A new species of *Amphipyra OCHSENHEIMER, 1816* from Taiwan, with description of larva, pupa and biology (Lepidoptera, Noctuidae, Amphipyrinae) 1

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Abstract: The new species *Amphipyra meifengensis* sp. n. (holotypt female type, in National Museum of Natural Science Taiwan, Taichung, belonging to the species-group of *A. pyramidea* (LINNAEUS, 1758)) is described from Meifeng in the central high mountains of Taiwan. A larva of the new species was found and successfully reared so that information on the biology and morphology of larva and pupa could be added. All hitherto known *Amphipyra*-species, especially those known from Taiwan, can be easily discriminated from this new species.

Key words: Lepidoptera, Noctuidae, Amphipyrinae, *Amphipyra meifengensis* sp. n., Taiwan, biology, foodplants, distribution, mtDNA, COI.

Eine neue Art von *Amphipyra OCHSENHEIMER, 1816* aus Taiwan, mit Beschreibung von Raupe, Puppe und Biologie (Lepidoptera, Noctuidae, Amphipyrinae)

Zusammenfassung: Die neue Art *Amphipyra meifengensis* sp. n. (Holotypus Weibchen, im National Museum of Natural Science Taiwan, Taichung, gehört zur Artengruppe von *A. pyramidea* (LINNAEUS, 1758)) wird aus Meifeng im zentralen Hochgebirge von Taiwan beschrieben. Eine Raupe wurde gefunden und durchgezüchtet, so daß Informationen zur Biologie sowie der Raupen- und Puppenmorphologie gegeben werden können. Sämtliche bekannten *Amphipyra*-Arten, insbesondere die aus Taiwan, unterscheiden sich deutlich von der vorliegenden neuen Art.

Introduction

Numerous research trips were undertaken for the German Academic Exchange Service (DAAD) project of the Bavarian State Collection of Zoology and the National Chung Hsing University Taichung (CHU) (Project No.: ID D/0039914, PPP-Taiwan), and additional cooperative projects (e.g. with the Highland Experimental Farm Meifeng) were undertaken in order to study the lepidopterous fauna of Taiwan. Many different localities were studied during this project, with Meifeng being the most frequent collecting site. Several papers about the Lepidoptera observed during these trips have already been published. In Meifeng especially, several species have been identified as undescribed or recorded as new for Taiwan, and many interesting biological observations have been published from this locality (e.g., BUSCHBAUM & MILLER 2002, SCHINTLEMEISTER 2003, SPEIDEL & BEHOUNEK 2005, BUSCHBAUM 2006, BUSCHBAUM et al. 2006, BUSCHBAUM & CHEN 2010, 2012, CHEN 2010, SCHACHT & al. 2010).

The genus *Amphipyra OCHSENHEIMER, 1816*

OCHSENHEIMER (1816) erected the genus *Amphipyra*, including 7 species, and *Phalaena tragopoginis* CLERCK, 1759 was subsequendy selected as its type-species by DUPONCHEL (1829).

The genus now contains 49 species in the Palaeartic region (FIBIGER & HACKER 2007). A few more species are known from North America (LAFONTAINE & SCHMIDT 2010), Africa (HACKER 2001, 2004) and from the Oriental Region (WARREN 1912–1938). Some new species were recently described from Central Asia and also from East and Far East Asia (OWADA 1988, HACKER 1992, 2004, AHN et al. 1996, HREBLAY & ROKAY 1997, 1998, HREBLAY et al. 1999, GYULAI & ROKAY 2008). In the last decades, new species have been described from the Indian and Indo-Chinese regions (NEPAL to THAILAND) (e.g., OWADA 1988, HREBLAY & ROKAY 1997, 1998, HREBLAY et al. 1999). In Europe, 10 *Amphipyra* species are known in total (KARSHOLT & RAZOWSKI 1996, FIBIGER & HACKER 2007). FUNAKOSHI (1992, 1994a, 1994b) published about the egg, larval and pupal morphology as well as biology of the Japanese *Amphipyra* species. *Amphipyra* was long treated as the type genus of the large and polyphyletic subfamily Amphipyrinae, but it is now known to be an isolated genus within the tritone Noctuidae, and the subfamily is now restricted to a few genera only (e.g. SPEIDEL et al. 1996, KRISTENSEN et al. 2007, ZAHIRI & al. 2010). The species-group of *A. pyramidea* is represented in Europe only by two species: *A. pyramidea* (LINNAEUS, 1758) and *A. berbera* RUNGS, 1949 (e.g., KOCH 1984, SKOU 1991, EBERT 1997), the former species being common and the latter scarcely recorded. Much has been published about the identification, discrimination, distribution and biology of these two species (e.g. URBAN 1968, 1969a, 1969b, EBERT 1997, REZBANAYI-RESER 1998, KAWAKAMI & SUGI 2000, FIBIGER & HACKER 2007). *Amphipyra pyramidea* is also recorded from East Asia (INOUE et al. 1982), where it was referred to as subspecies *obscura* OBERTHÜR, 1880 of *A. pyramidea*, which is now regarded as a synonym of the nominotypical subspecies (FIBIGER & HACKER 2007). FLETCHER (1968) discussed the species and subspecies of *A. pyramidea*, *A. berbera* and *A. monoliitha* GUENÉE, 1852. This paper, as the initial and still most important paper on the group in question, was supplemented for East Asia by OWADA (1996).

