Zootaxa 3137: 31–45 (2011)
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

A new avocado pest in Central America (Lepidoptera: Tortricidae) with a key to Lepidoptera larvae threatening avocados in California

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Abstract

Cryptaspasma perseana Gilligan and Brown, new species, is described and illustrated from Mexico and Guatemala. This species is a potential pest of the fruit of cultivated avocado, *Persea americana* (Lauraceae). Images of adults, male secondary structures, male and female genitalia, eggs, larvae, and pupae are provided. Details of the life history are reviewed. We provide characters to differentiate this pest from the most common avocado fruit pest in the region, *Stenoma catenifer* (Walsingham) (Elachistidae), and a key to identify Lepidoptera larvae threatening avocado in California. In addition, we provide a complete list of tortricids documented from different avocado varieties worldwide.

Key words: *Cryptaspasma*, Guatemala, Hass, Mexico, Microcorsini, *perseana*, *Persea americana*

Introduction

Cryptaspasma Walsingham is almost exclusively pan-tropical, comprising 34 described species (Brown 2005). It has been recorded from Central America, South America, southern North America, Africa, Madagascar, Australia, New Zealand, New Caledonia, the Orient, and the eastern Palearctic (Horak 2006). The genus has traditionally been considered the sole representative of the tribe Microcorsini (Diakonoff 1959, Horak and Brown 1991, Horak 1999); however, the Australian genus *Collogenes* Meyrick was recently transferred to the Microcorsini by Horak (2006). Microcorsini are hypothesized to be the most basal group in Olethreutinae (Razowski 1976, Horak 2006), and this is supported by recent phylogenetic analyses of the Tortricidae using molecular data (C. Mitter and A. Zwick, pers. comm.). The genus is currently divided into seven subgenera based on geographic distribution and structures of the male genitalia; Aarvik (2005) provided a key to the subgenera.

Species concepts and subgeneric classification in *Cryptaspasma* are poorly resolved, with Diakonoff (1959) providing the only complete revision of the genus to date. In addition to describing new species and illustrating type specimens, he defined five subgenera based primarily on male genitalic structures and geographic distribution. Kuznetsov (1970) proposed the tribe Microcorsini and elevated the five *Cryptaspasma* subgenera to genus rank. Subsequent authors have followed Diakonoff (1959) rather than Kuznetsov (1970) and treated the subgenera as such, although the taxonomic rank of these groups is largely subjective (Aarvik 2005) and questionable (Tuck, pers. comm.). Several new species were described in the later part of the 20th century from islands in the western Pacific and Indian Oceans (Clarke 1976, Bradley 1982, Diakonoff 1983). Brown and Brown (2004) described a new species of *Cryptaspasma* from the southeastern U.S. and provided the first complete world catalogue for the genus. Aarvik (2005) revised the African species of *Cryptaspasma* and proposed two new subgenera, increasing the total to seven. Horak (2006) revised the Australian *Cryptaspasma* and transferred *Collogenes* to Microcorsini. Most recently, Razowski (2011) reviewed the Neotropical Microcorsini and described a new species of *Cryptaspasma* from Costa Rica.

Accepted by J.-F. Landry: 11 Nov. 2011; published: 20 Dec. 2011

An undescribed species of *Cryptaspasma* was brought to the attention of the USDA in 2002, when larvae discovered in Hass avocados in Michoacán, México were thought to be that of *Stenoma catenifer* Walsingham (Elachistidae). The second author later confirmed that the larvae were of an undescribed *Cryptaspasma* species (mentioned in Brown and Brown 2004). In 2006–2007, visits to Guatemala by the third author confirmed the discovery of an undescribed species of *Cryptaspasma* infesting avocado fruit (detailed in Hoddle and Hoddle 2008, Hoddle 2011). Examination of the Mexican and Guatemalan specimens verified that they are conspecific, supported by both morphology and mtDNA analysis. The presence of a tortricid avocado pest in Central America and Mexico (Hoddle and Brown 2010) raises quarantine issues given the recent lifting of a U.S. import ban on Mexican Hass avocados.

Here we describe this new species of *Cryptaspasma* from Guatemala and Mexico. We present morphological details of adults and immature stages, details of its biology and life history, and provide characters for separating it from other tortricids and avocado-feeding Lepidoptera threatening avocado in California. In addition, we provide a complete list of tortricids documented from different avocado varieties worldwide.

Material and methods

Specimens were examined and dissected using a Wild M5A stereomicroscope (Wild Heerbrugg AG, Switzerland). Genitalia dissection methodology follows that summarized in Brown and Powell (1991) except that some preparations were mounted using Euparal mounting medium (Bioquip Products, Rancho Dominguez, CA). Larvae were prepared using the following method (O. Sage, pers. comm.): a small incision was made on the ventral mid-line near the head and the intact larva heated in 10% KOH for approximately 15 minutes; the larva was placed in water and the incision extended the full length of the body; the head capsule was carefully removed using forceps; the internal contents of the larva were removed with a brush and the cleaned larval skin stained lightly with chlorazol black; the skin was placed under glass pieces in a petri dish with 100% ethanol and left to dehydrate for one hour; the skin was then mounted in Euparal on a microscope slide; the head was stored in 80% ethanol. Adult, larval, and pupal photographs were taken using a Canon EOS 40D digital SLR (Canon U.S.A., Lake Success, NY) mounted on a Visionary Digital BK Lab System (Visionary Digital, Palmyra, VA). Microscope slide photos were taken using a Nikon DXM1200 digital camera mounted on a Nikon Labophot2 compound microscope (Nikon Instruments, Melville, NY). Some photographs are a combination of several layers produced with Helicon Focus 4.80 (Helicon Soft Ltd., Kharkov, Ukraine). All photographs were edited using Adobe Photoshop CS3 Extended and drawings were produced using Adobe Illustrator CS3 (Adobe Systems Inc., San Jose, CA).

