even with cucullus, no distinct thickened area on right or left costa, concave patch of lighter sclerotization medially on the inner side of each costa (Figure 2E). Elongate membranous pocket along ventral edge of costa originating near the base of the clasper and extending nearly as far distally as the clasper apex (Supp. fig. 4G and H). Claspers similar, dorsoventrally flattened except at apex where twisted and laterally flattened (Supp. fig. 4I), curved ventrally/inward distally (Figure 2A), apex strongly curved inward (Supp. fig. 4I). Clasper apices with scattered minute short setae, densest along sides of ventral margin (Supp. fig. 4G and H) apices only slightly expanded relative to subapical area due to irregular undulated flaring on ventral edges (Supp. fig. 4G and H). Ventral and dorsal margins of clasper base with sparse elongate setae (more elongate on dorsal margin at base) with sparse scattered shorter setae extending distally along margins (Supp. fig. 4G and H). Dorsal and ventral margins of both claspers fairly straight to slightly concave (viewed from inner side of valvae). Viewed from ventral side, both claspers with outer margins (bordering the valvae) strongly convex, inner margins (opposite the valvae) strongly concave (Supp. fig. 3A).

JUXTA (Figure 2K): Two elongate approximately symmetrical lobes, both narrowest posteriorly, progressively widening anteriorly. Lobes fused to anellus at posterior apex, touching each other at posterior end but not fused together.

ANELLUS (Figure 2K): Lobes fused together throughout and appearing as a single approximately symmetrical sclerotized

plate. Outer margins concave for most of length, slightly convex anteriorly. Anterior margins fairly straight to slightly concave except near outer edge where slightly convex. Posterior side paired rounded lobes separated by an inverted triangular membranous area at the midpoint. Band of sclerotized, dense, shallow depressions (pits) along midline, and narrower bands of the same along the lateral sides.

UNCUS (Figure 2H and L): Tubular, of similar width throughout but widest at base, gradually tapering apically, posterior margin strongly convex, anterior margin strongly concave; terminating in heavily sclerotized curved spine, pointed apically in lateral view (Figure 2H) but narrowly rounded in dorsoventral view (Figure 2L). Scattered lateral setae shorter than width of uncus (Figure 2L).

TUBA ANILIS (Figure 2F, Supp. fig. 3H and I): Membranous except for scaphium, posterior side weakly convex. Scaphium an elongate, rectangular plate, terminating about evenly with base of spine at apex of uncus.

AEDEAGUS (Figure 2J, Supp. fig. 4A–C): Translucent throughout. Coecum nearly straight, at most slightly bent just anterior of anterior opening. Aedeagus not bent at posterior margin of coecum, shaft with strong medial bend but fairly straight on each side of bend. Left flank of posterior ventral extension (“hood” over everted vesica) with a deep basal concave gouge (Figure 3C), and a lightly sclerotized quadrangular expansion between the apex and subapical area, extended at the posterior outer corner as a triangular pointed projection reaching farther posteriorly than the apex of the hood (Figure 3A). Right flank weakly concave basally, convex for a shorter distance medially, then with a deeper concave gouge before the apex (Figure 3A). Apex narrowly rounded (Figure 3A). Ventral aedeagus hood with right inner chord absent; left inner chord, right outer chord and left outer chord present; left inner chord and right outer chord progressively converge posteriorly but remain well separated where they terminate; a short, disjunct apical cord between the positions of the left inner and outer chords (Figure 3A).

DUCTUS EJACULATORIUS (Figure 2M): Slender region with sharp bend/folded over at base of scoop-shaped region. Scoop-shaped region outer side strongly convex basally, then concave for a short distance, then strongly convex distally for most of the length of the structure; inner side doubly convex basally, strongly concave distally for most of the length of the structure. Apex of scoop curves back around but remains well separated from the sharp bend at the terminus of the slender region.