1 Contribution to moths of Taiwan 6 (Contribution to moths of Taiwan 5: BUSCHBAUM, U., & CHEN, M.-Y. [2012], A NEW *Terthreutis* MEYRICK, 1918 species from Taiwan (Lepidoptera, Tortricidae). — Entomofauna, Ansfelden, 34 (26): 349-356).
The larva of the new species (Figs. 10–11) was found in Meifeng (Nantou Co., Taiwan), in the Hehuan Mountains at about 2100 m (24°5'13" N, 121°10'36" E) on 24. v. 2011. The foodplant, an introduced species of *Populus* (Salicaceae), showed traces of frass. The larva was placed in a plastic rearing box with tissue paper, some soil and *Populus* leaves. The nearly mature larva hardly fed and pupated a few days later, after burrowing into the soil. The pupal stage lasted from 26.–28. v. to 2. vii. 2011, about 5 weeks. The imago emerged at night of 2./3. vii. 2011.

The locality Meifeng is also known as the Meifeng Highland Experimental Farm of the College of Bio-Resources and Agriculture of the National Taiwan University. The locality is surrounded by natural mountain forest and open areas with dry meadows (Fig. 14).

**Methods and locality**

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**Systematics**

*Amphipyra meifengensis* sp. n.

(Figs. 1–4, 10–18.)


**Description**

Forewing length 23 mm, wingspan 54 mm (holotype ♀), forewing length of ♂ paratypes 25 mm, wingspan 56 mm. Head, thorax and abdomen dark brown, with dark yellowish orange scales. Subterminal fascia white, with black tips towards the base. Subterminal fascia and postmedial fascia fused at dorsal margin close to inner angle. Antemedial fascia diffuse. Orbicular stigma clearly marked, rounded, with black dot. Hindwing orange brown with darker brownish apex. The ground-colour of the forewing underside is almost entirely dark brown, grayish yellow only at dorsal margin from basis to apex. Hindwing underside fuscous brown at costal margin, below costal margin orange coloured from base to postmedial fascia; a clearly marked nail-like discal spot with black extension line towards basis is distinctive (see Fig. 2).

♀ genitalia (Figs. 15–16): Different from all other known *Amphipyra* species. Ductus bursae wide, papillae anales short, rounded, wide, compact, squar. Corpus bursae rounded, without clear signum, with peak-like end. Ductus seminalis arises from the anterior end of the corpus.

♂ genitalia (Fig. 17): Principally identical to all other species of the group of *A. pyramidea* (Owada 1996). Uncus well developed, distal part swollen, with blunt
end. Valva simple, approximately parallel-sided, slightly curved and tapering in apical portion. Phallus with the vesica furnished with 19 mostly slender, long cornuti, attached at terminal end, and very small spicules at the vesica base. The number of cornuti was identical in the 2 ♂♂ dissected, but more dissections would be required to establish their range.

**Differential diagnosis:** A. horiei Owada, 1996 has a large white subterminal fascia and a small white orbicular stigma without black dot inside, and the subterminal fascia ends in a white apical streak at costa. A. monolitha is also similar, larger, darker brownish black from subterminal fascia to middle of forewing. Ground-colour of forewing darker, that of the hindwing also darker with a more diffuse antemedial fascia. The underside of A. meifengensis sp. n. is unique in the whole species complex of A. pyramidea, darker and with more pronounced markings, with nail-like discal spot. Male genitalia: The numbers of cornuti given are 10–13 for A. pyramidea (Fibiger & Hacker 2007, Owada 1996), 7–17 for A. horiei (Owada 1996), 11 in a figure of A. monolitha surina (Owada 1996), and 34–36 for A. berbera (Fibiger & Hacker 2007). Thus, the number of long cornuti of A. meifengensis sp. n. is apparently outside the range of the related species. Female genitalia: Ductus bursae in the related species narrower and longer. The papillae anales of the related Amphipyra species are small, narrow and elongate. Ductus seminalis originates from the middle of corpus bursae in A. pyramidea. The ♂ genitalia are better usable than the ♀ genitalia for discrimination of species of the group of A. pyramidea, with several diagnostic features.

