Guidelines for Detection Trapping of Exotic Lymantriid and Lasiocampid Moths

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Scope:

This document describes procedures for trapping several exotic lymantriid and lasiocampid defoliators that are not known to be established in North America. Information on attractants, lure formulations, trap types, and trap deployment methods is included, along with some background on the biology of the target species and non-target species that could potentially be captured.

Specific details on trap density and geographic areas to be trapped are beyond the scope of this document. The overall design of the detection effort should be statistically sound and should consider such factors as the goal(s) of the trapping program, the behavior of the insect, cost-benefit estimates, and availability of resources. Unfortunately, for most species, the design process involves some guesswork as the relation of probability of capture to distance from trap and other factors is not well known.

General Guidelines:

Trapping procedures included here rely on attraction of male moths to synthetic versions of the species' sex attractant pheromones. The males' sensory systems are finely tuned to the component(s) of the pheromones, which accordingly are active in minute amounts. As is the case in all detection and delimitation surveys that use attractant-baited traps, care should be taken to avoid contaminating external surfaces of traps with attractant or cross-contaminating traps with attractants of different species. For example, use latex or latex-substitute gloves when handling lures, minimize direct contact with lures, do not touch external portions of traps with gloves that have contacted lures, and at a minimum re-glove after handling lures for one species before handling traps or lures for another. Care must also be taken to avoid cross-contamination via equipment that may come in contact with lures (e.g., staplers).

For species listed here, the most critical cross-contamination issue is ensuring that components of *Lymantria monacha* lures do not contaminate *L. dispar* traps, as several of those components are potent inhibitors of male *L. dispar*. When possible, *L. dispar* traps should not be assembled in the same time and space (e.g., same lab and day) as *L. monacha* traps and should not be transported together in the same vehicle (using the same vehicle on different days is acceptable provided that traps are transported in containers such as plastic garbage bags rather than being placed loose in the vehicles. This is good general practice in any case).

For storage, lures should be kept in a freezer or at least in a refrigerator. It is generally acceptable to store lures for different species in the same freezer if they are doubly contained in factory-sealed packages that are, in turn, held separately by species in a secondary closed container such as a glass jar or zip-lock bag. Partially used packages of lures can also be stored in the freezer but should be re-sealed using the manufacturer's original method; for example, a heat-sealing device should be used to restore the seal of packets that are constructed of plasticized laminates with impermeable membranes.

When trapping for multiple species at a single site, reduce the chances of interference among traps by maintaining an inter-trap spacing of 30 m or more whenever possible.

PRIMARY TARGET: SIBERIAN MOTH, *DENDROLIMUS SUPERANS SIBIRICUS*

ATTRACTANT: (*Z, E*)-5, 7-DODECANDIENAL AND (*Z, E*)-5, 7-DODECANDIENOL, 1:1

Will also trap:

(European) pine caterpillar a.k.a. pine lappet, *Dendrolimus pini*

May catch significant numbers of the following non-target native insects:

Forest tent caterpillar, *Malacosoma disstria*
Western tent caterpillar, *Malacosoma californicum* (lower probability)
Eastern tent caterpillar, *Malacosoma americanum* (low probability)

Narrative:

Dendrolimus is an old-world genus of lasiocampid (Lepidoptera) defoliators and includes a number of significant forest pests. Most notably, outbreaks of the Siberian moth (*D. superans sibiricus, = D. superans, D. sibiricus, D. superans albolineatus*) periodically kill vast areas of fir, larch, pine, or spruce in Russia and China. Other *Dendrolimus* species that can cause widespread defoliation within their native range include *D. pini, D. punctatus, D. tabulaeformis, D. houi, D. spectabilis,* and *D. kikuchii* (Kong et al. 2001). In addition, human contact with *D. punctatus* has been implicated in pinemoth caterpillar disease, a condition of unknown etiology that produces flu-like, dermatological, and arthritic symptoms; in more severe cases, chronic arthritis and skeletal deformities can result (Lawson and Yong-mo 1986; Lasiocampids in general have some odd health effects – *M. americanum*, for example, is associated with spontaneous fetal abortions in horses – see Webb et al. 2004).