VESICA (Figures 3A–F and 4A–C): Diverticulum 1 trilobed: 1a large (of comparable width to diverticulum 2 at its widest point), elongate, and fang shaped; 1b and 1c minute curved lobes concealed by 1a (Figure 3F). Diverticulum 2 multilobed: 2a broad and curved, bilobed, with a small secondary shallow curved lobe at the posterior edge of the primary lobe (Figure 3F); 2b elongate, tubular and narrow, making a strong curve at roughly a right angle and extending underneath 1a (Figures 3F and 4A and C); 2c usually a simple broadly curved lobe (Figures 3F and 4B and C), but a single specimen has two distinct lobes (Figure 4A). Diverticulum 3 bilobed, with 3a much larger

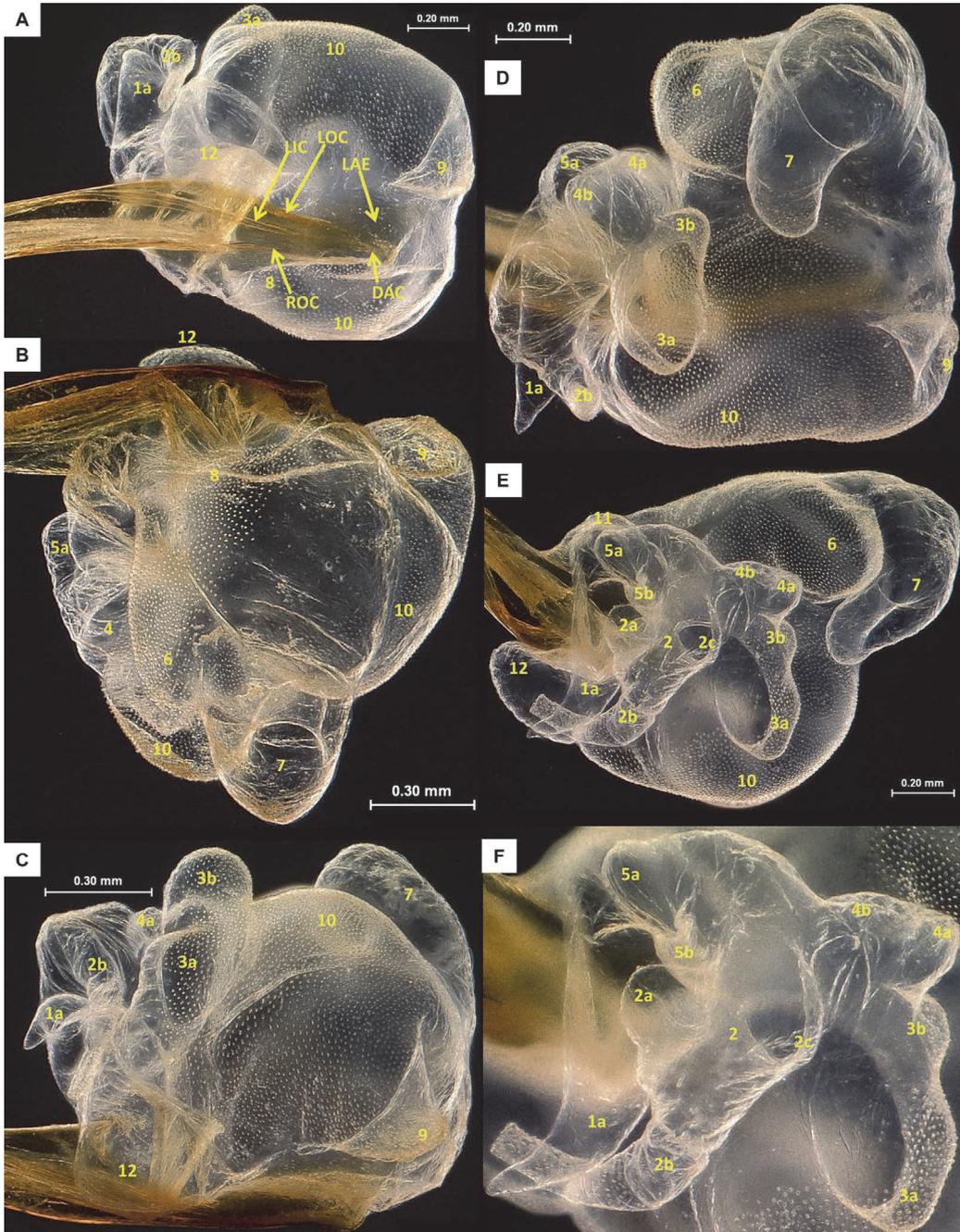


FIGURE 3. *Catocala aestivalia* holotype everted vesica (Dissection No. 2014HLK:2017). A, Ventral. B, Lateral (ventral hood above). C, Lateral (ventral hood below). D, Dorsal. E, Anterior. F, Anterior rosette of diverticula. Abbreviations: DAC, disjunct apical chord; LAE, left lateral apical expansion of ventral aedeagus hood; LIC, left inner chord; LOC, left outer chord; ROC, right outer chord. The vesica diverticula numbering system follows Kons and Borth (2014).

