Identification of Japanese *Lymantria* Species (Lepidoptera: Lymantriidae) Based on Morphological Characteristics of Adults

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Abstract: The morphological characteristics of adult male and female moths of seven Japanese *Lymantria* species which consisted of four Asian gypsy moth (AGM) species [*L. dispar japonica* (Motschulsky), *L. umbrosa* (Butler), *L. albescens* Hori and Umeno, and *L. postalba* Inoue] and three other species [*L. xylena* Swinhoe, *L. mathura* Moore, and *L. monacha* (Linnaeus)] were shown for species identification. We showed ground color and markings of wings and morphological characteristics of genitalia. These seven *Lymantria* species could be discriminated among species by the above mentioned morphological characteristics except a combination of Hokkaido populations of *L. dispar japonica* and *L. umbrosa*. This result suggests that morphological characteristics of adult male and female moths are useful in identifying these seven Japanese *Lymantria* species.

Key Words: *Lymantria*, AGM, morphological characteristics, species identification

Introduction

Many species in the tussock moth genus *Lymantria* are significant forestry pests, including the gypsy moth *Lymantria dispar* (Linnaeus). Schintlmeister (2004) was the first to perform a worldwide revision of the genus and reported a total of 167 species of *Lymantria*. Pogue and Schaefer (2007) reviewed 31 species and three subspecies of *Lymantria* that could result in severe damage to native forests and economic losses if accidentally introduced into North America. Of these *Lymantria* species, 12 are distributed in Japan (Pogue and Schaefer, 2007).

Pogue and Schaefer (2007) designated European gypsy moth (EGM) and Asian gypsy moth (AGM). According to Pogue and Schaefer (2007), EGM is a single subspecies of *Lymantria dispar dispar* (Linnaeus) which is distributed throughout Europe west of the Ural Mountains and North Africa and has been introduced into North America. AGM is composed of two subspecies of *Lymantria dispar* and other three species, which occur throughout temperate Asia, including Japan. Among these, *Lymantria dispar asiatica* Vnukovskij is distributed widely in continental Asia (China, Korea, Far East Russia etc.). In Japan, *Lymantria dispar japonica* (Motschulsky) is distributed in Honshu, Shikoku, Kyusyu and southwestern Hokkaido; *Lymantria umbrosa* (Butler) is distributed in Hokkaido, especially the eastern part; *Lymantria albescens* Hori and Umeno is distributed in southern Ryukyu Islands; and *Lymantria postalba* Inoue is distributed in southern Kyushu, Tsushima, Yakushima and northern Ryukyu Islands.

Kishida (2011) classified these Asian gypsy moth species into two species (*L. dispar* and *L. albescens*) (Table 1). Kishida (2011) classified *L. dispar* into two subspecies: *L. dispar japonica* for populations from southern Hokkaido, Honshu, Shikoku, and Kyushu; *Lymantria dispar hokkaidoensis* Goldschmidt for populations from northern and eastern Hokkaido. Additionally, Kishida (2011) classified *L. albescens* into three subspecies: *Lymantria albescens albescens* Hori and Umeno for populations from south of Amamioshima; *Lymantria albescens postalba* Inoue for populations from southern Kyushu, Tanegashima and Yakushima; *Lymantria albescens tsushimensis* Inoue for populations from Tsushima.

The biological traits of AGM are different from those
of EGM. For example, larvae of Asian origin have a broader host range (Baranchikov, 1989). In addition, eggs of AGM require shorter exposure to low temperature for diapause completion than EGM (Keena, 1996). Moreover, females of AGM can fly (Schaefer et al., 1984; Baranchikov, 1989), whereas females of EGM can not (Wallner et al., 1995; Keena et al., 2008). Additionally, the gravid females of AGM are attracted to lights in ports and they deposit eggs on ships (Wallner et al., 2007).

Therefore, the U.S. and Canadian governments have become very anxious about the invasion of AGM into their territories (Myers et al., 2000). Consequently, they have requested that countries with AGM to certify that ships destined for the United States and Canada are free from AGM egg masses (NAFPO, 2009). Thus, some of Japanese port authorities initiated an AGM control program in 2007 to reduce the AGM population in ports (Yokochi, 2007).

In addition to four AGM species, eight other *Lymantria* species are distributed in Japan (Pogue and Schaefer, 2007). Identification of these species is important, particularly to determine appropriate control methods and control areas around ports because their biology (host range, flight ability of adult females, and others) differs among species (Pogue and Schaefer 2007; Keena et al., 2008; Iwazumi and Arakawa, 2010).