In trapping tests, 1:1 blend of the presumed sex attractant pheromone components (*Z, E*)-5, 7-dodecandienal and (*Z, E*)-5, 7-dodecandienol produces capture comparable to that produced by virgin females (Klun et al. 2000, Kong et al. 2001, Khrimian et al. 2002). This blend also appears to be close to optimal for *D. pini* (Kovalev et al. 1993). Evidence from Kong et al. (2001) suggests that, while the alcohol used in *D. s. sibiricus* lures is also used in lures for *D. spectabilis* and *D. punctatus*, the presence of the aldehyde would largely inhibit attraction of the latter two species. Thus, while it's possible that small proportions of these latter two species may be captured by this trap (and other *Dendrolimus* species, whose pheromone chemistry is unknown, may also respond), the available evidence only supports claiming survey for *D. s. sibiricus* and *D. pini*. *D. pini* is, like *D. s. sibiricus*, a defoliator of conifers. *D. pini* is somewhat more specialized in that it is associated primarily with Scots pine *Pinus sylvestris*, but it will also feed on many other conifers if pressed. The lackey moth, *Malacosoma neustrium* (*neustria*?) is another European lasiocampid that responds to related compounds (the *E*, *Z* isomers of the same aldehyde and alcohol), but seems to show little orienting response to the (*Z*, *E*) forms and would be unlikely to be captured in *D. s. sibiricus* traps more than just occasionally (Rotundo et al. 2004).

Among non-target native insects, *M. disstria* uses one or both compounds (not clear from available literature) of the *D. s. sibircus* lure in its pheromone; a 1:1 blend did not improve capture over either of the two compounds alone (Chisholm et al. 1980). This lure is less than optimal for *M. disstria* (Chisholm et al. 1980, Chisholm et al. 1982), but still may catch very large numbers of this species in areas where they are prevalent (note that outbreaks of *M. disstria* have been occurring during the past few years in the Northeast). The trap is probably less effective or even non-attractive for *M. americanum* (Kochansky et al. 1996) and *M. californicum*, though field experience will provide a more definitive answer. In addition, there are other native lasiocampids (including *Malacosoma* species) whose pheromones have not been studied but could potentially be attracted to *D. s. sibiricus* lures.

Trapping method:

The available literature indicates that adult *D. s. sibiricus* and *D. pini* may be present from June to August in their native ranges (presumably on the earlier side in more southern areas), so detection trapping should focus on that period. Note that the physical appearance of *D. s. sibiricus* is quite variable (Fig. 1) and can be difficult for untrained personnel to distinguish from *D. pini* (Fig. 2A). Images of some North American lasiocampid moths are also included (Fig. 2, B-D).

The trap to use is a modified version of the standard gypsy moth milk carton. A single large entry port (2.5 cm wide X 3 cm high) is cut in each side by using a utility knife or similar tool to cut out the section of paperboard between the two existing entry ports. A plastic funnel (see Fig. 3; contact Otis lab for availability) is placed inside the trap (tube-down) so that the top edge of the funnel is at the level of the bottom of the entry ports. The lure is hung inside the top of the trap and a killing agent (DDVP strip) is placed in the bottom. Khrimian et al. (2002) formulated *D. s. sibiricus* attractant onto rubber septa and found that capture declined by ca. 50% when 4-week-old rather than fresh lures were used. Thus, we recommend replacing lures at least monthly in cooler areas and perhaps as often as every 2-3 weeks in hotter climates.

Hang traps in trees that are presumed to be potential hosts. We don't have a lot of knowledge of how *D. s. sibiricus* will fare on the various species of North American conifers. However, in Asia, they attack multiple species of larch, fir, spruce, and pine, suggesting that most North American Pinaceae are at least potential hosts. At the Otis quarantine facility, for example, we attempted to rear *D. s. sibiricus* on two N.A. species – balsam fir (*Abies balsamea*) and Douglas-fir (*Pseudotsuga menziesii*). We chose these species simply because they were available to us, but both proved to be good hosts.

