Unusual flight activity of a new species of *Hagnagora* Druce, 1885 (Lepidoptera: Geometridae) from Costa Rica

● Gunnar Brehm & Bolling Sullivan

Abstract. *Hagnagora marionae* sp. nov. (Larentiinae) is endemic to high montane rain forests (> 2500 m) in central and southern Costa Rica. The species and its diagnostic morphological characters are described, and the 1530 bp long full sequence of the cytochrome oxidase I gene is provided. *Hagnagora marionae* sp. nov. is locally common and displays flight activity both by day and by night. This behaviour is unusual since only a minority of geometrid moths are diurnal, and very few neotropical species have been recorded as both diurnal and nocturnal. Its hostplants are unknown. The species is potentially threatened by global warming due to its very local distribution and high elevational range.

Zusammenfassung. *Hagnagora marionae* sp. nov. (Larentiinae) ist eine endemische Art hochmontaner Regenwälder (> 2500 m) im zentralen und südlichen Teil Costa Ricas. Die diagnostischen morphologischen Merkmale der neuen Art werden beschrieben, und die 1530 Basenpaare lange Sequenz des Cytochrom Oxidase I-Gens wird dargestellt. *Hagnagora marionae* sp. nov. ist lokal häufig und sowohl am Tage wie in der Nacht flugaktiv. Das Verhalten ist ungewöhnlich, da nur ein geringer Teil der Geometriden-Arten tagaktiv ist, und es in der Neotropis nur wenige Nachweise einer kombinierten Tag- und Nachtaktivität gibt. Die Wirtspflanzen sind unbekannt. Aufgrund ihrer lokalen Verbreitung in hohen Lagen ist die Art durch den globalen Klimawandel potentiell gefährdet.

Key words. Lepidoptera, Geometridae, Barva Transect, COI gene, DNA barcoding, global change, insects, mimicry, new species, rain forest

Introduction

Costa Rica is well known as a country attractive to tourists because of its rich fauna and flora. This small tropical nation is a leader in compiling an inventory of its biological diversity through the activities of the Instituto Nacional de Biodiversidad (INBio). Costa Rica's butterfly fauna is among the best investigated in the neotropical region (DeVries 1987, 1997). However, many nocturnal and / or less conspicuous Lepidoptera species still await scientific description and investigation of their life histories. We here describe a new species of Geometridae, one of the largest Lepidopteran families globally (Scoble 1999). The species was collected during fieldwork carried out in 2003 and 2004. This was undertaken along an elevational gradient from the Caribbean lowland rain forests to high montane rain forests. A total of 739 geometrid morphospecies were quantitatively recorded along the gradient, and it is anticipated that more will be discovered, since sampling was incomplete (Brehm *et al.* in press). Collected morphospecies were compared with types or other reliably identified material in AMNH, BMNH, USNM, and ZSM (acronyms see below). About 53 % were assigned to named species (Brehm *et al.* in press), and the remainder is likely to include many undescribed species. No specimens of the species described in the present paper could be found in any of the large collections listed above, although it was locally common in the study area. INBio was the only institution to hold specimens. In addition to the species description based on morphological characters, the sequence of the cytochrome oxidase I (COI) gene will be documented. This will allow further studies on the phylogeny of the genus *Hagnagora* and related larentiine taxa, and might allow identification by using DNA sequence data in the future (see Hebert *et al*. 2004, Speidel *et al*. 2005).

Acronyms

AMNH	American Museum of Natural History, New York, USA
BMNH	Natural History Museum, London, United Kingdom
CMNH	Carnegie Museum of Natural History, Pittsburgh, USA
INBio	Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica
USNM	National Museum of Natural History, Smithsonian Institution, Washington D.C., USA
SMNS	Staatliches Museum für Naturkunde, Stuttgart, Germany
ZSM	Zoologische Staatssammlung, München, Germany

Hagnagora marionae sp. nov.

Holotype. ♂, Costa Rica: Provincia Heredia, N[ational] P[ark] Braulio Carrillo, rainforest, Volcán Barva area, 10°08.0' N, 84°06.9' W, Blacklight 30 W, Va (11), 27.IV.2003, 18.30 – 19.30 h, 2730 m, Gunnar Brehm leg. (INBio) (illustrated in Fig. 1, genitalia illustrated in Fig. 3).