**Larva**
(Figs. 10, 11.)
Typical pyramidea-group larva with a horn at end of abdomen. Ground-colour pale green. Head and first thoracic segment with two white lateral lines. Three bright yellow lines dorsally on first thoracic segment. Dorsal line bright yellow, with points on the line. Lateral white line from thorax to last segment with yellow upper border. On first thoracic and from first to eighths abdominal segment with large white black-bordered spiracles in the yellow border. Bright yellow angle in the terminal horned segment. Ventral prolegs distally red. No other Amphipyra species is known with such a colouration of the prolegs. In A. monolitha, the dorsal line is darker green and there is no yellow angled subdorsal line on the terminal segment.

Food plant: An introduced species of *Populus*.

**Pupa**
(Figs. 18a–18c.)
Length: 24 mm (exuvia after emergence of the moth). Dark brown to blackish. Frontal structure indistinct. Eyes, labial palps, and legs visible. Forewing structure and veins also visible. Wings cover 4 segments. Cremaster length: 1.5 mm, acuminate with two horn-like spines which are large, rounded, acuminate. The pupa is different from all other species of the A. pyramidea-species complex in cremaster structure and in the shape of the horn-like spines. In A. monolitha, the cremaster is conical and the horn-like spines are thinner and longer, with different structure. In A. berbera, the cremaster is slender with very thin and longer horn-like spines. In A. pyramidea, the cremaster is thinner and slender, with short, acuminate horn-like spines with small hooks (see Funakoshi 1994a for the Japanese species and Patocka 1995 for the European species A. pyramidea and A. berbera).

**DNA analyses**
The following sequences were obtained for the COI gene for the related Amphipyra species A. meifengensis sp. n., A. pyramidea and A. berbera, see Table 1. No data are so far available for A. monolitha and A. horiei which do, however, morphologically not so closely resemble A. meifengensis sp. n. Using Maximum Likelihood or Minimum Evolution methods for evaluation of the COI gene nucleotide sequences results in quite similar trees. The high bootstrap-values for the individual species show that they are quite stable. Astonishingly, Amphipyra perflua is shown to belong within the pyramidea-group using both methods (Figs. 19a, b), a result not expected by the study of the external appearance. A. perflua is indicated as a sister-species of A. berbera + A. meifengensis, and A. pyramidea is the sister-species to this complex. The position of A. perflua is identical, when Minimum Evolution method is used for evaluation (Fig. 19b). The Neighbor Joining (NJ) tree (Fig. 19c) received by bold, however, shows a different result. It indicates Amphipyra pyramidea as immediate neighbour of A. berbera + meifengensis. The Maximum Likelihood tree probably reflects phylogenetic relationship quite well, but is not in accordance with the NJ-tree and external appearance of the species concerning the position of A. perflua. It seems, however, to be well substantiated by generally high bootstrap-values (compare Figs. 19a–c).

**Discussion**
The new species belongs to the group of A. pyramidea. This is a group of species superficially very similar to the brown European A. pyramidea with laterally flattened uncus, with a broad, blunt end which is terminally acute on its ventral side. The valvae have almost parallel costal and ventral margins and are rounded only distally. The group of A. pyramidea in its narrow sense is represented in the region studied by the closely related trans-palaearctic species A. pyramidea (Owada 1996, Fibiger & Hacker 2007) which also occurs in North and South Korea and Japan and has also been reported from Taiwan (Owada 1996). Moreover, A. monolitha is also found in Taiwan. It is generally larger than A. pyramidea and inhabits subtropical areas at lower elevations,
whereas *A. pyramidea* inhabits higher elevations (Owada 1996). A further species, *A. horiei* Owada, 1996 (Owada 1996), was described from Amami-Oshima in the Japanese Ryukyu archipelago, where it is probably endemic. It has not been recorded from Taiwan. The ♀ genitalia provide no reliable characters (possibly except the number of cornuti) to separate these species, but *A. pyramidea* and *A. monolitica* can be readily discriminated by the ♀ genitalia (Owada 1996), and those of *A. meifengensis* sp. n. also are distinctive. The shape of the corpus bursae is different in virgin females and those who have copulated, so this character is difficult to use, whereas the origin of the ductus seminalis is clearly different in these species. In *A. pyramidea*, the ductus seminalis arises from the middle of the corpus whereas it arises from the anterior end in *A. monolitica* (Owada 1996), as in *A. meifengensis*. Based on this difference, a female of *A. pyramidea* (with ductus seminalis from about middle of corpus) is regarded as a subspecies may be doubtful. However, *A. meifengensis* sp. n. has an entirely different DNA barcode which clearly indicates specific rank, and larval data and the structure of the ♀ genitalia support this view.

