Metamasius hemipterus

Scientific Name
Metamasius hemipterus (Linnaeus, 1758)

Synonyms:
Calandra sacchari Gyllenhal, 1838
Curculio hemipterus Linnaeus, 1758
Curculio rufofasciatus De Geer, 1775
Curculio variegatus Fabricius, 1787
Sphenophorus ambiguus Gyllenhal, 1838
Sphenophorus decoratus Gyllenhal, 1838
Sphenophorus hemipterus (Linnaeus, 1758)
Sphenophorus inscripta Gyllenhal, 1838
Sphenophorus sacchari Gyllenhal, 1838
Sphenophorous nigerrimus Gyllenhal, 1838

Taxonomic note
Metamasius hemipterus includes three subspecies: *M. hemipterus carbonarius*, *M. hemipterus hemipterus*, and *M. hemipterus sericeus* (Vaurie, 1966). Differences are found in the color pattern of the elytra, pronotum, or venter but not in form (Vaurie, 1966). Some of the information contained in this datasheet may refer specifically to the subspecies *M. h. sericeus*, which is currently found in the United States (Florida).

Common Name
West Indian cane weevil, rotten cane stalk borer, rotten sugarcane weevil, silky cane weevil, weevil borer, West Indian sugarcane borer

Type of Pest
Weevil

Taxonomic Position
Class: Insecta, **Order:** Coleoptera, **Family:** Dryophthoridae

Reason for Inclusion in Manual
Additional Pests of Concern for 2013 (as *Metamasius* spp.);
Previously listed on the CAPS AHP Master Pest List

Pest Description
Eggs: The egg is yellowish cream, approximately 1.7 mm (approx. $^{1}/_{16}$ in) long, ovoid and semitransparent (CABI, 2012).

Larvae: The larva is white and robust with a width of 3.2 to 4.5 mm (approx. $^{1}/_{8}$ to $^{3}/_{16}$ in). Thoracic and abdominal sclerites are yellow in color while the head is brown with paler stripes on the dorsal side. Body length is 15 to 17 mm (approx. $^{9}/_{16}$ to $^{11}/_{16}$ in).

Three dorsal folds are present on the abdominal segments while the 9th abdominal segment is either smoothly rounded or transverse. Abdominal segments 1 to 8 have distinct spiracles (CABI, 2012).

The larva is described in Cotton (1924) and Anderson (1948). A generic key to larvae of Rhynchophorinae (including *Metamasius*) can be found in both papers.

Pupae: The pupa is elongate, narrow and contracted both anteriorly and posteriorly and is approximately 14.5 mm (approx. $^{9}/_{16}$ in) in length. Five pairs of functional abdominal segments are visible from above. Cocoons are reddish-brown, composed of plant fibers, and usually found within the host plant (CABI, 2012). The cocoons constructed by *M. hemipterus* are similar to that of *Rhynchophorus cruentatus* (Fabricius) (Giblin-Davis, 2001).

Figure 1 & 2. Dorsal and side view of *M. hemipterus* (Natasha Wright from Forestryimages.org)

Adults: "These key characters are taken from Vaurie (1966). Colour variable, entirely black, to black with basal red band of varying extent on elytra, or elytra streaked with red and black longitudinally; pronotum and venter black or various combinations of red and black; femora red, red with black stripes, or red with black bands or smudges; 9-14 mm [approx. $^{3}/_{8}$ to $^{9}/_{16}$ in] in length. Head with rostrum measured from apex to top of eye about as long as pronotum; rostrum basally inferiorly not angulate or toothed, but may

have feeble sinuation (males), rostrum with divided patch of tomentose yellow hairs above insertion of antennae (females). Prothorax with pronotum at base medially either virtually flat, or with a weak longitudinal depression; prosternum with distinct yellow hairs around front coxae. Scutellum not bilobed, but may be slightly emarginate anteriorly. Elytra with striae composed of punctures narrower than intervals. Metasternum almost three times longer than diameter of middle coxa. Legs with middle and hind tibiae not or scarcely perceptibly expanded and sinuate; males with inner edge of hind tibiae straight; tarsal lobes, except narrow glabrous midline, entirely hairy. Sides of body below, except abdomen either impunctate or very finely punctate. Male genitalia, with median lobe truncate apically, in lateral view with entire lateral line" (CABI, 2012).