PRIMARY TARGETS: GYPSY MOTH, *LYMANTRIA DISPAR*
ASIAN GYPSY MOTH, *LYMANTRIA DISPAR* (INCL. *L. DISPAR JAPONICA*)

ATTRACTANT: (+)-DISPARLURE

Will also trap:

Nun moth, *Lymantria monacha* (less than optimal; see narrative)

Other exotic species that may *respond:*

Indian gypsy moth, *Lymantria obfuscata*
Lymantria concolor
(some *Lymantria mathura* may respond)

Non-target native insects: Gypsy moth traps in the western U.S. have occasionally captured noctuid and pyralid moths in numbers great enough to suggest some attraction (records are sketchy).

Narrative:

Disparlure (*cis*-7,8-epoxy-2-methyloctadecane) was identified as the sex attractant pheromone of the gypsy moth by Bierl et al. (1970); several years later, (7*R*, 8*S*)-*cis*-7,8-epoxy-2-methyloctadecane, or (+)-disparlure, was shown to be the active enantiomer (Iwaki et al. 1974). This attractant, and the associated trap set-up (see below), is the same for either the North American (Western European) or Asian strains.

Trapping with (+)-disparlure will provide some detection capability for *L. monacha*, but, for areas that are believed to be at moderate to high risk of nun moth introduction and establishment, a more species-specific trapping method is preferred (see below). ODell et al. (1992) reported incidental capture of rosy gypsy moth *Lymantria mathura* in disparlure-baited traps, but this should not be considered as an adequate survey tool for that species; methods for trapping *L. mathura* are described below.

For other lymantriids, Bhardwaj (1987) reported trapping *Lymantria concolor*, a defoliator of fruit trees in temperate India, in disparlure-baited traps in 1982 and 1983. Given the date and location (India), we have to presume that (±)-disparlure was used. More certainly, the work of Beroza et al. (1973) on *L. obfuscata* was also conducted with the racemate; indeed, the first paper on differing responses of *L. dispar* to the two enantiomers was published the following year (Iwaki et al. 1974). In the absence of more recent information, we have no way of knowing if the males of these two species were responding to the (+) or (-) enantiomer, or to the combination of the two.

Trapping method:

Standard lure formulations include 500 µg of (+)-disparlure loaded into a plasticized string (Leonhardt et al. 1993) or plastic laminate (Hercon) dispenser. The delta trap is used for general detection trapping – it is deployed with ends folded in to restrict the size of the entry port and should be attached to the bole of a tree at breast to head height. The standard milk carton trap has a much higher capacity and should be substituted in areas where populations of gypsy moth are established. Unlike the delta, the milk carton is typically hung from a branch using a string. For either trap, the lure is stapled inside, approximately at the height of the entry ports. With the milk carton, the lure is typically stapled to a long garden tie that is, in turn, stapled to the inside of the trap at the top so that the lure hangs more or less in the center of the trap; a strip of laminated plastic containing DDVP is stapled to the garden tie below the lure. With the delta, the lure is stapled to the non-sticky panel. Either of the lures will last an entire field season without being changed. Traps should be hung in the immediate vicinity of preferred host trees. Typically, this means oak, but gypsy moths can successfully utilize many alternate species when oak is not available, including (among others) poplars, willows, birches, basswood, and sweetgum. Gypsy moths have one generation annually; timing of flight depends on local climate, and can vary from May or June in very warm areas to September in colder climates.

PRIMARY TARGET: **NUN MOTH, *LYMANTRIA MONACHA***

ATTRACTANT: **PHERO TECH LURE - (±)-DISPARLURE, (±)-MONACHALURE, 2-METHYL-*Z*7-OCTADECENE**
HERCON LURE - (±)-DISPARLURE

Hercon lure will also trap:

Gypsy moth, *Lymantria dispar*
Indian gypsy moth, *Lymantria obfuscata*
Lymantria concolor
(some *Lymantria mathura* may respond)

Phero Tech lure will also trap: We don't have enough experience with this lure to make predictions about capture of non-target species.