Traditionally, *Lymantria* species have been identified by using morphological characteristics of adult male and female moths (Inoue, 1982; Schintlmeister, 2004; Pogue and Schaefer, 2007; Kishida, 2011). In this study, we showed the morphological characteristics of adult male and female moths of seven Japanese *Lymantria* species which include four AGM species, and discussed identification method for these species.

### Materials and Methods

In this study, 12 males of three populations of *L. dispar japonica*, five males of one population of *L. umbrosa*, five males of one population of *L. albescens*, four males of one population of *L. postalba*, five males of one population of *L. xylina*, five males of two populations of *L. mathura*, and two males of one population of *L. monacha* were used (Table 2). Additionally, one female each of two populations of *L. dispar japonica*, one female each of one population each of *L. umbrosa*, *L. albescens*, *L. xylina*, *L. mathura*, and *L. monacha* were used. These specimens were collected mainly as adults between 2004 and 2012. Some specimens were collected as egg mass, sixth instar larva, or pupa, and reared in a laboratory until adult emergence. All these specimens were the voucher specimens in Arimoto and Iwaizumi (2014). The specimens are preserved at Yokohama Plant Protection Station under the serial voucher specimen number.

The photographs of adults were taken on polyurethane mat using a digital camera (COOLPIX 5200, Nikon, Tokyo, Japan). The images were enhanced with Adobe Photoshop Elements* 7.0 (Adobe Systems Incorporated, San Jose, CA, USA).

To prepare the genitalia, the abdomen of a male was broken off and put in 10% potassium hydroxide (KOH) in a test tube and heated for 30–40 minutes (depending on size) using a water bath (ISOTEMP 202, Fisher Scientific, Dubuque, Iowa, U.S.A.). The temperature was set at 60°C. The abdomen was then transferred to 70%...
The aedoeagus was dissected from the male genitalia. Ethyl alcohol in a petri dish under stereomicroscope (SZX 16, OLYMPUS, Tokyo, Japan) was used for this process. The left valve of the male genitalia was removed. All dissections were done with the aid of forceps in ventral side up and any additional cleaning was done. The abdominal pelt was slit up the right side with a stereomicroscope (SZX 16, OLYMPUS, Tokyo, Japan) placed in a glass genitalia vial containing glycerin and alcohol. Photographs of genitalia were taken with a digital camera (FX 380, OLYMPUS, Tokyo, Japan) mounted on a stereomicroscope (SZX 16, OLYMPUS, Tokyo, Japan). The images were enhanced with Adobe Photoshop Elements® 7.0.

The terms for lines and markings of wings and genitalia follow Pogue and Schaefer (2007).

### Results

In the seven Japanese Lymantria species used in this study, five species (L. dispar japonica, L. umbrosa, L. albscens, L. postalia, and L. xylena) belong to subgenus Porthetria (Fig. 1), one species (L. mathura) belong to subgenus Nyctria (Fig. 9), and one species (L. monacha) belong to subgenus Lymantria (Fig. 11). We showed ground colors and markings of wings and genitalia of male and female of these species. In this study, we

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* All voucher specimens are preserved at Yokohama Plant Protection Station under the serial voucher specimen number.
could not collect female of *L. postalba*. Therefore, we cited a photograph of a female of *Lymantria dispar postalba* Inoue in Inoue (1958) as *L. postalba* (Fig. 13). Consequently, we could not show the morphological characteristics of genitalia of female of *L. postalba*.

**Morphological characteristics of wings and genitalia of seven *Lymantria* species**

*Lymantria (Porthetria) dispar japonica* (Motschulsky)

Japanese name: Maimaiga

**Male** (Figs. 1, 2-4)

The ground color of the forewing is brown in the Nagoya population (Fig. 2) or cream in Hokkaido populations (Figs. 3, 4). The orbicular spot is black and present in the middle of the discal cell in the Nagoya population (Fig. 2) or minute in Hokkaido populations (Figs. 3, 4). The reniform spot is black, angulate, along the vein at the end of the discal cell. The ground color of the hindwing is brown in the Nagoya population (Fig. 2) or cream heavily suffused with dark brown in Hokkaido populations (Figs. 3, 4). The lateral process is absent from the tegumen of genitalia. The valve is undivided and not fused ventrally. The dorsal process of the valve is contiguous with the costal margin of the valve, straight, and the apex is narrowly rounded. The aedoeagus is slightly bent medially.

**Female** (Figs. 1, 13)

The ground color of the forewing is brownish-white. The orbicular spot is a small, black dot, present in the middle of the discal cell. The reniform spot is crescent-shaped along the veins at the end of the discal cell. The ground color of the hindwing is brownish-white. The hindwing has a dirty white fringe with fuscous spots between veins. The shape of the papilla analis of genitalia is quadrate.