Paratypes. 2♂, same data as holotype (ZSM, BMNH) (genitalia examined, DNA extraction in one); 1♀, same data as holotype (INBio); 1♂, same data as holotype, but time 19.30 – 20.30 h (SMNS) (genitalia examined). 1♀, same data as holotype, but Volcán Barva area, 10°08.3' N, 84°06.0' W, Blacklight 30 W, Vb (12), 28.IV. 2003, 20.30 – 21.30 h, 2730 m, Gunnar Brehm leg. (USNM) (genitalia examined), 2♂, Volcán Barva area, 10°08' N, 84°07' W, at day, 28. IV.2003, 2700 – 2800 m, Gunnar Brehm leg. (AMNH, CMNH).

The following specimens are deposited in the collection of INBio and are very likely to be conspecific with the examined material. 4♂ and 3♀ from Cerro de

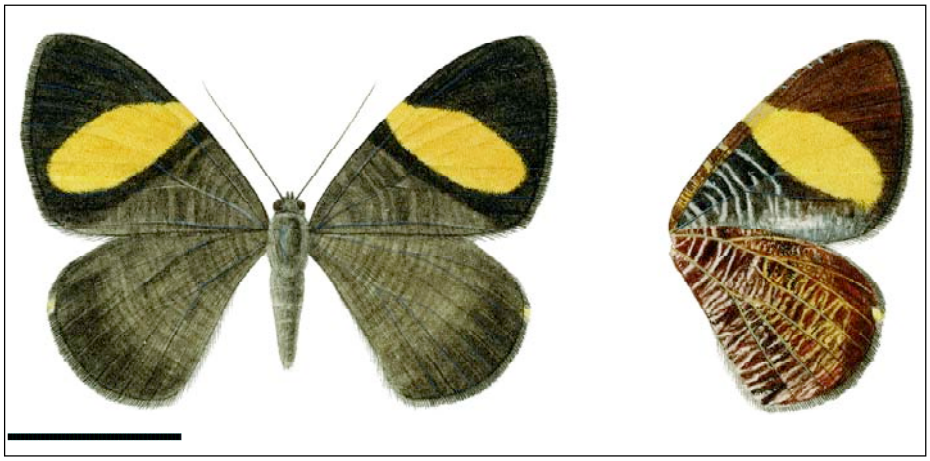

Fig. 1. Male of *Hagnagora marionae* sp. nov. Scale bar 1 cm.

Fig. 2. Habitat of *Hagnagora marionae* sp. nov. at Laguna Barva, Parque Nacional Braulio Carrillo, Provincia Heredia, Costa Rica (2800 m), 28.IV.2003. The species has frequently been observed by the first author flying by day in sunshine.

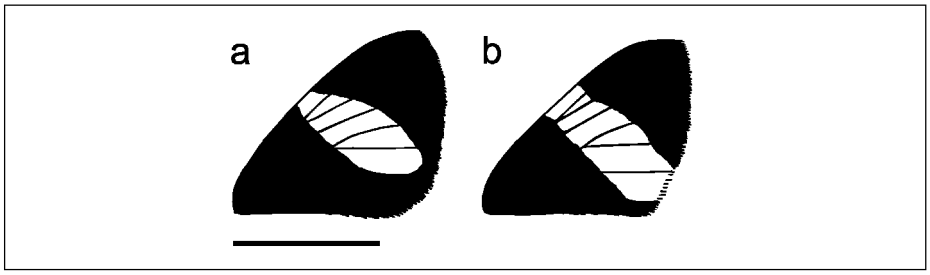

Fig. 3. Morphological differences between **a.** *Hagnagora marionae* sp. nov. and **b.** *H. ephestris* Felder & Rogenhofer. *Hagnagora marionae* sp. nov. is slightly larger and has a more rounded forewing shape than *H. ephestris*. The yellow blotch (shown as white in the Figure) in *H. marionae* sp. nov. has no contact with the outer wing margin. On the contrary, the blotch of *H. ephestris* extends fully from the costa to the outer margin of the wing.

la Muerte, 3150 m, 20. – 21.III.2004, Bolling Sullivan leg. (INBio) (genitalia of one pair examined). 4♂ and 3♀ from Estación Barva, Parque Nacional Braulio Carrillo, 2500 m; 3♂, 1♀ from Estación Cuerici, Sendero al Mirador, 4.6 km al E. de Villa Mills, Provincia San José, 2640 – 2700 m, [9.56°N, 83.70°W]; 2♂, 4♀ from Estación Ojo de Agua, Reserva Forestal Rio Macho, Provincia San José, 3000 m; 5♂, 8♀ from 1 km NE Cerro Asunción, Cerro de la Muerte, Provincia Cartago, 3100 m, [9.56°N, 83.77°W].