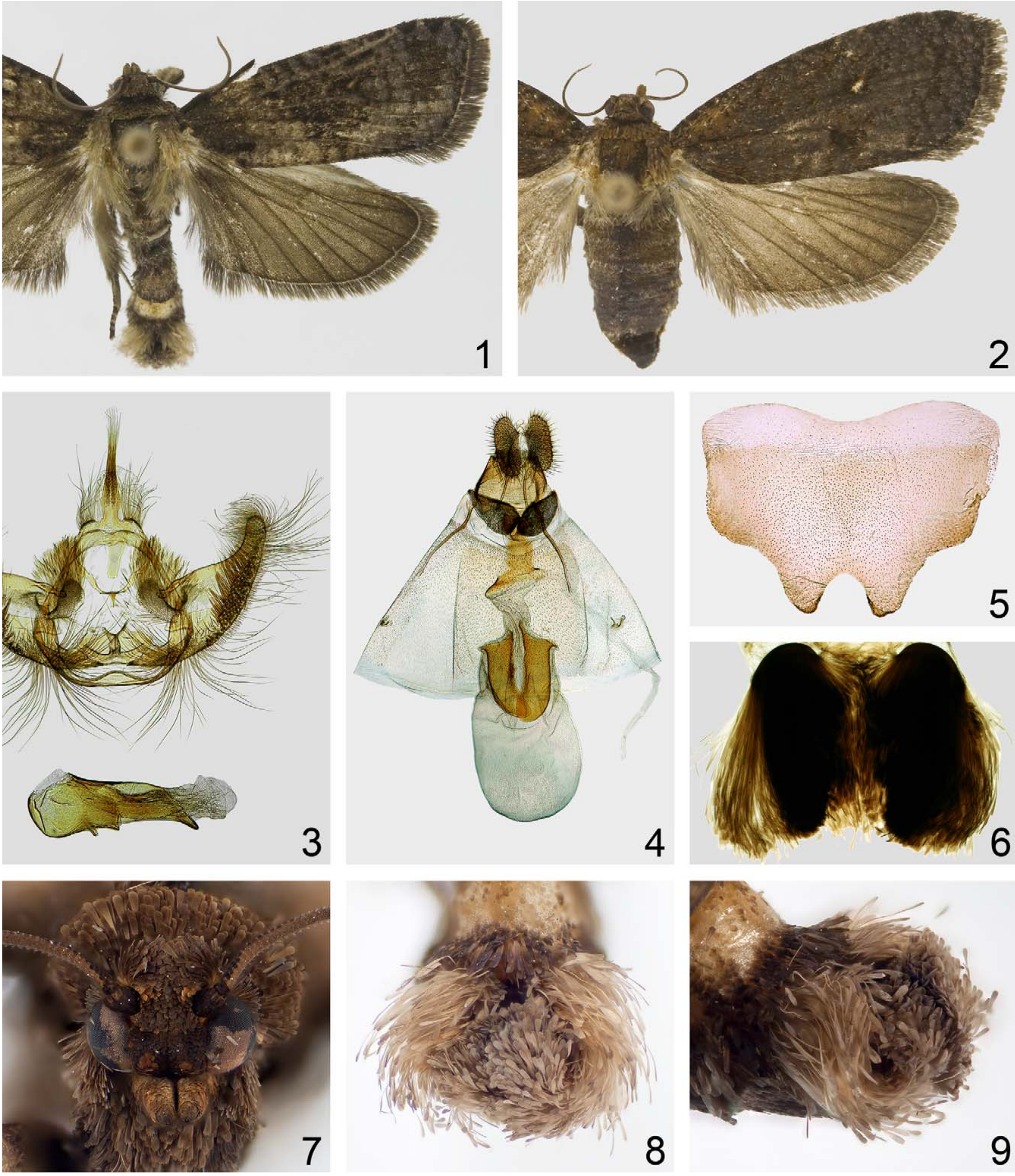
Morphological terms and wing pattern descriptions follow that in Diakonoff (1959), Aarvik (2005), Horak (2006), and Gilligan *et al*. (2008). We refer to the weakly sclerotized posteriorly projecting flap on the median portion of the male valva as a pulvinus (*sensu* Horak 2006)—"a pad-shaped densely bristled basal lobe." We refer to the shape of the scales in the coremata on the eighth abdominal tergite as rhopaloid (*sensu* Diakonoff 1959)—distally enlarged or inflated.

Abbreviations and symbols are as follows: AR = forewing aspect ratio, calculated by dividing forewing length by medial forewing width; ca. = circa (approximately); FW = forewing; FWL = forewing length, measured from base to apex including fringe; HW = hindwing; n = number of specimens examined. Abbreviations for depositories are as follows: CSCA, California State Collection of Arthropods, California Department of Food and Agriculture, Sacramento, Calif.; UCR, University of California, Riverside, Calif.; USNM, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

***Cryptaspasma* (*Cryptaspasma*) *perseana* Gilligan and Brown, new species**

(Figs. 1–27)

Systematics. *Cryptaspasma perseana* is assigned to the subgenus *Cryptaspasma* based on the following combination of characters (Aarvik 2005): uncus with hair-pencil; valva not swollen; pulvinus without spike(s); sacculus of valva without triangular, pointed prominence; and outer edge of valva not emarginate, thus sacculus and cucullus undifferentiated.



FIGURES 1–9. *C. perseana* adult characters. 1, male holotype. 2, female. 3, male genitalia. 4, female genitalia. 5, male eighth abdominal sternite. 6, male coremata, slide mounted. 7, head. 8, male coremata, posterior aspect. 9, male coremata, lateral aspect.