A detailed description of the adult stage can be found in Vaurie (1966).

Figure 3. Dorsal view of *Metamasius hemipterus* showing variability of color pattern on elytra (USDA-APHIS-PPQ, Miami, FL).

Metamasius hemipterus carbonarius:
"Pronotum and under side usually black or virtually so; elytra usually mostly black with, in some individuals, red basally" (Vaurie, 1966).

Metamasius hemipterus hemipterus: "Elytra on outer intervals either red in basal half or more, with or without black spot or patch diagonally from shoulder, or elytra streaked longitudinally with red and black, sides behind black shoulder patch with elongate, oval, red "window" on about sixth to eighth intervals; apex of elytra black or black with one or two red streaks to apex" (Vaurie, 1966).

Metamasius hemipterus sericeus: "Adults of *M. h. sericeus* vary in color from red to orange and black. In addition, the pattern of coloration on the elytra, pronotum and venter is also variable. The femora are typically red, or red with black patterning. Total length of adults from the tip of the rostrum to the end of the pygidium varies from 9 to 14 mm [approx. $^{3}/_{8}$ to $^{9}/_{16}$ in]" (Weissling and Giblin-Davis, 2010).

Biology and Ecology

Weissling et al. (2003) found that the average generation time for *M. hemipterus sericeus* was 63 days, mean egg production was 52 eggs, and oviposition began approximately 27 days after mating. In temperate regions, one generation occurs per year, while in hot and humid regions, two generations may occur per year (reviewed in Brito et al., 2005).

Females are attracted to wounds caused by rats, pruning, and other means. Females oviposit approximately 500 eggs in cracks or damaged areas of the host plant or in the petioles or crown shaft of certain species of healthy palms (Giblin-Davis et al., 1996a). Eggs hatch in about four days (Giblin-Davis, 2001).

After egg hatch, larvae tunnel in the lower stem and rhizome where they destroy maturing stems (Alpizar et al., 2002). They bore into the stems of *Saccharum* spp. (sugarcane) and *Musa* spp. (bananas) and occasionally bore the sheaths of *Cocos nucifera* (coconuts) (Vaurie, 1966). *Metamasius hemipterus* feeds on the pith of *Saccharum* spp. (sugarcane) and can sometimes bore into healthy tissue (Weissling and Giblin-Davis, 2010). In palms, bromeliads, and orchids, larvae typically bore into the leaf bases although they can also attack the stems (Vaurie, 1966; Giblin-Davis, 2001). Host material is usually already damaged when eggs are laid; however, the larvae bore galleries, which cause additional damage (Vaurie, 1966). Development takes approximately two months (Giblin-Davis, 2001). There are seven to nine larval instars

Figure 4. Exudate from oviposition holes caused by *M. hemipterus* in spindle palm (Timothy K. Broschat, Professor, Environmental Horticulture, University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS)).

Figure 5. *Phoenix canariensis* infested with *M. hemipterus*. Note older living leaves hanging down against the trunk (Timothy K. Broschat, Professor, Environmental Horticulture, University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS)).

(Mariau, 2001). After larvae feed for approximately seven weeks, they pupate in a fibrous pupal case (Weissling et al., 2003). In palms, mature larvae move to the petiole or stalk to pupate (Giblin-Davis et al., 1996b).

The pupal stage lasts around 15 days (Brito et al., 2005). Adults may emerge immediately after pupation is completed (usually around 10 days) or they may remain within the cocoon until conditions are favorable (Woodruff and Baranowski, 1985).

The adults are good fliers and can live from two to three months (Vaurie, 1966). Adults can be found in the interior of *Saccharum* spp. (sugarcane) and *Musa* spp. (bananas), on the ground, or under palm sheaths (Vaurie, 1966; Weissling and Giblin-Davis, 2010).

Damage

Metamasius spp. are generally considered secondary pests that are found in decaying or rotting trunks or stems; however, they can attack healthy plants (Vaurie, 1966). Some species attack bromeliad or orchid leaf bases (Vaurie, 1966). Most of the time, the plants or plant parts are already in bad condition but further damage is caused by the galleries (Vaurie, 1966).