Derivatio nominis. The species name is dedicated to Marion Schrumpf.

Description. *Habitus*. Adult males (Fig. 1) with an average wingspan of 17.5 ± 0.8 mm SD (n = 122, largest: 19 mm, smallest: 15 mm). Females (not illustrated but identical pattern) are slightly larger (n = 7, 17.8 ± 0.5 mm). The antennae are fasiculate with brown scaling dorsally, the bases are yellow-brown. Palpi are porrect, and are light yellow-brown ventrally; brown dorsally. The first segment is upcurved, slightly longer than second segment; third segment shortest, pointed. The frons brown with lateral edges yellow-brown; vertex brown with yellow-brown scales around margin; collar brown with infusion of yellow-brown scales. Thorax with small scales yellow-brown. Tegulae brown, long thin hair-like scales. Legs yellow-brown with infusion of brownish scaling; no unusual features. Abdomen covered with small, brown scales dorsally with a row of yellow-brown scales at the posterior end of each segment. Underside of abdomen yellow-brown. Forewing brown with a yellow band from mid costa almost to anal angle; the band is narrowest at costa and also narrowing near anal angle. Yellow scaling on basal portion of wing veins, remnants of cross-wing banding pattern visible when illuminated from below. Hindwing brown with white scaling between veins at margin giving a scalloped appearance. Underside of forewing repeates upperside pattern but with white cross-wing striations evident over a reddish brown ground basally, ground color extends to apex. Underside of hindwing with cross-wing striations on reddish brown ground, small white spot at dorsal base of cell. Fringe brown. The extent of yellow-white scaling between veins at the wing margin varies. It is generally more extended in females than in males, and more pronounced in populations from southern Costa Rica than in the population from the Barva area.

Male genitalia (Fig. 4). Overall length 1.90 mm, valve width 0.98 mm; aedeagus 1.54 mm; bulbous vesica exceeds aedeagus length, extends dorsally, smallish diverticula at 2/3 height, ductus enters aedeagus in basal third. Uncus slender, downcurved and swollen at tip, spatulate. Valve broad and rounded, sparsely hairy with two distinct hair brushes near costa. Juxta broad, shield shaped; saccus broadly triangular, pelt lacking distinct characters.

Female genitalia (Fig. 5). Overall length 4.39 mm, corpus bursae 2.29 mm, ribbon

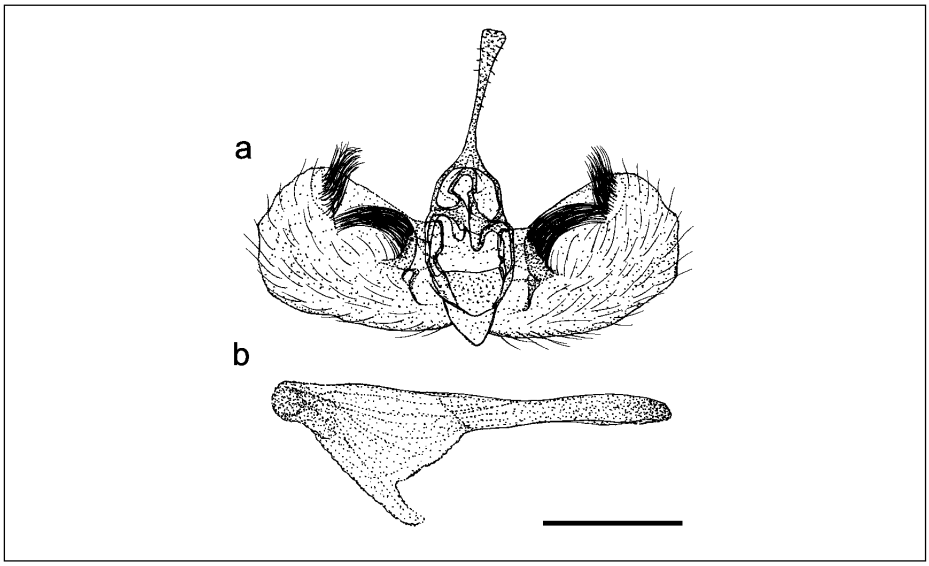

Fig. 4. Male genitalia of *Hagnagora marionae* sp. nov. (holotype). **a.** valves, **b.** aedeagus. Scale bar 1 mm.

signum 0.95 mm. Papillae anales elongated, slightly pointed, apophyses of approximately equal length, ostium bursae undifferentiated. Ductus bursae with sclerotised colliculum anterior to midpoint, colliculum extends about 2/3 around ductus. Corpus bursae bulbous with two ventral ribbon-like longitudinal signa and a poorly defined rugose patch on dorsal side.