Diagnosis. *Cryptaspasma perseana* is separated from other species in the subgenus *Cryptaspasma* by the following characters: *C. bipenicilla* Brown and Brown has two lengths of coremata on the male abdomen versus one length in *C. perseana*; *C. lugubris* (Felder & Rogenhofer) and *C. acrolophoides* Meyrick males have an uncus that is parallel-sided versus widened above the base and tapering distally in *C. perseana*; *C. athymopis* Diakonoff and *C. microloga* Diakonoff females have signa that taper to a dull point versus signa that are distally rounded in *C. perseana*. Other undescribed males in the subgenus *Cryptaspasma* from Central and South America differ from *C.*

perseana in having either two lengths of coremata, setae absent from the base of the valva and/or sex scaling on the male hindwing; females of undescribed species generally lack the ventrolateral triangular processes on the sterigma and/or have differently shaped signa.

FIGURE 10. SEM of male coremata scales.

Description. Adult. Male. *Head* (Fig. 7): Vertex rough scaled, dark brown intermixed with golden-brown; upper portion of frons rough scaled, concolorous with vertex, lower portion of frons smooth scaled, dark brown to black intermixed with orange-brown; labial palpus porrect, all segments combined ca. 1.3 times diameter of compound eye, first and second segments golden brown, second segment enlarged, third segment rounded, ca. 0.3 as long as second segment, dark brown distally; antenna ca. 0.4 as long as forewing, dark brown basally, brown apically, scape dark brown to black, sensory cilia ca. 0.2 times width of flagellomere; ocellus conspicuous. *Thorax* (Fig. 1): Dorsal and ventral surfaces brown; tegula covered with long pale-brown scales; fore leg densely covered with dark brown scales; mid- and hind femur with long broad brown scales on ventral surface; mid- and hind tibia with long hairlike brown scales on dorsal and ventral surfaces; metathorax with posterior pair of scale tufts composed of long thin pale brown scales. Forewing length 9.8–10.9 mm (mean = 10.3, n = 10); costal fold absent; costal margin weakly convex; ground color pale brown intermixed with black and grayish purple; costal strigulae present as paired or single pale brown marks, strigulae 3–9 paired or unpaired on costa, strigula 10 unpaired between R_4 and R_5 on apex; conspicuous orange spot between bases of M_1 and M_2; fasciae dark brown to black, poorly defined; basal fascia expressed as black scaling at base along dorsum; subbasal and median fasciae coalesced to form broad band of black scaling extending from costa to dorsum across discal cell; postmedian and preterminal fasciae undefined, apical half of wing variably mottled with dark brown and grayish-purple; fringe brown. Hindwing: Uniformly brown; fringe brown with lighter apices. *Abdomen* (Figs. 3, 5–6, 8–10): Brown to pale brown; eighth abdominal tergite with posterior pair of coremata (Figs. 6, 8–10) consisting of a single tuft of scales composed as follows: outer scales elongate and pale brown, middle scales rhopaloid and dark brown, inner scales larger, rhopaloid, and covered with secretions; eighth abdominal sternite (Fig. 5) tapered distally with large mesal excavation forming two distal lobes. Genitalia (Fig. 3) with uncus variably elongate, weakly widened above base and tapered towards apex with tuft of setae extending from distal half, setal tuft approximately same length as uncus; socii a pair of setose arched lobes laterad to uncus; gnathos a narrow band with triangular subscaphium; tegumen narrow; pedunculus a triangular lobe; valva triangular, covered in long thin setae concentrated at base and rounded apex; a row of small pointed spinelike setae running entire length of saccular margin projecting ventrally; sacculus with several rows of long blunt spinelike setae ca. 0.50–0.85 distance from base to apex of valva; median portion of valva with weakly sclerotized pulvinus densely covered in long rhopaloid scales; phallus ca. 0.50 length of valva, broad, tapering weakly to blunt apex; cornuti absent.

Female. *Head*: As in male. *Thorax* (Fig. 2): As in male except: Forewing length 10.5–12.1 mm (mean = 11.3, n = 9); costal margin weakly convex; ground color grayish brown; costal strigulae subdued, remnants of strigulae 5–9 visible in some individuals; conspicuous white and orangish-brown spot between bases of M_1 and M_2; fasciae undefined; basal half of wing infused with orangish-brown, apical half of wing variably mottled with dark brown and grayish-purple; black patch surrounded by orangish-brown in area of median fascia below discal cell; fringe brown. Hindwing: Uniformly brown; fringe brown. *Abdomen* (Fig. 4): Brown to pale brown, without modified scales. Genitalia with papillae anales broad and densely setose; apophyses anteriores and posteriores slender, anteriores ca. 1.6 times as long as posteriores; sterigma composed of a pair of ventrolateral, slightly convex, triangular processes separated posteriorly by a ventromedial gap, each process strongly and finely reticulated with cellular spaces bordered by walls and covered with fine spicules, posteromedial corners of processes with several long, thin setae; ductus bursae widened asymmetrically at middle and sclerotized on ventral side from antrum to middle of ductus, forming a ring encircling ductus at middle posterior to inception of ductus seminalis; bulla seminalis absent; corpus bursae large, pear-shaped, with reticulated wall; a pair of large, hollow, paddle-shaped signa, nearly equal in size, with base of right signum arising more posterad than that of left.

Egg (Figs. 18–19). Flat, oval, translucent, white when first laid, turning grey as larva develops. Eggs are laid in masses (described below).

Larva (Figs. 11–17, 21–22). Mandibles (Fig. 13) with inner teeth (sensu Passoa 1985) modified into long ridge with tooth at the distal end, retinaculum present as a triangular projection; distance between P1 and AF2 on head (Fig. 12) ca. 0.7 times distance between P1 and P2; a horizontal line connecting the AF2 setae on head (Fig. 12) passes closer to P2 than P1; all pinacula weakly sclerotized; L pinaculum on T1 (Fig. 11) anteriad to spiracle; SV groups on A1, 2, 7, 8, 9 with 3:3:3:2:2 setae; SD2 on A1–8 (Fig. 14) reduced, located on same pinaculum as SD1; SD pinaculum on A8 (Fig. 11) anteriad to spiracle; D2 setae on A8 (Fig. 15) on same "saddle" pinaculum and closer together than D1 setae; D1, D2, and SD1 setae on A9 (Fig. 17) all on same large "saddle" pinaculum; D1 and SD1 setae on A9 (Fig. 17) closer together than D2 and D1 setae; L pinaculum on A9 (Fig. 11) bisetose; distance between D1 setae on anal shield (Fig. 16) ca. 1.7 times distance between D1 and SD1 setae; anal comb absent.