*Lymantria (Porthetria) albescens* Hori and Umeno

Japanese name: Shiroyoshita-maimai

**Male** (Fig. 6)

The ground color of the forewing is white suffused with gray, especially along the costa and near the base. The orbicular spot is small, black, and present in the middle of the discal cell. The reniform spot is black, V-shaped, along the vein at the end of the discal cell. The ground color of the hindwing is white. The costa of the hindwing have an elongate band of dark gray from the base to the apex. The lateral process is absent from the tegumen of genitalia. The valve is undivided, not fused ventrally. The dorsal process of the valve is contiguous with the costal margin of the valve, straight, elongate, and its apex is knob-shaped. The aedoeagus is slightly bent medially.

**Female** (Fig. 13)

The ground color of the forewing is white lightly suffused with reddish-brown. The orbicular spot is black, minute, and present at the middle of the discal cell. The reniform spot is black, crescent-shaped along the veins at the end of the discal cell. The ground color of the hindwing is white. The color of the fringe of the hindwing is white. The shape of the papilla analis of genitalia is quadrate.

*Lymantria (Porthetria) postalba* Inoue

Japanese name: Ko-shiroyoshita-maimai

**Male** (Fig. 7)

The ground color of the forewing is light brown. The color of the area distal to the postmedial line is brown. The orbicular spot is a small dot present in the middle of the discal cell. The reniform spot is black, V-shaped, along the vein at the end of the discal cell. The ground color of the hindwing is light brown. The color of the costal margin of the hindwing is brown. The lateral process is absent from the tegumen of genitalia. The valve is undivided, not fused ventrally. The dorsal process of the valve is contiguous with the costal margin of the valve, straight, and its apex is narrowly rounded. The aedoeagus is slightly bent medially.
Female (Fig. 13)

The ground color of the forewing is white with a pale rufous tint. The orbicular spot is minute, present in the middle of the discal cell. The reniform spot is a faint angulate line present at the end of the discal cell. The ground color of the hindwing is white. The color of the fringe of the hindwing is white.

_Lymantriea (Porthetria) xylina Swinhoe_

Japanese name: Mae-guro-maimai

Male (Fig. 8)

The ground color of the forewing is white. The orbicular spot is absent. The reniform spot is not evident, incorporated into the postmedial line. The postmedial line is brown, crenulate and extends from the costa to the posterior margin. The ground color of the hindwing is white. The costal margin of the hindwing has a wide black band. The lateral process is absent from the tegumen of genitalia. The valve is undivided, not fused ventrally. The dorsal process of the valve is contiguous with the costal margin of the valve, straight, elongate, and its apex is narrowly rounded. The aedeagus is slightly bent at the middle.

Female (Fig. 13)

The ground color of the forewing is white. The orbicular spot and reniform spot are absent. The postmedial line is wide, light brown, angulate, and extends from the costa to the posterior margin. The ground color of the hindwing is white. The shape of the papilla analis of genitalia is quadrate. The length of the ductus bursae is very short, shorter than the length of the ventral plate of the ostium bursae.

_Lymantriea (Nyctria) mathura Moore_

Japanese name: Kashiwa-maimai

Male (Figs. 9, 10)

The ground color of the forewing is white. The color of all markings of the forewing is gray. The orbicular spot is round and adjacent to the reniform spot. The ground color of the hindwing is yellow. The color of all markings of the hindwing is gray. The lateral process is arising from the tegumen of genitalia. The valves are deeply divided to the dorsal and ventral processes. The dorsal process is bifurcated with the dorsal-most process shorter than the ventral process. The valves are fused ventrally. The aedeagus is straight. The width of the aedeagus is uniformly equal.

Female (Figs. 9, 13)

The ground color of the forewing is white. The orbicular spot is ovate. The reniform spot is present at the end of the discal cell. The ground color of the hindwing is white irrorated with pink. The shape of the papilla analis of genitalia is kidney-shaped.

_Lymantriea (Lymantriea) monacha (Linnaeus)_

Japanese name: Nonne-maimai

Male (Figs. 11, 12)

The ground color of the forewing is white. The color of all markings of the forewing is black. The reniform spot is chevron-shaped at the end of the discal cell. The ground color of the hindwing is pale gray. The lateral process is arising from the tegumen of genitalia. The valve is undivided, not fused ventrally. The thumb-like basal projection is present at the base of the valve. The dorsal process of the valve is contiguous with the costal margin of the valve, slightly curved, and slightly shorter than the valve. The aedeagus is slightly bent and narrowed just before the middle. The front shape of the aedeagus is triangular.