Narrative:

The situation with *L. monacha* is a bit complex. Currently, the *L. monacha* lure we are recommending for most situations contains a blend of racemic disparlure, racemic monachalure (*cis*-7,8-epoxy-octadecane), and 2-methyl-*Z*7-octadecene (20:20:1). This lure is produced by PheroTech, and a 410 µg loading rate should be specified. The old standard lure was 500 µg of (±)-disparlure formulated in a Hercon laminate (Hercon NM). Part of the complexity for *L. monacha* is that European and Asian populations have responded somewhat differently to available traps and lures. For example, in Europe, but not in Asia, traps with the PheroTech lure caught about twice as many males when compared to traps with only (±)-disparlure. Conversely, in Europe, traps with racemic vs. (+)-disparlure appeared to work equally well for *L. monacha*, whereas in Asia the (±)-disparlure-baited traps caught 3 to >10 times as many males in different tests. In the Russian Far East, capture was cut in half by folding the ends of the delta traps in (the standard deployment method for gypsy moth) rather than leaving them unfolded; in Europe, folding the ends didn't seem to make much if any difference. In both areas, traps with the Phero Tech lure excluded gypsy moths *much* better than those with disparlure (even racemic disparlure). Hanging traps from branches also seems to work better for nun moth when compared to the typical practice (for gypsy moth delta traps) of placing them on boles of trees. The standard gypsy moth detection trap will catch nun moths to some degree, but gypsy moth traps range anywhere from a somewhat-less-than-optimal to rather poor tool for *L. monacha* detection depending on the variables noted above.

Trapping method:

If you want to really cover your bases and put out a good nun moth survey, use PheroTech lures (410 µg loading rate) in open-ended delta traps hung from branches of host trees. In Europe, *L. monacha* is most notably a pest of Norway spruce, *Picea abies*, and Scots pine, *Pinus sylvestris*, but the species has a very broad host range and does well on many additional hosts, including (among others) larches, oaks, maples, birches, and a variety of fruit trees. In the area that is generally infested with gypsy moth, incidental catch of male gypsy moths is to be expected in nun moth traps despite the inhibitory effect of the (-)-disparlure, monachalure and methyloctadecene; however, this is unlikely to become a problem (i.e., loading traps to the point of reduced efficiency) except in areas with moderately high to outbreak-level gypsy moth populations. Please provide feedback (david.r.lance@aphis.usda.gov) if you find this to be untrue or have other problems when using these trapping protocols. The Otis lab is not supplying Phero Tech lures (buy directly from Phero Tech), but will provide the Hercon NM lures.

Note that one down side of leaving the ends of the delta traps open is that it makes the trap more accessible to non-target organisms including both invertebrates and vertebrates (e.g., tree frogs, small birds). These organisms can at times remove captured moths or become trapped themselves.

PRIMARY TARGET: **ROSY GYPSY MOTH, *LYMANTRIA MATHURA***

ATTRACTANT: ***Z*,*Z*-(9*S*,10*R*)-9,10-EPOXY-3,6-NONADECADIENE (4)**
***Z*,*Z*-(9*R*,10*S*)-9,10-EPOXY-3,6-NONADECADIENE (1)**

Will also trap: We don't have enough experience with the *L. mathura* lures to make predictions about capture of exotic, non-target lymantriids, although the primary pheromone compound appears to be fairly unique.

Non-target native species that may respond: A number of North American geometrids respond to monoepoxide derivatives of 19-carbon trienes, so it may be possible, in some cases, that geometrids will be captured in substantial numbers. Those that are known to respond to the primary component of *L. mathura* pheromone include *Epirrhoe sperryi* and *Prochoerodes transversata* (Wong et al. 1985). In addition, some gypsy moths were captured during *L. mathura* trapping tests in Russian Far East, but, especially given the small numbers, it's unclear if the cause was cross-attraction or cross-contamination of trapping supplies with minute amounts of disparlure. In those same tests, a number of noctuid moths responded to various ratios of these pheromone components; these moths were not identified beyond the family level (Yurchenko, Mastro, Khrimian & Oliver *unpublished data*).

Narrative:

Oliver et al. (1999) identified the sex attractant pheromone of *Lymantria mathura* as *Z*,*Z*-9,10-epoxy-3,6-nonadecadiene; in particular, the 9*S*,10*R* enantiomer was determined to be active. Gries et al. (1999), though, reported that, in Japan, the 9*R*,10*S* enantiomer was also needed for optimal response (at 20% of total). In a subsequent trapping test by the authors of the former paper, a 4:1 ratio of 9*S*,10*R* to 9*R*,10*S* appeared far superior to pure 9*S*,10*R* in the Russian Far East as well (Yurchenko et al. *unpublished data*). More recently, methods for both synthesizing and formulating the attractants have been improved (Khrimian et al. 2004).