Pupa (Figs. 23–26). Length 9.0–11.6 mm (mean = 10.6, n = 13); abdominal segments 3-8 with two dorsal rows of spines: anterior row larger with ca. 18-32 spines; posterior row smaller with ca. 25-42 spines.

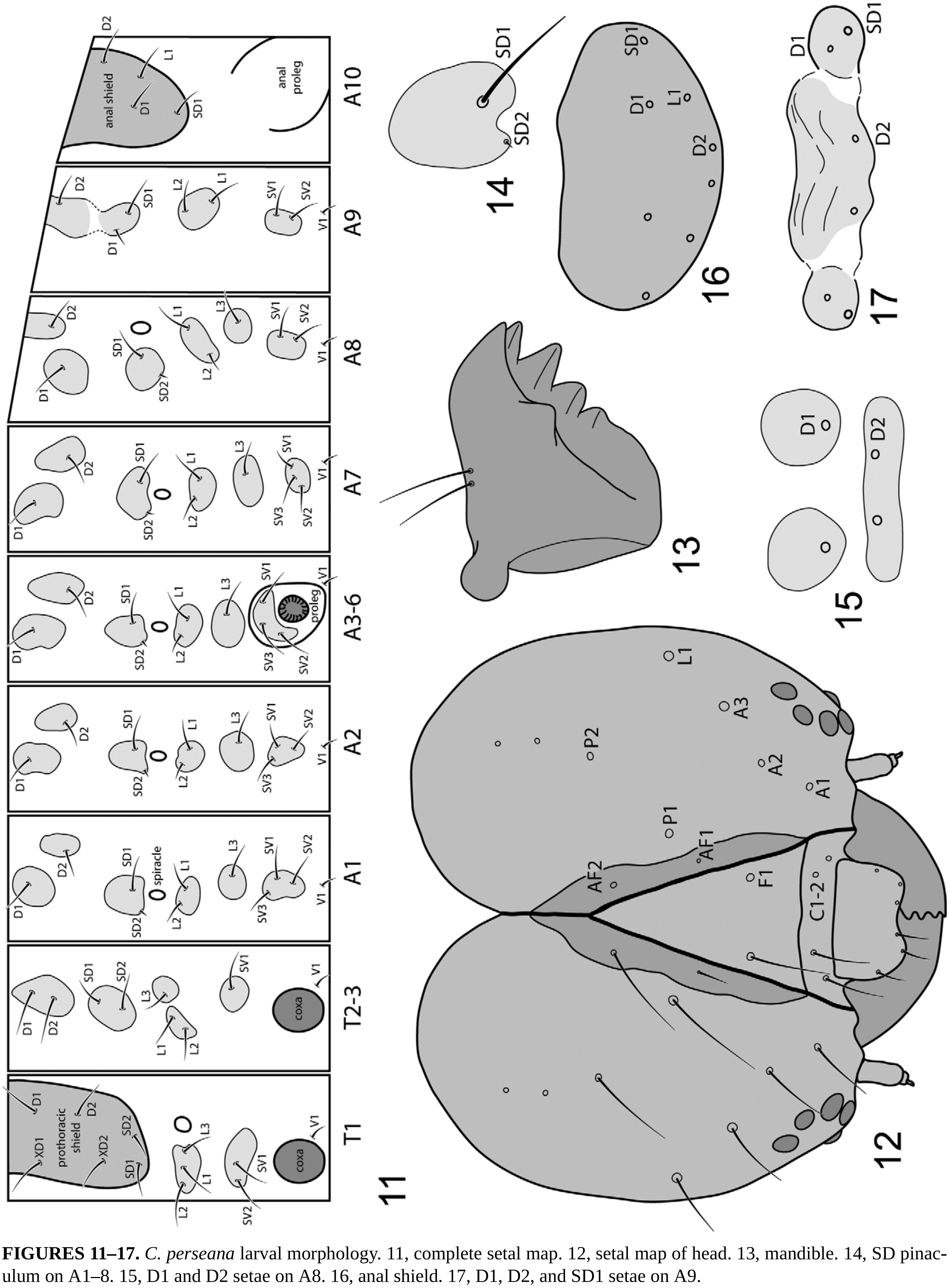
HOLOTYPE: ♂: GUATEMALA, Sacatepéquez, Finca San Miguel Urias, San Miguel Dueñas, 1495m, 14°31'27" N, 90°46'34" W, ex. Hass avocado fruit, XII 2006-III 2007, M. & C. Hoddle, USNM.

PARATYPES: 40 ♂, 60 ♀: GUATEMALA, same data as for holotype (4 ♂ CSCA; 1 ♂ TMG; 5 ♂ UCR; 8 ♂ USNM, genitalia slides USNM 124,660, TMG 488, TMG 489; 6 ♀ CSCA; 1 ♀ TMG; 5 ♀ UCR; 8 ♀ USNM, genitalia slides USNM 124,661, TMG 491); Sacatepéquez, Palin, Finca El Recuerdo, 1390m, 14°26'07" N, 90°40'52" W, ex. Hass avocado fruit, 8 XI 2006-16 XII 2006, M. Hoddle (5 ♂ UCR; 1 ♂ USNM, genitalia slide USNM 124,475; 6 ♀ UCR); Sacatepéquez, San Pedro de las Huertas, 14°31'55" N, 90°44'4" W, ex. Non-Hass avocado fruit, lab-reared, II-III 2007, M. Hoddle (15 ♂ UCR; 30 ♀ UCR); MÉXICO, Michoacán, near Morelia, Nuevo Parangaricutiro, Huerta Ladera 3, ex-larva, 7 XI 2002, Luis Cervantes (1 ♂ USNM, genitalia slide TMG 492; 4 ♀ USNM, genitalia slide TMG 493).