Genetics. The complete mitochondrial cytochrome oxidase subunit I and adjacent tRNAs were sequenced from one of the paratypes as described in Speidel *et al.* (2005). The 1554 bp long fragment is shown in Appendix 1. The COI sequence data is deposited as barcoding sequence in EMBL/GenBank and available under acc. no. AM051082. (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi). The sequence allows exploration of the phylogeny of *Hagnagora* and related larentiine taxa in the future.

Diagnosis. The most similar species appears to be *Hagnagora ephestris* Felder & Rogenhofer 1875 since this species also has a large yellow blotch on the forewing. Figure 3 illustrates the differences between *Hagnagora marionae* sp. nov. and *H. ephestris*. *Hagnagora marionae* sp. nov. tends to be slightly larger and its forewing is more rounded than that of *H. ephestris*. The yellow blotch (shown as white in Fig. 3) in *H. marionae* sp. nov. has no contact with the outer wing margin. On the contrary, the blotch of *H. ephestris* extends completely from the costa to the outer margin of the wing. Moreover, the male genitalia of *H. marionae* differs from that of *H. ephestris* (not illustrated). The uncus of *H. marionae* sp. nov. is spatulate, whereas that of *ephestris* is pointed, and *H. marionae* sp. nov. has two hair brushes on the distal part of the valve, whereas *ephestris* has only one brush. Whether or not *H. ephestris* or another species of *Hagnagora* is the sister species of *H. marionae* sp. nov. needs to be demonstrated in future studies.

Distribution. The species is only known from a comparatively small area at high elevations in central and southern Costa Rica. The northernmost records are from Volcán Barva in the Cordillera Central (10.13°N, 84.12°W, see description and holotype) while the southernmost records are from the Cordillera de Talamánca (9.56°N, 83.70°W). Available data suggest that *Hagnagora marionae* sp. nov. is a species endemic to very high elevations (>2500 m a.s.l.) in Costa Rica. Despite intensive sampling along the Barva Transect, no specimen was recorded at any of the lower sites. For example, *H. marionae* sp. nov. was not present among the 1700 geometrid specimens quantitatively collected during four collecting nights at a site at 2140 m in 2003 and 2004 (ca. 5 km from Volcán Barva's summit; map: Brehm *et al.* in press). The actual geographical range might extend further south along the Cordillera de Talamánca into Panama (Volcán Chiriqui), but no records of the species are available from this partly inaccessible region. Since the species is restricted to very high elevations, it seems unlikely that its range extends across the lowlands of the Isthmus of Panama to the South-East. Moreover, there are no very high elevational habitats in north-western Costa Rica and Nicaragua, except for Volcán Poás in close proximity to Volcán Barva.

Its local and endemic distribution at very high elevations makes the species (together with other endemics) particularly vulnerable to the effects of global warming. For example, the peak of Volcán Barva has an elevation of 2906 m. If the climate becomes warmer, the species will have no opportunity to escape from its current range to higher elevations and might become locally extinct. Potential refuges would only remain in the southern part of Costa Rica where the mountains are higher.

Habitat and flight behaviour. The habitat of *H. marionae* sp. nov. is high montane rain forests dominated by *Quercus* species (Fig. 2). The hostplant is unknown. Hostplant records exist for two *Hagnagora* species: *H. ephestris* Felder & Rogenhofer 1875 and *H. mortipax* Butler 1872. Larvae of both species were observed on *Clethra* species (Clethraceae), while *H. mortipax* was also found on *Cordia* (Boraginaceae) (Brehm 2002).