Lures for *L. mathura* are not currently manufactured commercially. Instead, a ~4:1 blend of 9*S*,10*R* to 9*R*,10*S* is produced by ARS scientists under an interagency agreement with APHIS-PPQ. This is formulated into a plasticized string dispenser either by ARS or under contract with a commercial firm.

Trapping method:

Use a wing trap such as the Pherocon 1C with the string lure attached to the inside of the upper half (lid) of the trap (if you must use a delta, leave the ends open [unfolded] and attach the lure inside the trap to the non-sticky side). The lure should have a field life comparable to that of the gypsy moth string lure (several months). Seasonal timing of flight for *L. mathura* in cooler areas will be roughly comparable to that of *L. dispar* or *L. monacha*. This species, however, is reportedly bivoltine in warmer portions of its range (e.g., India), with adults present in the spring (e.g., April) and again in late summer. Presumably, bivoltinism could also occur in southern portions of the United States. Appearance of *L. mathura* should be distinct enough from other lymantriids to avoid confusion, unless trapped specimens are in poor condition (Fig. 4).

Place traps in or in the immediate vicinity of host trees. *L. mathura* feed on wide variety of trees but seem to do best on members of the Fagaceae including oaks and, in particular, beech (*Fagus* spp.; see Zlotina et al. 1998).