Etymology. The specific name is derived from the larval host, *Persea americana*.

Distribution. *Cryptaspasma perseana* is recorded from Michoacán, México and central Guatemala.

Biology. Hoddle and Hoddle (2008) described the biology of *C. perseana* (as "*Cryptaspasma* sp. nr. *lugubris*") reared under laboratory conditions; their findings are summarized here. Females laid eggs in masses (Figs. 18–19) containing an average of approximately 21 individual eggs (range of 2 to 73 eggs), primarily on smooth plastic surfaces, although some eggs were laid directly on intact avocado fruit and exposed avocado seeds. Eggs hatched in approximately 11 days (at 22°C) and larvae bored into avocado seeds where they completed development. A single avocado seed supported between 5–8 individual larvae. Larvae completed development in approximately three weeks (at 22°C) and left the seeds in search of pupation sites, although 5% of larvae pupated within feeding tunnels



FIGURES 11–17. *C. perseana* larval morphology. 11, complete setal map. 12, setal map of head. 13, mandible. 14, SD pinaculum on A1–8. 15, D1 and D2 setae on A8. 16, anal shield. 17, D1, D2, and SD1 setae on A9.

FIGURES 18–27. *C. perseana* immature stages. 18–19, egg masses. 20, larval damage to avocado fruit. 21–22, larvae. 23–25, pupae. 26, pupa exuvium extruding from avocado. 27, adult resting on avocado.

in the seed (Fig. 20). Larval damage was typically characterized by feeding tunnels in seeds, damaged pulp, and accumulation of frass at the opening of feeding tunnels. In the laboratory, larvae pupated between layers of paper towels; we hypothesize that pupation occurs primarily under bark or in leaf litter in natural settings. Larvae remained in a prepupal stage for approximately 2–4 days and in the pupal stage for 8–12 days (at 22°C). The pupal exuvium extrudes from the pupal chamber upon adult eclosion (Fig. 26). Adult sex ratio was found to be 46:54 male:female under laboratory conditions.

Adult females use pheromones to attract males. Pheromone gland extracts have been made, potential pheromone compounds isolated and identified, but field testing has not been conducted (Millar and Hoddle unpublished). Female calling was observed in the laboratory, characterized by rapid wing vibrations and a slight upturn of the abdomen with large pheromone glands protruding from the posterior. Calling was observed to commence almost immediately following sunset and lasted for approximately one hour, after which all obvious locomotor activity associated with mating by males and females ceased. At sunrise, adult moths rapidly moved to dark concealed hiding places at ground level to rest. When provided with access to a mix of 10% honey and water, adults lived for up to seven days (at 22°C).

It is unclear if females prefer to oviposit on fresh fruit still on the tree or on intact fruit that has recently fallen to the ground. Brown and Brown (2004) hypothesized that *Cryptaspasma* species are specialists on hard seeds of fallen fruit, suggesting that females do not oviposit on fruit that remains on the tree. Hoddle and Hoddle (2008) reviewed this issue and concluded that, based on field observations of dropped fruit, the likelihood of dropped avocado fruit being consumed by animals in a few days was very high. Thus any eggs laid by *Cryptaspasma* females on freshly dropped fruit would be eaten by animals as would any larvae that had not yet tunneled into the seed. Because Hoddle and Hoddle (2008) reared *C. perseana* from intact green fruit that was stated to be freshly picked from trees by a vendor (this was corroborated by circumstantial evidence; the fruit, at time of purchase were in a net sack on the vendor's back and the vendor was carrying a fruit picking pole), they suggest that oviposition and subsequent larval boring to the seed could have occurred before intact fruit dropped to the ground. Fruit may drop because of larval feeding, or because of strong winds causing fruit drop independently of larval infestation.

One species of endoparasitoid, a *Pseudophanerotoma* sp. (Hymenoptera: Braconidae: Cheloninae), was reared from ca. 30% of field collected *C. perseana* larvae. This is the first host record for a *Pseudophanerotoma* species; members of the Cheloninae are generally egg and larva parasitoids of tortricoids and pyraloids (J. Luhman pers. comm.).

Additional color photographs of all life stages of *C. perseana* and *Pseudophanerotoma* sp. are available (Hoddle 2011).

Discussion

Avocado (*Persea americana* Miller) is a member of the Lauraceae native to México and Central America. This species has a long history of domestication, and over 1000 varieties of avocado are grown worldwide (UCR 2010). One of the most popular varieties is the Hass avocado, which is the primary commercial cultivar for major avocado producers in California, México, and Central America (Hoddle and Hoddle 2008). Worldwide, México has been the top avocado producer and the United States the top avocado importer for the past several years. It is estimated that yearly worldwide avocado production will reach 4.7 million tons worth over $7.5 billion retail dollars by 2012 (Market 2008).

The import of Hass avocados into the United States from México has been a controversial topic in recent years. Avocado fruit imports from México were banned under U.S. Federal law from 1914 to 2005 due to the risk of importing specialist avocado fruit pests into the United States (Lambert 2004). On January 31, 2005, Federal regulations were lifted, allowing import of avocadoes from Michoacán, México into all states except California, Florida, and Hawaii for a period of two years; after January 31, 2007, avocados could be imported and distributed in all 50 States (Lambert 2004). The import of Mexican avocados into California that commenced in February 2007 was especially controversial, as Mexican imports competed with the California crop, which was valued at $327 million (U.S.) during the 2007–2008 growing season (CAC 2008, Hoddle and Brown 2010). In addition to economic impacts, import of avocados from other countries into the United States increases the risk of introducing avocado-feeding pests, especially internal-feeding species of Lepidoptera, Coleoptera, and Diptera. Although the number of leaf-feeding avocado pests has increased in California over the past two decades, the ban on avocado imports from México may have been significant in preventing the establishment of internal fruit-feeding pests (Hoddle and Hoddle 2008).