than 3b (Figure 3F). Diverticulum 4 bilobed, 4a and 4b of similar size, often shallowly separated. The two lobes of diverticulum 4 appear less distinct if lobe 4 is tilted forward rather than viewed directly from the side (Figure 4B). If diverticulum 4 is viewed directly from the side, then diverticulum 5 is tilted, and its two lobes appear less distinct (Figure 4C). Diverticulum 5 bilobed, both lobes of similar area and width at base, with 5b only slightly smaller than 5a (Figures 3F and 4A–C). Diverticulum 6 large, broad, simple lobe, densely covered with small inverted teeth (Figure 3D and E). Diverticulum 7 large, strongly curved and extending over the dorsal side of the vesica, gradually and progressively tapering to a broadly rounded apex (Figure 3D and E). Diverticulum 8 very shallow and smoothly curved, covered with minute inverted teeth (Figure 3B). Diverticulum 9 short and broad, projecting posteriorly-inward (Figure 3A and B). Diverticulum 10 extensive, broad, shallow and smoothly curved, with many minute inverted triangular teeth (Figure 3C and D). Diverticulum 11 small, shallow and smoothly curved (Figure 3E). Diverticulum 12 prominent, smoothly curved, simple (Figure 3E), extending partway over the ventral aedeagus hood (Figure 3A). Diverticulum 13 absent or indiscernible.

Female genitalia ($n = 7$). PAPPILLAE ANALES (Figure 2S and T, Supp. fig. 8A and B): Papillae widest in roughly basal half, abruptly tapering medially, thin and tubular for roughly distal half. Dorsal side convex basally, fairly straight distally; ventral side fairly straight anterior and posterior of constriction; lateral sides fairly straight to weakly convex basally, concave at constriction, fairly straight to slightly concave distally. Three distinct bands of sclerotization: heavily sclerotized dorsal band, extending throughout wider basal region and about half the length of the narrower distal region; broad ventral band, extending distal to the base of the constriction; narrow heavily sclerotized lateral band, extending the length of the narrow area but present only at the distal edge of the wider area. Longest setae at base, projecting posteriorly and outward at acute angles usually less than 45°. Shorter setae throughout papillae project posterior/outward or perpendicular, some curve back ventrally on narrow distal portion, with increasing density toward apices.

INTERSEGMENTAL MEMBRANE BETWEEN PAPPILLAE AND SEGMENT 8 (Supp. fig. 7A–C): Bulged out medially, posterior end approximately 0.85 times width of anterior end. Length/width at anterior end is approximately 1.0.

SEGMENT A8 (Supp. fig. 7A–C): Well separated from lamella antevaginalis due to the fairly straight intersegmental membrane between them. Shape as shown (Supp. fig. 7A–C), typical of *C. grynea* species group. Elongate, posteriorly projecting setae encircling posterior margin, except in area of ventral midline.

INTERSEGMENTAL MEMBRANE BETWEEN LAMELLA AND SEGMENT 8 ON VENTRAL SIDE (Supp. fig. 9B): Fairly straight (Supp. fig. 7B), prominent sclerotized sinus vaginalis with dense triangular minute teeth in the pattern shown (Supp. fig. 9B), sclerotized area ovoid, fused with sternite 8 with a pair of short, narrow bands.

LAMELLA ANTEVAGINALIS (Figure 2S, Supp. figs. 9A and 10A–F): Posterior margin variable in shape as is typical of *C. grynea* species group: convex, fairly straight or slightly concave on sides. Anterior margin even more variable in shape, strongly tapering and slanting anteriorly-outward from the midline, posterior notch present and shallow or absent. Slit in lamella antevaginalis along ventral midpoint wide and triangular posteriorly, sometimes triangular throughout and sometimes narrowing to a slit anteriorly (probably depending on the position of the lamella lobes when the specimen died); sides not sclerotized or thickened anteriorly.

ANTRUM (Figure 2S and T, Supp. figs. 9A and 10A–F): Sclerotized throughout except a small area around juncture with corpus bursae. Sides convex, widest at anterior end of slit in lamella antevaginalis, gradually tapering anterior to this position and more strongly tapering posteriorly.

DUCTUS BURSAE (Figure 2S and T): Elongate, rectangular and strongly dorsoventrally flattened with a sclerotized plate on each inner side, curved dorsally but not twisted.

CORPUS BURSAE (Figure 2S and T): Posterior section with longitudinal wrinkles much smaller than anterior section covered with minute inverted triangular teeth. Posterior section with sides convex, widest at juncture with anterior section. Anterior section globular and taller than wide.