Figure 6. Close-up of leaf base of *Phoenix canariensis* infested with *M. hemipterus* (Timothy K. Broschat, Professor, Environmental Horticulture, University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS)).

Damaged palms often produce an amber-colored, gummy exudate and have chewed plant tissue coming out of the gallery window at the frond bases, which break prematurely (Giblin-Davis, 2001). When peeling the outer leaf, the younger leaf bases may be scarred with galleries dug by feeding larvae (Broschat et al., 2010). *Metamasius hemipterus* larvae can also bore into *Saccharum* spp. (sugarcane) and *Musa* spp. (banana) stems and occasionally *Cocos nucifera* (coconut) sheaths (Vaurie, 1966). The plant is weakened as *M. hemipterus sericeus* larvae bore into the stems and petioles, which provides access to fungi or other pests (Weissling et al., 2003). Damage caused by *M. hemipterus* is rarely lethal to palms (Giblin-Davis, 2001; Weissling and Giblin-Davis, 2010). As soon as larval development begins, the cane stalks begin to rot, giving off a distinctive acetic acid odor (Wolcott, 1948). In *Saccharum* spp. (sugarcane), growth slows; plants turn yellow; and stalks become riddled with large galleries (Wyniger, 1962). In *Musa* spp. (banana), plant growth slows; leaves wilt and wither; young plants will turn yellow and collapse; and pseudostems, which are heavily mined, will often break (Wyniger, 1962).

Pest Importance

Metamasius hemipterus usually attacks damaged or unhealthy host plants, but it has caused losses in bananas, pineapple, and sugarcane in the Caribbean (Woodruff and Baranowski, 1985; O'Brien and Thomas, 1990). This weevil has already caused some economic losses in Florida on sugarcane cultivar CP85-1382 (CABI, 1999). In Florida, estimated losses to sugarcane production are has high as $402.40/ha (Sosa et al., 1997). Heavy infestations may reduce cane yields by up to 25%. In Ecuador, heavy infestations have reduced cane yield by 10 to 15% and sucrose yield by 20 to 30% (reviewed in Sosa et al., 1997).

Certain palm species are more prone to damage by *M. hemipterus* than others such as *Phoenix canariensis* and *Ravenea rivularis*, which have soft or fleshy frond bases, and *Roystonea* and *Hyphorbe* spp., which have crown shafts. The weevils can crawl into the moist recesses between frond bases (Giblin-Davis, 2001). This species can pose a risk to the ornamental palm industry because damage caused by *M. hemipterus* can lead to aesthetic problems, such as exudate running down the stem or crown shaft of the palm (Weissling and Giblin-Davis, 2010).

Although the subspecies *M. hemipterus sericeus* is generally attracted to damaged stems caused by mechanical cultivation, harvesting equipment, rats, other borers, disease, or natural growth cracks in sugarcane, it can serve as an important pest of nursery palms and banana plantings in South Florida as well as the West Indies and Central and South America. Infestations can go undetected in certain trees which can cause an increase in the weevil population (Weissling and Giblin-Davis, 2010).

Known Hosts

This is the only species of *Metamasius* reported on *Elaeis* and *Cocos* (coconut), but it mostly develops on *Saccharum* spp. (sugarcane) (Mariau, 2001).

Major hosts

From Vaurie (1966):
Musa spp. (Banana), *Saccharum spp.* (Sugarcane), and *Saccharum officinarum* (Sugarcane).

Minor hosts

From Vaurie (1966):
Ananas comosus (pineapple), *Carica papaya* (papaya), *Chamaedorea cataractarum* (cascade palm), *Cocos nucifera* (coconut), *Hyophorbe verschaffeltii, Lantana* spp. (lantana), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Musa* x *paradisiaca* (=*Musa sapientum*) (banana), *Oenocarpus bataua* var. *bataua* (=*Jessenia bataua*) (Pataua palm), *Phoenix canariensis* (Canary island date palm), *Psidium* spp. (guava), *Ptychosperma macarthurii* (Macarthur palm), *Ravenea rivularis* (majesty palm), *Roystonea borinquena* (Puerto Rican royal palm), *Roystonea regia* (royal palm) (=*Roystonea elata*), *Sorghum bicolor* (sorghum), *Washingtonia robusta* (Washingtonia palm), and *Zea mays* (maize).

