Zootaxa 1989: 23–38 (2009)
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

An unexpected hotspot of moth biodiversity in Chilean northern Patagonia (Lepidoptera, Geometridae)

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Abstract

In a small area around Huinay station, northern Patagonia (Chile), 75 geometrid moth species were collected at light in three subsequent nights, 87 in a short 11-day period under suboptimal weather conditions. This surprisingly high diversity is due to lack of habitat destruction and complete overlap of Valdivian and Patagonian fauna elements. An annotated neighbour joining tree of COI data (5’ barcoding fragment) is presented and the taxonomy of all species is discussed. Three new combinations are proposed: *Danielaparra fragmentata* (Dognin, 1906), **comb. n.**, transferred from *Hoplosauris*; *Hoplosauris multivirgulata* (Mabille, 1885), **comb. n.**, transferred from *Physoloba*; *Calta debilis* (Butler, 1882), **comb. n.**, transferred from *Odontothera*. *Daniela viridis* (Parra, 1996) is a new synonym of *Danielaparra fragmentata*.

Key words: taxonomy, barcoding, COI5’, nDNA, neighbor joining tree, *Danielaparra fragmentata* (Dognin, 1906) **comb. n.**, *Hoplosauris multivirgulata* (Mabille, 1885) **comb. n.**, *Calta debilis* (Butler, 1882) **comb. n.**, Andina Region

Un inesperado “hotspot” de biodiversidad de polillas en el norte de la Patagonia chilena (Lepidoptera, Geometridae)

Resumen

En una pequeña área en los alrededores de la estación Huinay, al norte de la Patagonia, se colectaron 75 especies de geométridos con trampas de luz en tres noches consecutivas y 87 especies en un período de 11 días bajo condiciones climáticas subóptimas. La alta diversidad de geométridos se debe a que en la zona de estudio existen hábitat prístinos, y en ella se superponen elementos faunísticos Valdivianos y Patagónicos. Se entrega un árbol con datos COI (5’ fragmento Barcoding) y se discute la taxonomía de todas las especies. Se proponen tres nuevas combinaciones: *Danielaparra fragmentata* (Dognin, 1906) **comb. n.** es transferida desde el género *Hoplosauris*; *Hoplosauris multivirgulata* (Mabille, 1885) **comb. n.** es transferida del género *Physoloba*; y *Calta debilis* (Butler, 1882) **comb. n.** es trasferida desde *Odontothera*. *Daniela viridis* (Parra, 1996) es un nuevo sinónimo de *Danielaparra fragmentata*.

Palabras claves: Taxonomía, Barcoding, COI5’, nDNA, árbol Neighbor joining, *Danielaparra fragmentata* (Dognin, 1906), **comb. n.**, *Hoplosauris multivirgulata* (Mabille, 1885), **comb. n.**, *Calta debilis* (Butler, 1882), **comb. n.**, Región Andina

Introduction

The native forest of southern South America is well-known for the exceptional degree of endemism of its biota, as a product of geographic isolation, geomorphologic heterogeneity and great environmental changes

Accepted by L. Gall: 9 Dec. 2008; published: 27 Jan. 2009

having occurred since the Tertiary. Under these conditions the distribution of many plant and animal species was severely delimited and evolution of endemic genera and species facilitated (Jerez 2005; Armesto *et al*. 1996). These attributes characterize the winter-rainfall Valdivian rainforests as a global reserve of biodiversity, ranked as one of the 25 hotspots of biodiversity worldwide by Myers *et al*. (2000) and Conservation International (2008).

The Geometridae are considered to be "of particular value as indicators given their relatively restricted mobility" (Scoble 1995; Minet & Scoble 1999). They have been frequently used for exemplary assessment and measurement of biodiversity patterns in all continents (e.g. Brehm 2002; Beck *et al*. 2002; Intachat & Holloway 2000; Axmacher *et al*. 2006; McQuillan 2004; etc.).

In January 2008 the authors undertook a brief collecting trip to Huinay station, northern Chilean Patagonia, for the project "*Looking for Gondwanaland relicts: the Geometridae of the Nothofagus forests of Chile and Tasmania*" (DFG, German research foundation, HA 1806/7-1). Though biodiversity assessment was not the primary scope of the project, it became evident quickly that this fairly unexplored region of northern Patagonia is inhabited by a surprisingly high number of species of arthropod primary consuments, such as Geometridae.

Study area

The study area in "Huinay" belongs to the San Ignacio del Huinay Foundation (Figs. 1–2; cf. http://www.huinay.cl). The territory covers nearly 34,000 hectares in the Xth region of Chile (the Lake District, "Los Lagos", northern Patagonia). The station (42°22´ S, 72°24´ W) lies at the shore of the Comau fjord, 45 km S Hornopiren, 110 km SSE of Puerto Montt. In the expedition of January 2008 only a small sector in close proximity to the Huinay station was investigated, with five collecting sites at a maximum distance of 2 km from the station, at an altitudinal gradient of only ca 50 m. One collecting night at 800 m (by Greifenstein & Flauger) at 0°C yielded no geometrid moths. The site is characterised by a spectacular mountainous relief with an altitudinal gradient from 0 m to more than 2000 m at a distance of a few km. The steep slopes are covered by a dense rainforest with species-rich flora up to an altitude of approx. 1, 300 m. For details of geology, habitats and flora see http://www.huinay.cl.