Worldwide, nearly 100 species of Lepidoptera in 20 different families have been recorded from avocado fruit and/or foliage (HOSTS 2009, Hoddle and Brown 2010). Among these are 37 species of tortricids (Table 1), most of which appear to be generalists. The following is a summary of select Lepidoptera that either are known pests or represent potential pests of avocados in California.

TABLE 1. Tortricidae reported to feed on avocado.

Genus/species	Subfamily	Reference	Region/country
"*Cnephasia*" *jactatana* (Walker)	Tortricinae	Stevens *et al.* 1995	New Zealand
Amorbia cuneana (Walsingham)	Tortricinae	LACM Index; Busck 1929; Faber *et al.* 2010; Waite & Barrera 2002; Wysoki *et al.* 2002	California
Amorbia emigratella Busck	Tortricinae	MacKay 1962; Zimmerman 1978; Coria *et al.* 2007	Hawaiian Islands, Mexico
Amorbia santamaria Phillips and Powell	Tortricinae	Hoddle & Brown 2010	Guatemala
Archips capsigerana (Kennel)	Tortricinae	Liu 1983; Liu & Li 2002	China
Archips machlopis (Meyrick)	Tortricinae	Yunus & Ho 1980	Malaysia
Archips micaceana (Walker)	Tortricinae	Lee & Winney 1981	Hong Kong
Archips occidentalis (Walsingham)	Tortricinae	Erichsen & Schoeman 1994	South Africa
Argyrotaenia amatana (Dyar)	Tortricinae	LACM Index; Freeman 1958	USA
Argyrotaenia franciscana (Walsingham) [1]	Tortricinae	LACM Index; Powell 1964b	USA
Argyrotaenia montezumae (Walsingham)	Tortricinae	USNM collection	Mexico
Argyrotaenia urbana (Busck)	Tortricinae	Hoddle & Brown 2010	Guatemala
Cacoecimorpha pronubana (Hubner)	Tortricinae	Swirski *et al.* 1995; Waite & Barrera 2002	Israel
Clarkeulia dimorpha (Clarke)	Tortricinae	d'Araujo Silva *et al.* 1968	Brazil
Cryptoptila immersana (Walker)	Tortricinae	Waite & Barrera 2002	Australia
Ctenopseustis herana (Felder and Rogenofer)	Tortricinae	Stevens *et al.* 1995; Waite & Barrera 2002	New Zealand
Ctenopseustis obliquana (Walker)	Tortricinae	Stevens *et al.* 1995; Waite & Barrera 2002	New Zealand
Epiphyas postvittana (Walker)	Tortricinae	Stevens *et al.* 1995; Brown *et al.* 2010	Australia, New Zealand
Homona spargotis Meyrick	Tortricinae	Pinese & Brown 1986	Australia
Isotenes miserana (Walker)	Tortricinae	Waite & Barrera 2002	Australia
Lozotaenia capensana (Walker)	Tortricinae	Erichsen & Schoeman 1994	South Africa
Netechma pyrodelta (Meyrick)	Tortricinae	Hoddle & Brown, 2010; USNM collection	Guatemala
Orthocomotis herbacea Clarke	Tortricinae	Clarke 1956; Brown 2003	Costa Rica
Planotortrix excessana (Walker)	Tortricinae	Stevens *et al.* 1995	New Zealand
Planotrotrix octo Dugdale	Tortricinae	Stevens *et al.* 1995	New Zealand
Platynota stultana Walsingham	Tortricinae	Powell 1983	North America
Cryptaspasma bipenicilla Brown & Brown	Olethreutinae	Brown & Brown 2004	Puerto Rico
Cryptaspasma perseana Gilligan & Brown	Olethreutinae	Brown & Brown 2004; Hoddle & Hoddle 2008; Hoddle & Brown 2010	Guatemala, Mexico
Lobesia stericta Meyrick	Olethreutinae	Erichsen & Schoeman 1994	South Africa
Sorolopha elaeodes temenopis (Meyrick) [2]	Olethreutinae	Meyrick 1936	Taiwan
Sorolopha phyllochlora (Meyrick) [3]	Olethreutinae	Meyrick 1936	Asia
Sorolopha semiculta (Meyrick) [4]	Olethreutinae	Meyrick 1936	Asia, Taiwan

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TABLE 1. (continued)

Genus/species	Subfamily	Reference	Region/country
Thaumatotibia leucotreta (Meyrick)	Olethreutinae	Bradley *et al.* 1979; Erichsen & Schoeman 1994	Europe
Thaumatotibia zophophanes (Turner)	Olethreutinae	Waite & Barrera 2002; Horak 2006	Australia
Histura perseavora Brown	Chlidanotinae	Brown & Hoddle 2010	Guatemala
Histuroides costaricana Razowski	Chlidanotinae	Brown & Hoddle 2010	Costa Rica
Polyortha Dognin [new species]	Chlidanotinae	Hoddle & Brown 2010	Guatemala

[1] as *Argyrotaenia citrana*; [2] as *Argyroploce temenopis*; [3] as *Olethreutes phyllochlora*; [4] as *Argyroploce heteraspis* in Taiwan

Amorbia spp. (Tortricidae: Tortricinae)

Amorbia cuneana (Walsingham), the western avocado leafroller, is considered a primary but sporadic pest of avocado in California (Faber *et al.* 2010). Its putative synonym, *A. essigana* Busck, was described as an avocado pest in southern California nearly 80 years ago, and avocado feeding populations may actually represent this "pheromone race" (e.g., Hoffman *et al.* 1983; Bailey *et al.* 1986; Bailey *et al.* 1988). Adults are present from late April to July and again in September to November in central California and year round in southern California (Powell and Opler 2009). Larvae cause damage by feeding on leaves, skeletonizing them in early instars and consuming the entire leaf in later instars. Economic losses occur when larvae web leaves to fruit or feed on the skin of fruit in a cluster, causing cosmetic damage (Faber *et al.* 2010).