Wild hosts

From Vaurie (1966):
Bauhinia spp. (bauhinia), Graminaceae (grasses), and *Iriartea ventricosa*.

Most *Metamasius* species are considered secondary pests. *Metamasius hemipterus sericeus*, in contrast, is an important pest of palms, sugarcane, pineapple and bananas in the West Indies, Mexico, and Central and South America (Giblin-Davis et al., 1996a).

Pathogens or Associated Organisms Vectored

Ramirez-Lucas et al. (1996) state that this weevil may be a vector of red ring disease caused by *Bursaphelenchus cocophilus* (Cobb) (a nematode) in oil palm trees in Colombia. Although this species may be a potential vector, it is not likely to be a particularly effective one. The number of nematodes associated with *Metamasius hemipterus* is small compared with the number associated with *Rhynchophorus palmarum* and *Dynamis borassi* (Hagley, 1964; Griffith et al., 2005).

In Barbados, *M. hemipterus* has been implicated in the transmission of a fungus causing leaf-bitten disease in coconut (reviewed in CABI, 2012).

Known Distribution

Vaurie (1966) states that this species is found throughout the Caribbean and Central America, the southern portion of Mexico, and the northern half of South America.

Asia: Indonesia* and Philippines;* **Africa:** Cameroon, Congo, Equatorial Guinea, Gabon, and Nigeria; **Caribbean:** Antigua and Barbuda, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, and the U.S. Virgin Islands; **Central America:** Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama; **North America:** Mexico; **South America:** Argentina, Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Uruguay, and Venezuela (Vaurie, 1966; CABI, 2012).

*EPPO (2008) states that records in Indonesia and Philippines are doubtful. Since the original dates of the records (1904 and 1925) there have been no new records.

Metamasius hemipterus is also established in parts of Florida.

Pathway

There have been at least 1,049 interceptions of this species at U.S. ports of entry since 1985. This includes interceptions identified as *Metamasius hemipterus* (928) as well as interceptions of the three subspecies, *M. hemipterus hemipterus* (28), *M. hemipterus sericeus* (60), and *M. hemipterus carbonarius* (33). Almost all of the interceptions occurred on plant material, most notably *Musa* spp. (including *M. acuminata* and *M. paradisiaca*) (810 interceptions), *Chamaedorea* sp. (45), and *Heliconia* sp. (21). Most infested material originated from Ecuador (729), followed by Costa Rica (97), Dominican Republic (41), and Venezuela and Mexico (both 40). In addition to this, interceptions

identified only as *Metamasius* sp. have occurred at least 1,561 times at U.S. ports of entry (AQAS, 2012, queried June 4, 2012).

This species has been intercepted in the Netherlands, the United Kingdom, and Australia (EPPO, 2012). The interception in the Netherlands occurred on a consignment of *Phoenix* palm plants for planting originating from Costa Rica. The United Kingdom interception occurred on imported banana material (EPPO, 2006). EPPO (2006) states that the pathway (over long distances) for this species is through host plants shipped as plants for planting and also cut branches.

This species may spread naturally through flight of adults. Peña et al. (1995) state that *M. h. sericeus* is a good flier and can disperse rapidly in host fields.

Potential Distribution within the United States

There are currently no host or risk maps available for this species. The main host, sugarcane, is found throughout much of the southern half of the United States (USDA-NRCS, 2012). According to the 2007 Census of Agriculture, there are four states that grow sugarcane for harvest: Florida, Hawaii, Louisiana, and Texas (USDA-NASS, 2009). Palms for landscaping, which also serve as hosts of *M. hemipterus*, are grown in 23 states (USDA-NASS, 2010).

Survey

CAPS-Approved Method*:

There are two CAPS-approved methods for *M. hemipterus.* Visual surveys may be used to detect larval populations before adults emerge. A trap and lure combination may be used to detect adult populations.

Visual inspection

Visual inspection may be used if palms with highly suspect damage and signs of infestation are observed. Symptoms caused by *M. hemipterus* are usually observed at the petiole bases. Infested Canary Island date palms may show characteristic windowing with frass at the petiole base. Bleeding (gummy exudates) and oviposition wounding can sometimes be observed in palms with large crown shafts (Giblin-Davis, 2013b, personal communication).