DUCTUS SEMINALIS (Figure 2R): Coiled basal section with 7 to 9 coils. Distal section with an oblong bulla seminalis and a simple tube at distal end.

COLLATERAL GLAND COMPLEX (Figure 2R, Supp. fig. 11A–C): Adjoining differentiated canals of receptacle duct with 10 to 13 coils including vesicle, which is similar to the penultimate coil (Supp. fig. 11A); gradual transition to simple region of receptacle duct along length of vesicle; vesicle unsclerotized (Supp. fig. 11B). Utriculus very elongate, with many narrow longitudinal grooves throughout, base with 3 to 4 coils (Supp. fig. 11C, black arrow). Lagena ovoid with a long, narrow base (Supp. fig. 11C). Collateral gland elongate and tubular, very gradually widening basal to distal and then abruptly widening into a globular slightly ovoid sack from which large paired glands arise (Supp. fig. 11B). Oviductus communalis paired branches elongate, longer than simple base (Supp. fig. 11A). Vagina roughly ovoid (Figure 2R).

Immature stages. Eggs deposited with extensive albuminous cement (Figure 2W, Supp. fig. 13A and B), dorsum reflects rainbow colors in bright light of daylight (Supp. fig. 13C), sculpturing as shown (Supp. fig. 13A–D). One larva photographed in the prepupal phase inside its cocoon of frass, silk and leaves of *Crataegus aestivalis* (Figure 2P and Q).

COI 5' mitochondrial DNA. Three characters are polymorphic with a sample size of 26 specimens: 99(A and G), 181(A and G) and 286(A and G). The *Catocala aestivalis* holotype 20448-COI-14 has the following sequence for COI 5' positions 1 to 658:

AACTTTATATTTTATTTTGGAAATTTGAGCAG
GAATAGTAGGAACCTTCATTAAGATTATTAATTC

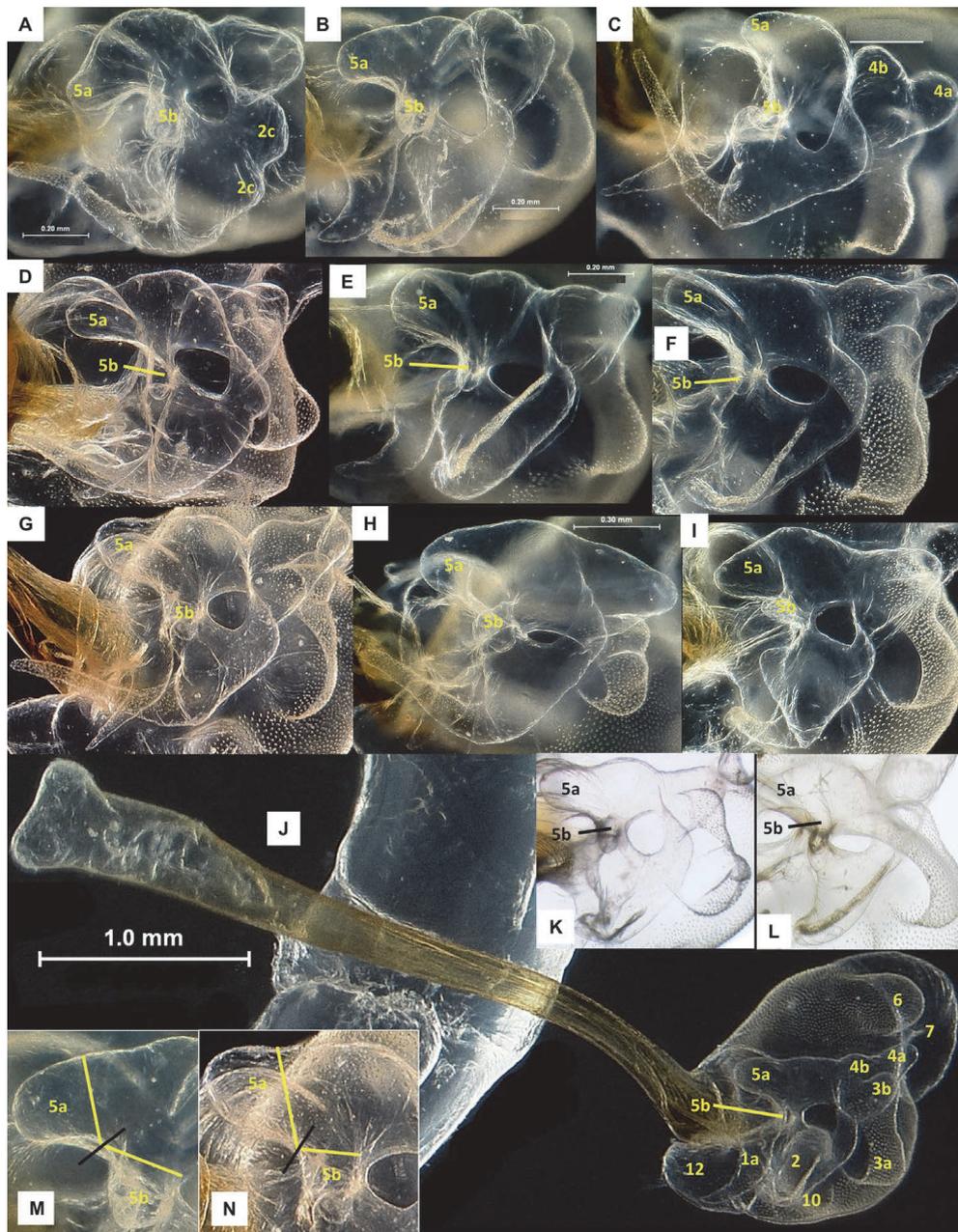


FIGURE 4. Comparison of the vesica (anterior aspect) between *Catocala aestivalia* (top row), southern *C. crataegi* complex [Texas, USA] (second row), *C. crataegi* (third row) and *C. pretiosa* and *C. blandula* (fourth row). The vesica diverticula numbering system follows Kons and Borth (2014). **A**, *C. aestivalia* (Dissection No. 2014HLK:2033). **B**, *C. aestivalia* (Dissection No. v2014HLK:2032). **C**, *C. aestivalia* (Dissection No. 2014HLK:2034). **D**, Southern *C. crataegi* complex [Texas, USA] (Dissection No. 2014HLK:2028). **E**, Southern *C. crataegi* complex [Texas, USA] (Dissection No. 2014HLK:2068). **F**, Southern *C. crataegi* complex [Texas, USA] (Dissection No. 2014HLK:2069). **G**, *C. crataegi* (Dissection No. 2014HLK:2030). **H**, *C. crataegi* (Dissection No. 2014HLK:2066). **I**, *C. crataegi* (Dissection No. 2014HLK:2067), diverticulum 5b bent about 90° to left. **J**, Southern *C. crataegi* complex [Texas, USA] (Dissection No. 2014HLK:2069) aedeagus oriented with vesica in anterior aspect. **K**, *C. pretiosa* [Texas, USA] (Dissection No. 2011HLK:1191). **L**, *C. blandula* [Kentucky, USA] (Dissection No. 2010HLK:652). **M**, Same as 4B, zoomed in on diverticulum 5. **N**, Same as 4G, zoomed in on diverticulum 5. Note: Diverticulum 2b is not fully extended in B, E, F, K and L.

GAGCTGAATTAGGTAATCCTGGATCTTTAATTGGA
 GATGATCAAATTTATAATACTATTGTAACAGCTCAT
 GCTTTTATTATAATTTTTTTTATAGTTATAACCAAT
 TATAATGGGGGATTTGGTAATTGATTAGTACCAT
 TAATACTAGGAGCCCTGATATAGCTTTCCCCCG
 TATAAATAATATAAGTTTTGACTTCTTCCCCCT
 CATTAACCTTATTAATTTCAAGAAGAATCGTA
 GAAAATGGAGCAGGAAGTGGATGAACAGTATATCC
 CCCCCTTTTCACTAATATTGCTCATAGAG
 GTAGTTCAGTAGATTTAGCTATTTTTCTTTACATT
 TAGCTGGAATTTCTTCAATTTTAGGAGCTAT
 TAATTTTATTACCACAATTTAATATAACGAT
 TAAATAATTTAATATTGATCAAATACCTTTATT
 TATTTGAGCCGTAGGAATTACAGCTTTCTTCT
 TCTTCTTTCTTTACCAGTTTTAGCCGGAGCTATTAC
 TATACTTTTAACTGATCGAAATTTAAACTTTC
 CTTTTTGTGCTGCTGGAGGAGGATCCTATTT
 TATATCAACATTTATTT

Etymology. The new species is named for its only documented food plant, *Crataegus aestivalis* (Walter) Torr. and A. Gray.