Female (Figs. 11, 13)

The ground color of the forewing is white. The color of all markings of the forewing is black. The reniform spot is chevron-shaped at the end of the discal cell. The ground color of the hindwing is pale gray. The shape of the papilla analis of genitalia is rectangular.

Discussion

1. Identification of adult male by ground color and marking of wings

In seven Japanese _Lymantriea_ species used in this study, _L. mathura_ (Fig. 10) which belong to subgenus _Nyctria_ could be discriminated among the other six species by the yellow ground color of the hindwing. _L. monacha_ (Fig. 12) which belong to subgenus _Lymantriea_ could be discriminated among the other six species by the white ground color of the forewing with all black markings. In five species which belong to subgenus _Porthetria, L. xylina_ (Fig. 8) could be discriminated among the other species by the white ground color of its forewing with an unclear reniform spot incorporated into the postmedial line. The forewing postmedial line of _L. xylina_ (Fig. 8) was brown, crenulate and extended from the costa to the posterior margin. _L. albescens_ (Fig. 6) could be discriminated among other species by the white hindwing with a dark gray band that extended from the base to apex of the costa. _L. postalba_ (Fig. 7) could be discriminated among other species by the light brown hindwing with brown costal margin. _L. dispers japonica_ (Fig. 2) could be discriminated among other species by
the brown ground color of the hindwing. _L. umbrosa_ (Fig. 5) could be discriminated among other species by the cream hindwing that was heavily suffused with dark brown. However, the color of the hindwing of the Sapporo population (Fig. 3) and Otaru population (Fig. 4) of _L. dispar japonica_ were the same as _L. umbrosa_ (Fig. 5). The ground color and markings of forewing of these Hokkaido populations of _L. dispar japonica_ (Figs 3, 4) were also the same as _L. umbrosa_ (Fig. 5). Therefore, Hokkaido populations of _L. dispar japonica_ could not be discriminated from _L. umbrosa_.

As mentioned above, the seven Japanese _Lymantria_ species could be discriminated by ground color and markings of wings of adult males except for a combination of Hokkaido populations of _L. dispar japonica_ and _L. umbrosa_.

2. Identification of adult male by morphological characteristics of genitalia

In seven Japanese _Lymantria_ species used in this study, _L. mathura_ (Fig. 10) which belong to subgenus _Nyctria_ could be discriminated among other six species by the tegumen with lateral process, deeply divided valve with prominent dorsal and ventral processes, and valves fused ventrally. _L. monacha_ (Fig. 12) which belong to subgenus _Lymantria_ could be discriminated among the other six species by the shape of aedoeagus. The aedoeagus of five species which belong to subgenus _Porthetria_ were slightly bent and narrowed just before the middle. Additionally, the front shape of aedoeagus of _L. monacha_ was triangular (Fig. 12). _L. monacha_ could be discriminated among the other six species by the above mentioned morphological characteristics of aedoeagus.

As mentioned above, the seven Japanese _Lymantria_ species could be discriminated by morphological characteristics of male genitalia except combinations among _L. dispar japonica, L. umbrosa_ and _L. postalba_.

3. Identification of adult female by ground color and marking of wings

In seven Japanese _Lymantria_ species used in this study, _L. mathura_ which belong to subgenus _Nyctria_ could be discriminated among the other six species by white irroration with pink color of the hindwing (Fig. 13). _L. monacha_ which belong to subgenus _Lymantria_ could be discriminated among the other six species by white ground color of forewing with all black markings (Fig. 13). In five species which belong to subgenus _Porthetria_, _L. xylina_ did not have orbicular spot and reniform spot on forewing (Fig. 13). The postmedial line on the forewing of _L. xylina_ was wide, light brown, angulate and extended from the costa to the posterior margin (Fig. 13). _L. xylina_ could be discriminated among other species by these markings of forewing (Fig. 13). The ground color of forewings of _L. dispar japonica_ and _L. umbrosa_ were brownish-white and these two species had orbicular spot and reniform spots on forewings (Fig. 13). The ground color of hindwings of these two species were brownish-white and the hindwings of these two species had a dirty white fringe with fuscous spots between veins (Fig. 13). These two species could be discriminated among other species by the above mentioned ground color and
markings of wings (Fig. 13). However, these two species could not be discriminated because ground color and markings of wings of these two species were very similar (Fig. 13). The ground color and fringe of hindwings of L. albescens and L. postalba were white and the fringes of hindwings of these two species did not have spots between veins (Fig. 13). These two species could be discriminated among other species by these ground color and markings of hindwings (Fig. 13). However, these two species could not be discriminated because ground color and markings of wings of these two species were very similar (Fig. 13).