In Hawaii, the Mexican leafroller, *Amorbia emigratella* Busck, is considered a pest on a variety of plants, including avocado, although this species is native to México and Central America (Zimmerman 1978). Larval damage appears similar to that of *A. cuneana* and also *E. postvittana* (Zimmerman 1978).

An additional species, *Amorbia santamaria* Phillips & Powell, was reared from avocado in Guatemala by Hoddle and Hoddle (2008).

Argyrotaenia franciscana (Walsingham) (Tortricidae: Tortricinae)

The orange tortrix, *Argyrotaenia franciscana*, is a polyphagous species that is an occasional pest of avocado in California. This species is found primarily in cooler coastal areas and river valleys, where adults may be present year round; only two generations are present in warmer inland areas (Powell 1964). Larvae feed in silken shelters on outer shoots and can cause economic damage by chewing holes in fruit and even causing fruit to drop by feeding on the stem (Faber *et al.* 2010).

Cacoecimorpha pronubana (Hübner) (Tortricidae: Tortricinae)

The carnation tortrix, *Cacoecimorpha pronubana*, was discovered feeding on winter daphne (*Daphne odora* Thunb.) in California in early 2011 (M. Epstein, pers. comm.). A native of northern Africa, this species was first documented from North America in Oregon in 1964 (Powell 1969), and it is also present in Washington (E. LaGasa, pers. comm.). Larvae are highly polyphagous, having been recorded from more than 160 species of plants in 42 families (Razowski 2002). Wyoski and Izhar (1976) reported *C. pronubana* as a pest of avocado in Israel in the early to mid-1970s, causing surface damage to fruit in orchards.

Epiphyas postvittana (Walker) (Tortricidae: Tortricinae)

The light brown apple moth, *Epiphyas postvittana*, native to Australia, was discovered in California in 2006 (Brown *et al*. 2010). Larvae are highly polyphagous, having been recorded on over 500 species of plants, including avocado (Brown *et al.* 2010). Although not yet recorded on avocado in California (M. Epstein, pers. comm.), larvae can cause economic damage by webbing leaves to fruit or feeding on the surface of fruit (Brown *et al.* 2010).

***Caloptilia, Marmara,* and *Phyllocnistis* spp. (Gracillariidae: Gracillariinae, Phyllocnistinae)**

Marmara gulosa Guillén and Davis, the citrus peelminer, has been reported as a pest of avocado in California (Waite and Barrera 2002; as *M. salictella* Clemens). Larvae cause damage by mining the surface of fruit, causing significant scarring, and they may also mine shoots and leaves (Guillén *et al.* 2001, Waite and Barrera 2002). *Caloptilia perseae* (Busck) is considered a pest of avocado in México, where larvae mine leaves but rarely cause significant damage (Wysoki *et al.* 2002). Davis and Wagner (2011) described several new species of *Phyllocnistis* from Central America and the southeastern U.S. that mine leaves of avocado; none of these species are recorded from California.

***Platynota stultana* Walsingham (Tortricidae: Tortricinae)**

Platynota stultana, the omnivorous leafroller, was introduced into southern California in the late 1800's (Powell and Opler 2009). It has subsequently expanded its range into northern California, while at the same time expanding its host range onto a variety of non-native plants (Powell 1983). This species is considered a pest in greenhouses and vineyards, but it also attacks row crops, citrus, and occasionally avocado. Adults are present year round in southern and central California. Larvae feed primarily in shelters constructed of rolled or folded leaves. Economic damage occurs when larvae web leaves to fruit or feed directly on fruit, causing superficial damage and secondary infection by bacteria and fungi.

***Sabulodes aegrotata* (Guenée) (Geometridae: Ennominae)**

Sabulodes aegrotata, the omnivorous looper, is a highly variable and polyphagous species that sometimes causes damage to avocado, citrus, and walnuts (Powell and Opler 2009). In California, adults are present year round, with populations increasing in the warmer months. Larvae cause economic damage by feeding on both leaves and fruit, leading to disfigurement and scarring of fruit (Faber *et al.* 2010).

***Stenoma catenifer* Walsingham (Elachistidae: Stenomatinae)**

Stenoma catenifer is the most important lepidopteran pest of avocado in the Neotropics (Wysoki *et al.* 2002). Although not yet found in California, this species has been recorded damaging avocados in Argentina, Brazil, Colombia, El Salvador, Guatemala, Guyana, Honduras, México, Panama, Perú, and Venezuela, with crop losses as high as 60–80% (Hoddle and Hoddle 2008). This pest has demonstrated the ability to invade new areas because of the accidental movement of infested avocado fruit. This situation was realized in 2000 in the Galápagos Islands (Landry and Roque-Albelo 2003). *Stenoma catenifer* larvae cause damage similar to those of *C. perseana*; larvae of the latter discovered in México in 2002 were initially thought to be those of *S. catenifer.* Larvae of the two species are separated by the following characters: D2 pinacula on A9 fused dorsally (creating a mid-dorsal saddle) in *C. perseana*, whereas D2 pinaculum and D1 pinaculum are fused subdorsally in *S. catenifer* (creating a shared subdorsal pinaculum); L pinaculum on A9 trisetose in *S. catenifer*, bisetose in *C. perseana*; and SV pinaculum on A1 and A7 bisetose in *S. catenifer,* trisetose in *C. perseana.* Cervantes (1999) provides a complete setal map and larval description for *S. catenifer.*

***Thaumatotibia leucotreta* (Meyrick) (Tortricidae: Olethreutinae)**

The false codling moth, *Thaumatotibia leucotreta,* is a native of sub-Saharan Africa. This polyphagous species is a serious pest of citrus and cotton and has been recorded from more than 50 plant species in over 30 families (Brown *et al.* 2008, van der Geest *et al.* 1991). In South Africa, *T. leucotreta* is considered the most significant Lepidoptera pest of avocado (Erichsen and Schoeman 1994). Larvae cause direct damage by tunneling in the fruit just beneath the skin, and larval feeding often results in secondary damage caused by bacteria and fungi (Erichsen and Schoeman 1994).