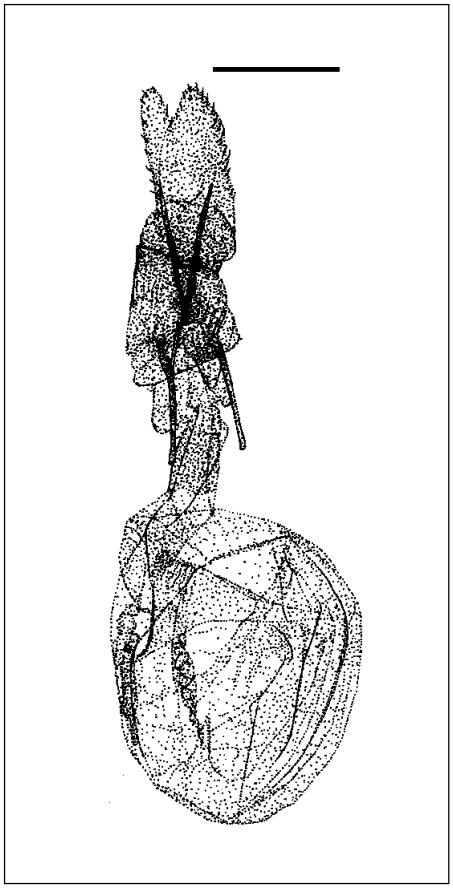

Fig. 5. Female genitalia of *Hagnagora marionae* sp. nov. (specimen from Cerro de la Muerte) Scale bar 1 mm.

Interestingly, *H. marionae* sp. nov. was observed flying by day and night. Although the species has been recorded only at a few sites in Costa Rica, it was common in the area of Volcán Barva. The species was frequently observed flying in bright sunshine, e.g. at the Laguna de Barva (illustrated in Fig. 2). Only a few specimens (all males) could be collected because of their rapid and restless flight behaviour. It remains to be shown whether the females also fly by day. The species has also been frequently recorded during quantitative blacklight sampling (2 x 15 W) at two sites in the Barva area (2730 m each). During eight collecting nights (18.30 – 21.30 h), a total of 209 specimens of the species were quantitatively recorded, and only six of these were females. However, ten specimens collected at night in the area of Cerro de la Muerte (southern Costa Rica), had a sex ratio of 1:1. Diurnal *and* nocturnal activity is a behaviour pattern that is infrequently observed in Geometridae and Lepidoptera. Most Lepidoptera species are either active during the day, or active at night. Diurnal butterflies can sometimes be found in light trap samples due to disturbance of their roosting (own observations), and some hesperiids and brassolines are often active at twilight (e.g. DeVries 1987). When disturbed, many nocturnal moths such as most Geometridae also fly during the day, but only over short distances and in order to escape a predator (e.g. Ebert 2001). Most geometrid moths are nocturnal, but diurnal activity has been observed in a number of genera, e.g. *Archiearis* Hübner [1823] 1816, *Camptogramma* Stephens 1831, *Entephria* Hübner [1823] 1816, *Epirrhoe* Hübner [1823] 1816, *Epirrita* Hübner 1822, *Eulithis* Hübner 1821, *Idaea* Treitschke 1825, *Jodis* Hübner [1823] 1816, *Lythria* Hübner [1823] 1816, *Minoa* Treitschke 1825, *Odezia* Boisduval 1840, *Rheumaptera* Hübner 1822, *Scopula* Schrank 1802, *Scotopteryx* Hübner [1825] 1816, and *Xanthoroe* Hübner [1825] 1816 in Europe (Ebert 2001, Hausmann 2001). Examples from North America include *Trichodezia* Warren 1895 (Muma & Fullard 2004), as well as *Heliomata cycladata* Grote & Robinson 1866, *H. infulata* Grote 1863 and *Lomographa semiclarata* (Walker 1866) which are known to be active by day and night (Covell 1984, B. Sullivan, pers. observ.). Brehm *et al.* (2005) observed 25 exclusively diurnal species in southern Ecuador (only 2 % of a total of 1266 recorded geometrid species) of the following geometrid genera: *Devarodes* Warren 1904, *Erateina* Doubleday 1848, *Eubaphe* Hübner 1823, *Eudule* Hübner 1823, *Heterusia* Hübner [1831] 1825, *Sangalopsis* Warren 1895, *Siosta* Walker 1856, *Smicropus* Warren 1895, and *Thersana* Walker [1865] 1864. Only five species (0.4 %) were collected at day and night: *Erycinopsis diaphana* Felder 1874, *Hagnagora anicata* Felder & Rogenhofer 1875, *Myrmecophantes albifascia* Maassen 1890, *Perissopteryx commendata* Schaus 1912, and *Scotopteryx fulminata* Dognin 1893. None of these species were commonly seen in the day, and the observation of *Perissopteryx* was most probably accidental because of disturbance. It is notable that almost all diurnal geometrid species observed in Ecuador are conspicuously coloured (including the above mentioned species from the temperate zones). Some clear-winged genera such as *Myrmecophantes* Warren 1894 and *Erycinopsis* Felder 1874 probably mimic unpalatable ithomiine butterflies, while others have colourful blotches. This could indicate a strong evolutionary selection in diurnal geometrids for protection through chemical defences in the context of mimicry and aposematism. Unfortunately, very little is known about the life histories of most species. It is also unknown whether geometrids tend to be Batesian or Müllerian mimics since no experiments with predators have been reported. In conclusion, diurnal-nocturnal flight behaviour has rarely been observed in neotropical geometrids. The phenomenon is poorly understood and offers an interesting field of future research.