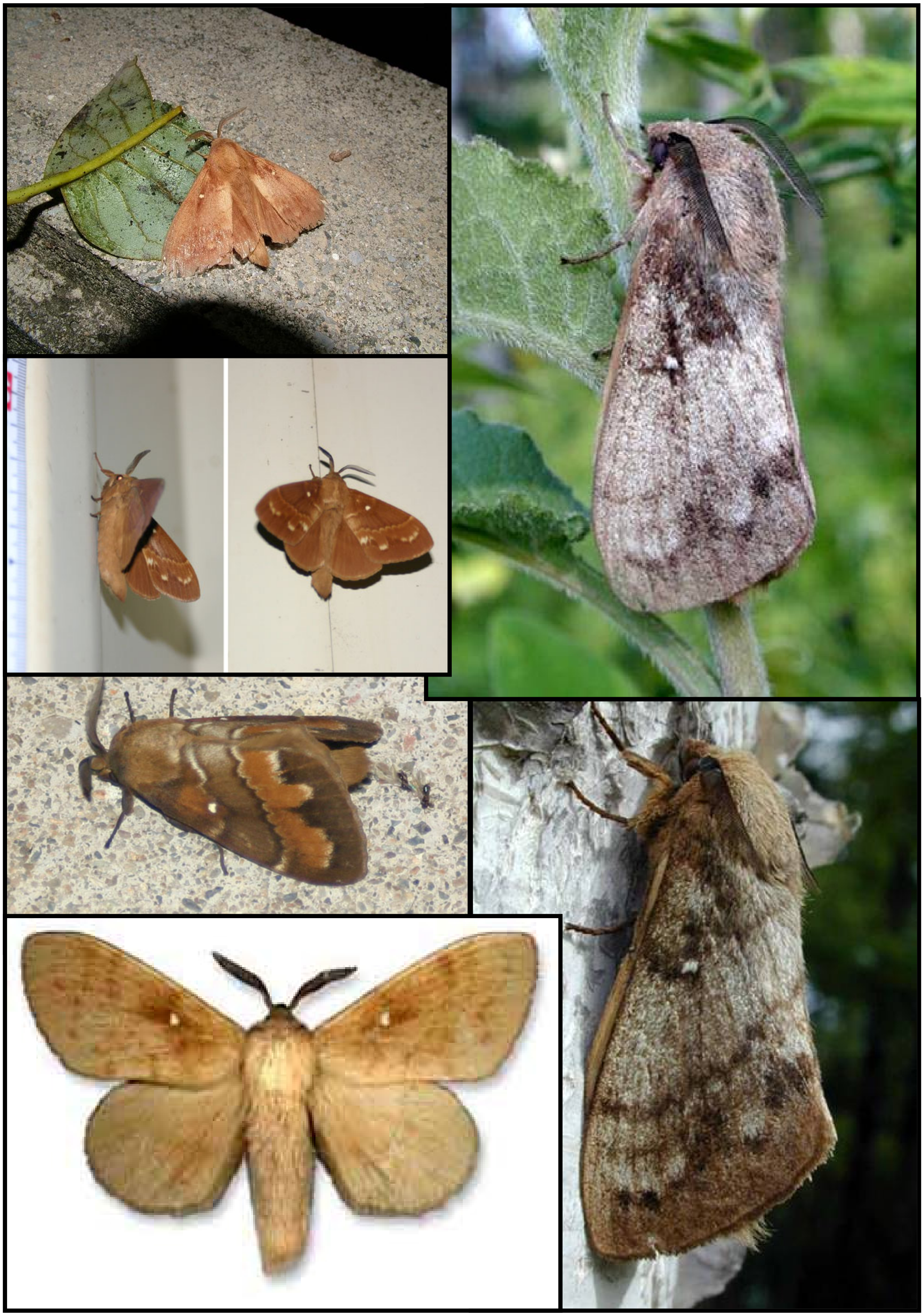

Fig. 1. *Dendrolimus superans* males, various color forms from Japan (left side) and Russia (right side)