Discussion

Because of the overlap in wing pattern, and the close similarity of several taxa in the *C. grynea* species group, specimens of *C. aestivalia* have previously been associated with several names. Kons and Borth (2006) treated *C. aestivalia* as *C. crataegi*, and Gall and Hawks (2010:62) stated *C. aestivalia* to be “what we presently consider ... *C. blandula* populations from lowland coastal areas in the southeastern USA (e.g., notably around Gainesville, Florida).” Moreover, and unsurprisingly, specimens of *C. aestivalia* have been identified in personal and institutional collections under an even wider array of names, often as *C. pretiosa* and *C. mira*.

We consider that *Catocala aestivalia* is likely a host specialist on *Crataegus aestivalis*. In northern Florida, this plant grows in or at the edge of hydric hardwood forest along streams (Figure 5) and rivers. The *C. aestivalia* we have reared to adults were all taken as wild larvae on *Crataegus aestivalis*. We have collected larvae from *Crataegus spathulata* Michx., *C. viridis* L., *C. flava* Aiton and *C. marshallii* Eggl. (including at sites where we found *Catocala aestivalia* adults to be common) but have not found *C. aestivalia* larvae on these other *Crataegus* species. Moreover, *Crataegus aestivalis* occurs at all sites where we found *C. aestivalia* adults to be common, including Hogtown Creek (Alachua County), Aspalaga Road (Gadsden County), Clyde Hopkins Park (Gads-

den County), the Apalachicola Bluffs and Ravines Preserve (Liberty County) and a culvert west of Highway 271 (Jackson County).

Other sites where we have recorded adult *C. aestivalia* either have *Crataegus aestivalis* within a few miles and/or have produced few specimens. At the American Entomological Institute property in Gainesville (Alachua County), *Crataegus uniflora* Münchh. is the only *Crataegus* species present, and only one specimen of *C. aestivalia* was taken despite intensive collecting from 2001 to 2013 (although three specimens were collected in 2014). However, *C. aestivalia* is common approximately 4.8 km from the Institute at Hogtown Creek. Individual bait traps along Buena Vista Road in Jackson County, Florida, yielded zero to four specimens per trap during surveys in 2006 and 2007. We found no *Crataegus aestivalis* in the immediate vicinity of these traps, although the plant occurs no more than 4.3 km away, and might occur closer in areas of hydric hardwood forest along the Chattahoochee River that are difficult to access. On 1–2 May 2007, on cool nights with relatively low moth activity, three bait traps around the *Crataegus aestivalis* yielded 17 specimens of *C. aestivalia*, whereas seven to nine bait traps along Buena Vista Road yielded only one specimen on the same two nights. Furthermore, we have found no *Catocala aestivalia* larvae on the *Crataegus spathulata*, *C. viridis* and *C. flava* present along Buena Vista Road. A single specimen from Dixie County, Florida, is from a site where we have not searched for *Crataegus*, but the habitat is a hydric hardwood forest along a large stream, the typical habitat of *C. aestivalia* and *Crataegus aestivalis*.

The only area where we have collected *C. aestivalia* in Florida where we have searched for and not found *Crataegus aestivalis* nearby is in Apalachicola National Forest in Liberty County: two specimens in pitcher plant bog and cypress swamp along Forest Road 111 just east of Bay Creek; one specimen in the vicinity of a hydric forest corridor along Hickory Branch; and one specimen in a hydric forest corridor along Revell Branch. However, because only four specimens have been taken in this area with intensive collecting, and numerous unexplored streams and tributaries with hydric hardwood forest corridors occur nearby, we suspect the few specimens we collected here were not in the breeding habitat.



FIGURE 5. Hydric hardwood forest along Hogtown Creek, Alachua County, Florida, USA, at type locality of *Catocala aestivalia*.

The only other species of *Catocala* larvae we have found on *Crataegus aestivalis* is *C. mira*, which in northern Florida also utilizes at least *C. spathulata*, *C. flava* and *C. uniflora*.

We have sampled around *C. aestivalis* only in northern Florida. However, based on the state and county distribution of *Crataegus aestivalis* shown on the US Department of Agriculture Natural Resources Conservation Service Plants Database website (USDA/NCRS 2014), *Catocala aestivalia* might occur in a narrow band along the Atlantic Coastal Plain from Georgia to Virginia, and in coastal Alabama and southern Mississippi. The localities in eastern Texas and western Mississippi where we have collected specimens of the southern *crataegi* complex are outside the recorded geographic distribution of *Crataegus aestivalis*, which according to the USDA/NRCS website does not extend north or west of the southeastern quadrant of Mississippi.

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