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Appendix 1. Complete cytochrome oxidase I gene sequence of *Hagnagora marionae* sp. nov. The figured sequence starts with 16 bp of the tRNA, followed by 1530 bp of the COI gene, and by 8 bp of tRNA.

[tRNALeu]
ATTTTATCTTTTTGTG

[COI]
CGAAAATGACTTTATTCAACAAACCATAAAGATATTGGAACTTTATATTTTATTTTTGGTATTTGAGCGGGTATAATTG
GAACATCTTTAAGATTATTAATTCGAGCTGAATTAGGAAACCCAGGATCTTTAATTGGGGATGATCAGATTTACAATA
CAATTGTTACTGCTCATGCATTTATTATAATTTTTTTTATAGTTATACCTATTATAATTGGAGGATTTGGAAATTGATTAGT
TCCTTTAATACTAGGGGCCCCTGATATAGCTTTTCCCCGTATAAATAATATAAGATTTTGACTATTACCTCCCTCCATTAC
CCTTTTAATTTCAAGAAGAGTAGTAGAAAATGGAGCAGGGACAGGATGAACTGTATACCCCCCCCTGTCTTCTAACA
TTGCTCATAGAGGAAGATCTGTAGATTTAGCTATTTTTTCATTACATTTAGCTGGAATTTCTTCAATCCTGGGAGCTATT
AATTTTATCACAACTATTATCAATATACGCCTTAATAATATATTTTTTGATCAGTTACCTTTATTTGTATGAGCTGTAGGTA
TTACAGCTTTTTTACTATTACTTTCATTGCCTGTTTTAGCAGGGGCCATTACTATATTATTAACAGATCGAAATTTAAAT
ACTTCATTTTTTGACCCGGCTGGGGGAGGAGACCCTATTCTTTACCAACATTTATTTTGATTTTTTGGACACCCAGAA
GTTTACATTTTAATTTTACCTGGATTTGGGATAATTTCCCATATTATTTCCCAAGAAAGAGGTAAAAAAGAAACCTTTG
GGTGTTTAGGAATAATTTATGCTATAATAGCTATTGGAATTTTAGGGTTTATTGTTTGAGCACACCATATATTTACTGTG
GGAATAGATATTGATACTCGAGCCTATTTTACTTCTGCAACTATAATTATTGCTGTTCCTACAGGAATTAAAATTTTTAG
ATGATTAGCCACATTACACGGAACTCAAATTCTTTACACTCCTTCAATTTTATGAAGATTAGGATTTGTATTTTTATTCA
CTGTAGGAGGATTAACAGGAGTAATTTTAGCTAATTCATCTATTGACATCACTCTCCATGACACATATTATGTTGTAGC
TCATTTTCACTATGTTTTATCAATAGGGGCTGTATTTGCTATTTTAGGAAGATTTATTCATTGATATCCTTTATTTACAGG
ACTATATTTAAACCCATATTTATTAAAAATTCAATTTTTTGTTATATTTATGGGAGTAAATTTAACATTTTTCCCTCAACAT
TTTTTAGGTTTAGCTGGAATACCTCGTCGATACTCAGATTATCCTGATTCTTACATTTCCTGAAATATAATTTCTTCCTTA
GGTTCTTATATTTCTTTATTAGCAGTTATATTAATTTTAATTATTATTTGAGAGTCTATAATTAATCACCGAATAATTTTAT
TTACTTTAAACATATCATCTTCAATTGAATGATTCCAAAACTTACCTCCTGCAGAACATTCATATAATGAACTACCTATT
TTAAGAAGA