Thaumatotibia leucotreta is not established in California; however, a single male was collected in a pheromone trap in Ventura County in July, 2008 (Gilligan *et al.* 2011). This species is one of the most commonly intercepted tortricids on pepper (Solanaceae: *Capsicum annuum* L.) and eggplant (Solanaceae: *Solanum melongena* L.) at U.S. ports-of-entry (Brown 2006, Gilligan *et al.* 2011).

Other Lepidoptera pests

Other species of Lepidoptera have been occasionally recorded on avocado in California (M. Epstein, pers. comm.); although we are unaware of other species reaching pest status in the state. Noctuidae, Arctiinae, Papilionidae, Hesperiidae, and Psychidae have been reported on avocado in México (Waite and Barrera 2002, USDA 2004); however, these species, where known, are not present in California. It is conceivable that any highly polyphagous species of Lepidoptera would feed on avocado if given an opportunity as many of the known pests are general feeders.

Key to Lepidoptera larvae threatening avocado in California

The following key, with characters modified from Gilligan and Epstein (2009), includes avocado-feeding species currently found in California and avocado-feeding species in other parts of the world that would threaten California avocado production should they become introduced. This is not a complete list of avocado-feeding Lepidoptera and the key is not intended to definitively key out all Lepidoptera larvae found on avocado. The purpose of the key is to assist identifiers and growers in recognizing the most commonly encountered avocado-feeding species in California and to help separate native from potentially harmful introduced species.

This key assumes that: 1) the larva was found feeding on avocado; 2) the larva is mid- to late instar; and 3) the user is familiar with larval morphology and terminology. Because many Lepidoptera larvae are difficult to identify to species, any identifications made with this key should be confirmed by an expert, and larvae should be reared to adulthood if possible to confirm larval identifications.

1	Larval damage apparent as mines in surface of fruit, leaves, or shoots	Gracillariidae
-	Larval damage not as above or unknown	2
2	Prothoracic prespiracular pinaculum bisetose	3 (macrolepidoptera and Pyraloidea)
-	Prothoracic prespiracular pinaculum trisetose	4 (microlepidoptera)
3	Prolegs present on abdominal segment 6 (A6) and A10 only	Geometridae (including *Sabulodes aegrotata*)
-	Prolegs present on A3-6 and A10 or A5-6 and A10	Other macrolepidoptera (including Noctuidae)
4	L1 and L2 setae on segments A2-7 close together or on same pinaculum	5 (Gelechioidea/Tortricidae)
-	L1 and L2 setae on segments A2-7 widely separated	Other microlepidoptera
5	D2 setae on A9 on shared mid-dorsal (saddle) pinaculum; D2 and D1 pinacula not fused subdorsally	6
-	D2 setae on A9 on separate pinacula (no mid-dorsal saddle); D2 and D1 pinacula fused subdorsally	*Stenoma catenifer*
6	Anal comb present; D1 and SD1 setae separate from D2 on A9	7
-	Anal comb absent; D2, D1, and SD1 setae all on same large pinaculum on A9	*Cryptaspasma perseana*
7	Prothoracic prespiracular pinaculum extended below spiracle	*Thaumatotibia leucotreta*
-	Prothoracic prespiracular pinaculum not extended below spiracle	8
8	Prothoracic shield with dark lateral line	*Amorbia* spp.
-	Prothoracic shield with irregular dark marks on posterolateral corners	*Cacoecimorpha pronubana*
-	Prothoracic shield without dark lateral line or other markings	Other Tortricidae* (including *E. postvittana*, *P. stultana, A. franciscana*)

* It is difficult or impossible to separate larvae of the three tortricid species listed here without using advanced characters. See Gilligan and Epstein (2009) for additional characters that can be used to separate tortricid larvae in California.

Acknowledgements

We thank the following persons who provided loans to specimens under their care: Marc Epstein, California Department of Food and Agriculture; Sabine Gaal-Haszler, Naturhistorisches Museum Wien, Vienna; Steven Passoa, United States Department of Agriculture; Kevin Tuck, The Natural History Museum, London; and Doug Yanega, University of California, Riverside.

David Adamski Department of Entomology, National Museum of Natural History, Smithsonian Institution and Scott Whittaker, Lab Manager, Scanning Electron Microscopy Laboratory, Smithsonian Institution assisted with use of the SEM. Jocelyn Millar, University of California, Riverside isolated and identified pheromone compounds. John Luhman, Department of Entomology, University of Minneosta assisted with parasitoid identification. Charles Mitter, Department of Entomology, University of Maryland, and Andreas Zwick, Staatliches Museum Für Naturkunde, Stuttgart provided access to unpublished molecular data. Norman Barr, United States Department of Agriculture, Mission Laboratory, assisted with DNA sequencing.

The following persons provided comments on the manuscript and/or other useful information: Leif Aarvik, Natural History Museum, University of Oslo; Marc Epstein; Thomas Henry, USDA, SEL, Washington, DC; John Heppner, McGuire Center, University of Florida, Gainesville; Kevin Hoffman, California Department of Food and Agriculture; Ronald Ochoa, USDA, SEL, Beltsville, Maryland; Steven Passoa; and Obediah Sage, California Department of Food and Agriculture.

Portions of this research were funded through a cooperative agreement with California Department of Agriculture, Colorado State University, and USDA-CPHST under the supervision of Terrence Walters.

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