Figure 7. Homemade bucket trap with entrance holes (Image courtesy of Amy Roda, USDA-APHIS).

If permission can be obtained by the property owner, remove palm fronds by pulling the frond to the ground or cutting the frond at the base with a pole cutter. Once the frond has been removed, inspect the base of the frond for tunneling, larvae, pupae, or adults.

Trapping

1.1 Trap and Lure

The trap for *M. hemipterus* is a home-made bucket trap (instructions found in **1.2 Trap Construction**) or a commercial palm weevil trap. For home-made traps, the bucket may range in size from one to five gallons. There are three attractants needed to trap for *M. hemipterus*: two lures and a food bait that is prepared on site. The two lures are 1) an aggregation pheromone (4-methyl-nonan-5-ol and 2-methyl-heptan-4-ol) and 2) ethyl acetate (Personal communication R. Giblin-Davis, 2013a; Giblin-Davis et al., 1996a). The food bait should consist of at least 250 g (8.8 oz) of 2 to 5 cm (approx. $^{3}/_{4}$ to 2 in) long stem pieces of sugarcane or pineapple. Pieces of sugarcane 15 cm (6 in) split lengthwise may also be used. All three attractants (the two lures and food bait) are required to report negative data for *M. hemipterus*.

The aggregation pheromone and ethyl acetate lures should both be replaced every six weeks (42 days).

IPHIS Survey Supply Ordering System Product Names:

1) *Metamasius hemipterus* Aggregation Lure
2) Palm Weevil Lure, Ethyl Acetate
3) Palm Weevil Bucket Trap

Note: Do not include lures for other palm pests in the same trap when trapping for *M. hemipterus.*

1.2 Trap Construction

Traps may either be purchased or constructed on site. Traps should have the following features:

- Holes large enough (approximately 3 cm (1 $^{3}/_{16}$ inches)) to permit weevil entry in the side of the bucket, cut near the rim (Figure 7).
- Sufficient space at the bottom for a liquid mixture that is used to trap and kill the weevils that enter the trap.
- A tight-fitting trap lid to prevent contamination of the trap contents.
- Trap lid with a loop for hanging the trap in trees.

Figure 8. Lid of homemade bucket trap with hanging lure (Image courtesy of Amy Roda, USDA-APHIS).

1.3 Food Bait Preparation

Completely cover the food bait with a liquid solution. The liquid is critical as the weevils are attracted to the humidity and it prevents the weevils from crawling out of the trap. A 50/50 or 1:1 solution of propylene glycol (low-toxicity anti-freeze such as RV & Marine Antifreeze) and water. The solution minimizes

evaporation and the likelihood of beetles escaping. Enough water and propylene glycol should be added to completely cover the bait and in a quantity that will remain until the next servicing date. Surrounding environmental conditions will dictate how quickly the trap will dry; and the quantity of liquid or frequency of servicing may need to be adjusted.

Note: The food bait should be placed in the bottom of the bucket and covered with liquid. Food baits should not be placed in separate containers or bottles. Weevils could crawl onto these containers and fly out of the trap.

Use a wire to attach the two lures to the trap lid, allowing the lure to suspend about one-half inch above the liquid (Figure 8).

1.4 Trap Placement

For surveys in the urban environment, traps should be suspended from trees or poles. Traps should be hung approximately 2 meters (6.6 feet) above the ground. This will reduce the possibility of disturbance by people, pets, and wild animals. Hang the traps from **non-host** trees, telephone poles, or other vertical structures within 30 meters (100 feet) of a host tree.

Note: It is important to hang the traps from non-host trees. Native palm weevils can be attracted to the food bait and can attack the trees if traps are hung in host trees.

Note: If traps will be placed in a unique environment (*i.e.*, non-urban, palm nursery, or production areas, etc.), please contact Amy Roda for instruction on trap placement.