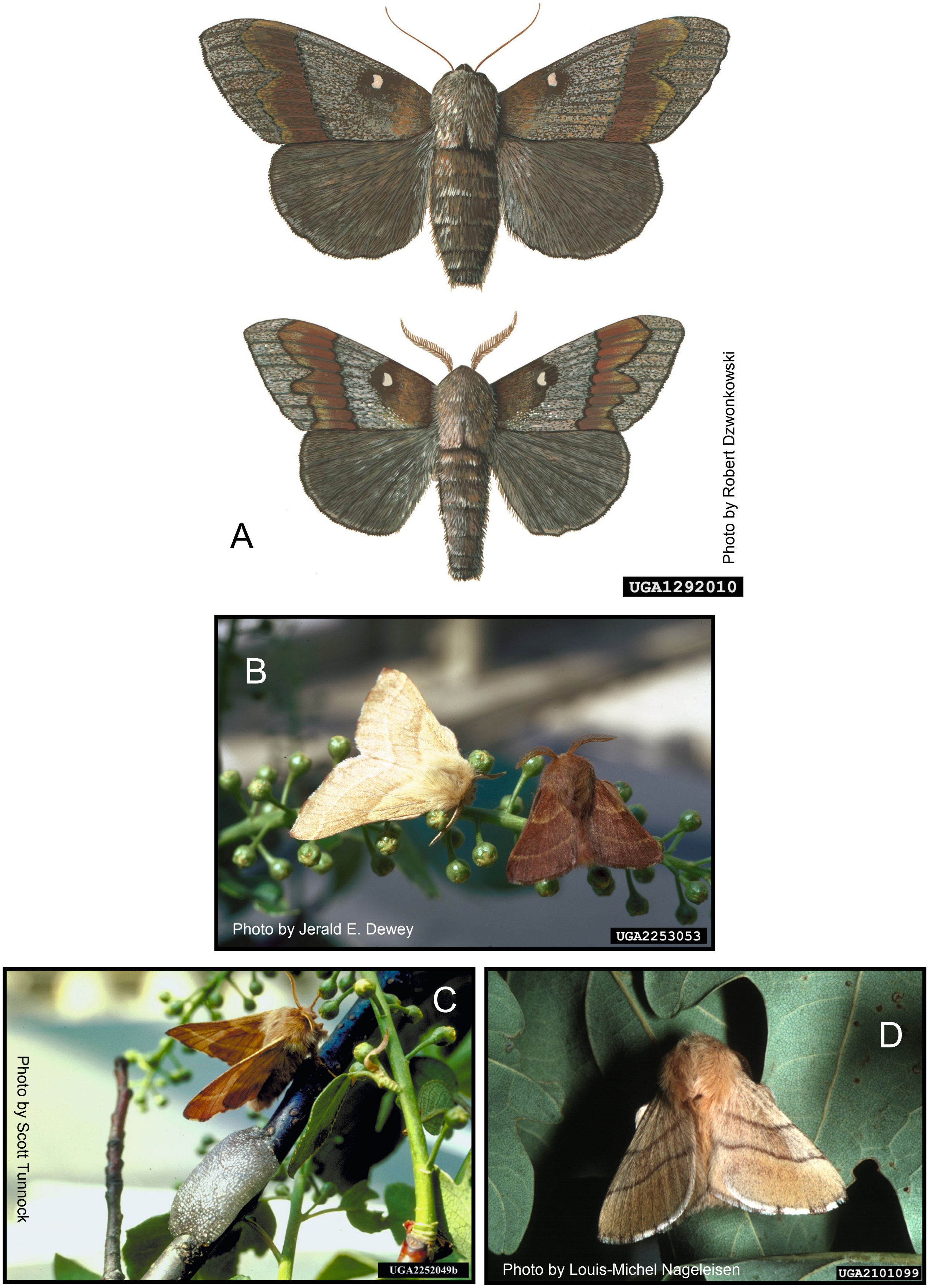

Fig. 2. A. *Dendrolimus pini* female (top) and male (bottom); B. adult *Malacosoma californicum*; C. *Malacosoma disstria* adult and egg mass; D. *Malacosoma neustreum.*

Fig. 3. Internal funnel for *Dendrolimus* traps. Dusty coffee cup included for scale

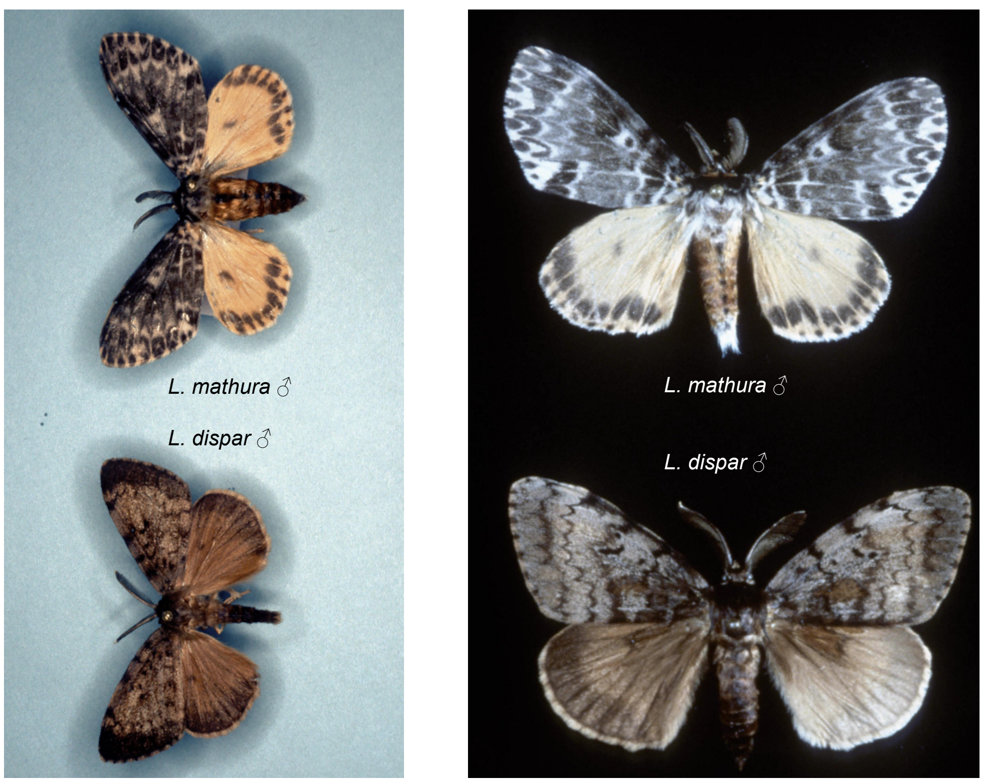

Fig. 4. Specimens of *Lymantria mathura* (top) and *L. dispar* (bottom).

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