[tRNAVal]
TTCTAATA

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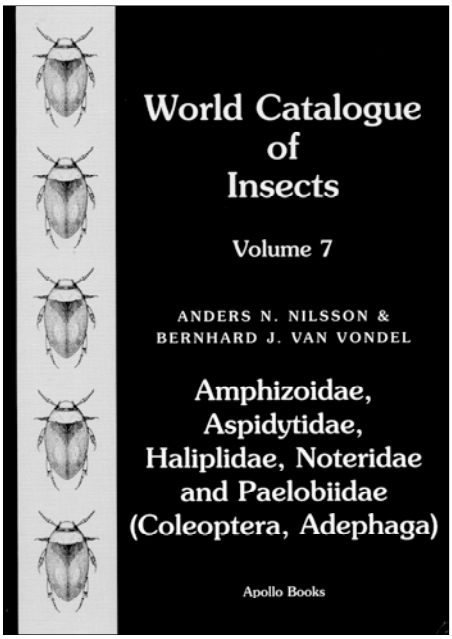
Buchbesprechung

Nilsson, A. N. & van Vondel, B. J. 2005. *Amphizoidae, Aspidytidae, Haliplidae, Noteridae and Paelobiidae (Coleoptera, Adephaga)*. World Catalogue of Insects. Vol. 7. 171 S. Apollo Books. ISBN: 87-88757-49-8. Preis: DKK 320,–. Bezug unter: apollobooks@vip.cybercity.dk.

Hier liegt also Band 7 des World Catalogue of Insects vor. Nun wird ja manchmal behauptet, der Herr hätte, als die Welt erschaffen wurde, eine besonderes Faible für Käfer gehabt. Waren es wohl Wasserkäfer? Mit Band 7 existieren nun nämlich bereits vier aktuelle Weltkataloge für eben diese, Band 1 der Serie enthielt die Hydraenidae, Band 2 dann Hydrophiloidea, 3 die Dytiscidae. Mit dem vorliegenden Band fehlen bei den aquatischen adephagen Käfern nur noch die Taumelkäfer, ein riesiger Schritt vorwärts für alle, die sich mit Wasserkäfern befassen.

Egal, ob ökologisch, faunistisch, taxonomisch oder gar molekular-phylogenetisch. Mit Anders Nilsson und Bernhard van Vondel haben zwei renommierte Experten einen Katalog vorgelegt, der noch besser ist, als frühere Bände. Unten auf den Seiten ist fett aufgedruckt,



innerhalb welcher Familie bzw. Gattung man sich befindet, was die „Navigation" erheblich erleichtert. Zu jeder Art werden Originalbeschreibung zitiert, sowie die Synonyme und wichtige taxonomische Akte.

Dann, in einem separaten Block – und das ist eine fantastische Informationsquelle – finden sich umfangreiche Literaturzitate zu faunistischen Meldungen. Beispiel: Bei *Haliplus immaculicollis* Harris, 1828 kann man anhand der dem Artnamen folgenden Kürzel NA und NT sofort erkennen, dass die Art nearktisch und neotropisch verbreitet ist, die Typuslokalität ist „North America", und Staines hat die Art z. B. 1986 aus Maryland gemeldet. Es ist auch ersichtlich, dass der Autor, in diesem Fall van Vondel, die Art erstmals aus Mexiko melden kann, basierend auf Material, welches im USNM deponiert ist.

Um es kurz zu machen: Dieser Katalog ist eine reiche Quelle taxonomischen und faunistischen Wissens, welches ihn zu einem Standardwerk machen wird. Einzig warum Anders Nilsson die Hygrobiidae nun als Paelobiidae führt, ist mir nicht klar. Der erstere Name erfreut sich extrem weiter Verbreitung und Anwendung, und mir persönlich sind keine signifikanten Schriften der letzten Jahrzehnte bekannt, welche den letzteren, wenn gleich auch älteren Namen verwenden würden. Hier wäre es aus Gründen der Stabilität sicher sinnvoller gewesen, den Namen Hygrobiidae per Kommissionsbeschluss zementieren zu lassen.

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