As mentioned above, the seven Japanese Lymantria species could be discriminated by ground color and markings of wings of adult females except combinations of L. dispar japonica and L. umbrosa, and L. albescens and L. postalba.

4. Identification of adult female by morphological characteristics of genitalia

In this study, we could not collect female of L. postalba. Therefore, we could not show the genitalia of female of L. postalba.

In six Japanese Lymantria species used in this study, L. mathura which belong to subgenus Nyctria could be discriminated among the other five species by kidney-shaped papilla analis (Fig. 13). L. monacha which belong to subgenus Lymantria could be discriminated among the other five species by rectangular shaped papilla analis (Fig. 13). The four species which belong to subgenus Porthetria could be discriminated among L. mathura and L. monacha by quadrate shaped papilla analis (Fig. 13). In four species which belong to subgenus Porthetria, L. xylina could be discriminated among the other three species (L. dispar japonica, L. umbrosa, and L. albescens) by very short ductus bursae (Fig. 13). However, the morphological characteristics of genitalia of L. dispar japonica, L. umbrosa and L. albescens were similar among species (Fig. 13). Therefore, these three species could not be discriminated among species.

As mentioned above, the six Japanese Lymantria species could be discriminated by morphological characteristics of female genitalia except combinations among L. dispar japonica, L. umbrosa and L. albescens.

In this study, the seven Japanese Lymantria species which include four AGM species could be discriminated among species by morphological characteristics of adult male and female moths except a combination of Hokkaido populations of L. dispar japonica and L. umbrosa.

The information about morphological characteristics of adult male and female moths of seven Japanese Lymantria species which were shown in this study is useful to identify adult male and female moths of those Lymantria species which occur in and around port areas. In the future, the investigation for clarification of the biology about occurrence of those Lymantria species in and around port areas is expected.

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References


和文摘要

日本産Lymantria属（チョウ目：ドクガ科）の成虫の形態的特徴による識別（英文）

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種を識別するため、日本産Lymantria属7種、即ち、アジア型マイマイガ（AGM）指定4種（マイマイガ、エゾマイマイ、シロシタマイマイ及びコシトシタマイマイ）及びその他3種（マエグロマイマイ、カシワマイマイ及びノンネマイマイ）の雌雄成虫の形態的特徴を示した。翅の地色及び斑紋、及び交尾器の形態的特徴を示した。これらの日本産Lymantria属7種は上記の形態的特徴により、北海道産のマイマイガ及びエゾマイマイの組み合わせを除き種間で識別出来た。この結果は雌雄成虫の形態的特徴がこれらの日本産Lymantria属を同定するため有用であることを示唆する。
Fig. 1 Lines and markings of wings and terminology of genitalia of male and female of subgenus *Porthetria*. All figures are *L. dispar japonica*. 

1. **Male: Lines and Markings of Wings**

2. **Male: Terminology of Genitalia**

3. **Female: Lines and Markings of Wings**

4. **Female: Terminology of Genitalia**

(lateral)

(ventral)
Fig. 2 Males and their genitalia of *L. dispar japonica* (Nagoya population).
Fig. 3 Males and their genitalia of *L. dispar japonica* (Sapporo population).
Fig. 4 Males and their genitalia of *L. dispar japonica* (Otaru population).
Fig. 5 Males and their genitalia of *L. umbrosa* (Otaru population).
Fig. 6 Males and their genitalia of *L. albescens* (Naha population).
Fig. 7 Males and their genitalia of *L. postalba* (Tsushima population).
Fig. 8 Males and their genitalia of *L. xylinia* (Naha population).
Fig. 9  Lines and markings of wings and terminology of genitalia of male and female of subgenus *Nyctria*. All figures are *L. mathura*.
Fig. 10 Males and their genitalia of *L. mathura* (Otaru and Yokosuka population).
1. Male: Lines and Markings of Wings

2. Male: Terminology of Genitalia

3. Female: Lines and Markings of Wings

4. Female: Terminology of Genitalia

Fig. 11  Lines and markings of wings and terminology of genitalia of male and female of subgenus Lymantria. All figures are L. monacha.
Fig. 12 Male and their genitalia of *L. monacha* (Tomakomai population).
Fig. 13  Females and their genitalia of seven *Lymantria* species. The photographs of genitalia are shown laterally and ventrally.