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1.5 Trap Servicing

Collect insect specimens from the trap and replace food bait every seven to nine days. The pheromone and ethyl acetate lures should be replaced every six weeks (42 days). The release rates and longevity of the lures are also based on temperature (*i.e.*, the release rate increases at higher temperatures). Lures may need to be changed more frequently in hot, dry regions such as Texas and California. It is also of crucial importance to keep enough water and propylene glycol in the traps to completely cover the food bait.

1.6 Survey Site Selection

Areas with host plant material should be targeted. These can be sugarcane fields (considered the main host of this species) as well as areas that have other host material, mainly palms. In Florida, this species is most commonly encountered in *Phoenix canariensis* (Canary island date palm) and *Ravenea rivularis* (majesty palm) (Broschat et al., 2010). Nurseries as well as residential or public areas where palms are used as ornamentals can also be targeted for survey.

1.7 Time of year to survey

Populations in Florida were found to build up during the spring, summer, and early fall (reviewed in Weissling and Giblin-Davis, 2010).

Note: It is not appropriate to survey for this species in areas where it is known to occur in the United States, specifically Florida.

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at http://caps.ceris.purdue.edu/.

Key Diagnostics/Identification

CAPS-Approved Method*:

Morphological. Key characters that separate the dryophthorids in question from other families of Coleoptera are:

1) Beak (=rostrum) extends anteriorly from head (Fig. 9)
2) Antennae elbowed (Fig. 9)
3) Antennal club mostly glabrous with restricted area of dense pubescence (Fig. 10)

Figure 9. Beak and antennae of dryophthoroid beetle (USDA-APHIS-PPQ, Miami, FL).

Figure 10. Antennal club of dryophthoroid beetle (USDA-APHIS-PPQ, Miami, FL).

The genus *Metamasius* can be distinguished from other similar genera by looking at morphological characteristics which are listed in Anderson (2002a) and Brodel (2002), found here: http://inside.aphis.usda.gov/ppq/nis/content/documents/Brodel2002.pdf.

Vaurie (1966) has a key to help distinguish species of *Metamasius*. Anderson (2002b) provides a key to the *Metamasius* spp. (including *M. hemipterus*) found in Costa Rica and Panama.

Identification to the subspecies level will not be required to report negative or positive data for this species.

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at http://caps.ceris.purdue.edu/.

Easily Confused Pests

Metamasius species can be taxonomically difficult to distinguish because of the large number of species in the genus (O'Brien and Thomas, 1990). *Metamasius hemipterus* is similar to both *M. benoisti* (found in Ecuador) and *M. ensirostris* (found in South America) (Vaurie, 1966).

There is one native *Metamasius* species in the United States, *M. mosieri*. However, this species is easy to differentiate from most pest *Metamasius* spp. *Metamasius mosieri* is red and black with two round spots on the elytra and is only about 6 to 9 mm (approx. $^{1}/_{4}$ to $^{3}/_{8}$ in) long (Woodruff and Baranowski, 1985). Another *Metamasius* species found in Florida is *M. callizona*. Both *M. mosieri* and *M. callizona* attack bromeliads. Neither are likely to be captured in *M. hemipterus* traps (Brodel, 2013, personal communication). An image of all three *Metamasius* spp. can be found in Larson et al. (2001).

Another genus in the same tribe as *Metamasius*, *Sphenophorus*, may be confused with this species as well. *Sphenophorus* spp. have different hosts (grasses and corn). It is unknown if they would be attracted to the trap for *M. hemipterus* (Brodel, 2013, personal communication). Two keys illustrating the difference between *Metamasius* and *Sphenophorus* are Anderson (2002a) and Brodel (2002). Species of *Rhynchophorus* are much larger than species of *Metamasius* or *Sphenophorus* (Brodel, 2013, personal communication).

Damage caused by *M. hemipterus* may be confused with that caused by *Rhynchophorus* spp. Stages of both genera may be found within the same palm tissues. The cocoons of *Rhynchophorus* spp. are much larger than those made by *M. hemipterus* (Broschat et al., 2010).

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This datasheet was developed by USDA-APHIS-PPQ-CPHST staff. This pest is included as a target in the Palm Survey. Additional information can be found in the **Palm Commodity-based Survey Guidelines**. Cite this document as:

Molet, T. 2013. CPHST Pest Datasheet for *Metamasius hemipterus*. USDA-APHIS-PPQ-CPHST.