**Table 1**: Data of the specimens used for the mtDNA sequence analyses. — Abbreviations: GBAC = GenBank Access Code; HT = holotype; PT = paratype; SL = Sequence Length (data from Bold in bp [= base pairs]); — = GBAC not yet available. Depositions: NMNST = National Museum of Natural Science Taiwan, Taichung; TLMF = Tiroler Landesmuseum Ferdinandeum, Innsbruck, Austria; ZSM = Zoologische Staatssammlung München [Munich], Germany.

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<th>Process-ID</th>
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**Representation of Amphipyra species in Taiwan and temperate East Asia**

Most species of this Palaearctic genus occur at higher altitudes in Taiwan. Only *A. monolitica* is recorded from lower altitude in subtropical areas of the warm temperate zone, whereas *A. pyramidea* is distributed in the cold temperate zone in Japan and Taiwan according to Owada (1996). Also the other species of *Amphipyra* recorded from this area are only found above 2000 m elevation.
The evolutionary method was used; other automatically as follows. When the number of common sites was < 100 or less than one fourth of the total number of sites, the maximum parsimony (Ulmaceae, Eurya japonica, Populus). Fig. 19a: Molecular phylogenetic coding. All possible 100 and A. monolitha for A. meifengensis. Mitochondrial DNA COI-barcode trees with likelihood method (Tamura & Kumar 2002). The ME tree was searched using the Close-Neighbor-Interchange (CNI) algorithm (Nei & Kumar 2000) at a search level of 0. The Neighbor-joining algorithm (Saitou & Nei 1987) was used to generate the initial tree.

Figs. 19a–c: Mitochondrial DNA COI-barcode trees with A. meifengensis sp. n. In Figs. 19a + b, codon positions included were 1st + 2nd + 3rd + Non-coding. All positions containing gaps and missing data were eliminated. There were a total of 376 positions (= base pairs) in the final dataset. Evolutionary analyses were conducted in MEGA (Tamura et al. 2011), the bootstrap consensus tree inferred from 1000 replicates is taken to represent the evolutionary history of the taxa analyzed (Felsenstein 1985). The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test are shown next to the branches. Branches corresponding to partitions reproduced in less than 50% bootstrap replicates are collapsed.

The analysis involved 24 nucleotide sequences (23 species). Compare Table 1 for details of the specimens. — Fig. 19a: Molecular phylogenetic analysis by Maximum Likelihood method, based on the Data specific model (Nei & Kumar 2000). Initial tree(s) for the heuristic search were obtained automatically as follows. When the number of common sites was < 100 or less than one fourth of the total number of sites, the maximum parsimony method was used; otherwise BI (ML) method with MCL distance matrix was used. A discrete Gamma distribution was used to model evolutionary rate differences among sites (5 categories + G, parameter = 0.7122). The rate variation model allowed for some sites to be evolutionarily invariable ([+I], 66.64970% sites). The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. — Fig. 19b: The evolutionary history was inferred using the Minimum Evolution method (Rzhetsky & Nei 1992). The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the Maximum Composite Likelihood method (Tamura et al. 2004) and are in the units of the number of base substitutions per site. The rate variation among sites was modeled with a gamma distribution (shape parameter = 3). The differences in the composition bias among sequences were considered in evolutionary comparisons (Tamura & Kumar 2002). The BE tree was searched using the Close-Neighbor-Interchange (CNI) algorithm (Nei & Kumar 2000) at a search level of 0. The Neighbor-joining algorithm (Saitou & Nei 1987) was used to generate the initial tree. — Fig. 19c: Neighbor Joining tree, as downloaded from the BOLD website.

- *Amphihiphy schrenckii* Ménétriès, 1859: below 2200 m
- *Amphihiphy shryhana* Chang, 1991: above 3200 m
- *Amphihiphy fuscusa* Chang, 1991: above 3200 m

Funakoshi (1994) listed all the known foodplants for the generally polyphagous species of *Amphihiphy* from Japan and East Asia: Quercus spp. (Fagaceae), Celtis sinensis (Ulmaceae), Eurya japonica and Cleveya japonica (Theaceae), Prunus spp. (Rosaceae), Acer palmatum (Aceraceae), Elaeagnus umbellata (Elaeagnaceae), and Ligustrum japonica (Oleaceae) for *A. monolitha* and Quercus spp. (Fagaceae), Malus spp., Prunus spp. and Pyrus serrata (Rosaceae), Vitis vinifera (Vitaceae) and Syringa reticulata (Oleaceae) for *A. pyramidea*. *Populus* is not recorded as a foodplant from Japan. The present record is the first for *Populus* sp. as foodplant for the genus *Amphihiphy* in Asia, though it has been reported for *A. pyramidea* from Europe (e.g., Evert 1997).

Including *A. meifengensis* sp. n., 10 species of the genus *Amphihiphy* OCHSHEIMER, 1816 are recorded from Taiwan:
References


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Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

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