Materials and methods

Both authors collected at Huinay station from January 4 to January 9, with 5 additional days until January 14 of collecting performed by Thomas Greifenstein (Munich) and Norbert Flauger (Casa Maria, Venezuela). The weather was optimal in the first two nights, sub-optimal in the third, and extremely cold for the rest of the period with maximum day temperatures of approx. 13° C, and minimum temperatures of approx. 4° C, accompanied by heavy rainfall and snow down to ca 400 m.

Moths were collected at a white sheet resp. tower with 160W mercury bulbs from sunset to around 01:00-02:00 hrs. On three nights collecting took place at two different sites simultaneously. All moths were laid on cotton layers the next morning, stored in a deep freezer and mounted in Germany after a short exposure to humidication for approximately 2 hours. Legs of representative specimens per species were immediately separated into matrix boxes (CCDB, Canada) for DNA barcoding, and for nuclear DNA analysis. 242 geometrid specimens of the January collectings were DNA-barcoded and 70 used for nDNA analysis. All barcoded specimens were databased and photographed, with pictures accessible in the taxonomy browser of BOLD (2008) or at the Geometrids of Huinay website (Hausmann & Parra 2008). Most vouchers are stored at the Zoologische Staatssammlung München (ZSM), with parts of the material at the collection of the University Concepción.

FIGURE 1. Huinay station, view from the Comau fjord.

FIGURE 2. Collecting site at 100 m distance from the station (photo Thomas Greifenstein).

FIGURE 3. *Neorumia gigantea* (Photo Gunter Forsterra).

Beating of larvae from several plant species e.g., various *Nothofagus*, Myrtaceae (*Luma apiculata*) and Pteridophyta was performed for ca 3 hours. Fogging for larvae was conducted with both a small sprayer and a medium sized dispenser on six plants: *Nothofagus dombeyi*, *Luma apiculata* (2x), *Aristolochia chilensis*, *Eucryphia cordifolia* and Pteridophyta. Larvae were preserved in 100% ethanol and pre-identified through DNA barcoding.

Species diversity (identification, taxonomy) was assessed by a combined approach of morphological and molecular techniques. Traditional methods included morphospecies grouping according to wing pattern and coloration, such as genitalia structures with morphometric analysis (taxonomic work on the Chilean fauna is quite time consuming and challenging because the fauna is poorly studied, all diagnoses thus must be carefully worked out, and a large number of current generic combinations appear to be incorrect —which emphasizes the need for generic revision at a global scale). A DNA profile (COI 5’ barcoding fragment, 658 bp) was created for re-identification and species grouping of Chilean geometrids, including >700 specimens of >200 Chilean species (ca 70% of the known fauna). Simultaneously tissues of about 100 taxa were collected into alcohol for analysis of other genes. Initial work focused on 28S and EF1alpha genes and will be the subject of future publications, since the taxon sampling is still too fragmentary to allow overall analyses of relationships at higher ranks (genus and tribe).

Results

The first three collecting nights from 4–6 January 2008 yielded 75 geometrid species. Owing to poor weather, the subsequent eight nights brought an increase of only 12 species, with the overall total being 87 geometrid species. Altogether approximately 1,000 individuals of Geometridae were collected. With subsequent sparse spring and autumn collecting at Huinay station by several colleagues (Tilla Roy, Reinhard Fitzek, Roland Melzer, Roland Meyer), the number of species increased to 135 geometrid species (2,200 vouchers).

The combined approach of morphological and molecular analysis helped to accelerate the biodiversity assessment and allowed new generic combinations or tentative assignments to tribes. The neighbour joining tree is presented in Figs. 4a–4c, with taxonomic annotations. A list of the species is given in the Appendix. To date, 46 species have been identified to species, 39 to genus, and two are awaiting generic assignment. Many of the unassigned species may proved to be new to science. Photographs of moths and their genitalia may be accessed online through the Hausmann & Parra (2008) and BOLD (2008) websites.

Larval collecting, though limited, yielded 13 Lepidoptera larvae. Six of these were geometrids, belonging to three species. By comparison to the adult DNA barcode profiles, all six larve larvae were identified to species.

Remarks to the neighbour joining (NJ) tree of COI data (Figs 4a–4c):

[Larentiinae 1]

[1–4] *Synpelurga corralensis* (Butler, 1882): Tentatively assigned to Trichopterygini, as suggested by position in the NJ tree in a multigene analysis (COI, EF1alpha, 28S).

[5–6] *Danielaparra fragmentata* (Dognin, 1906), **comb. n**.: *D. viridis* (Parra, 1996) synonym (L. Parra unpublished). In BMNH collection and in Scoble (1999) as "*Hoplosauris fragmentata*"; separate genus from *Hoplosauris* justified by strongly different structure of genitalia: transtilla of male genitalia with microspines and valves without androconium. Taxon *imbricaria* Felder & Rogenhofer, 1875 possibly a synonym. Tentatively assigned to Trichopterygini, as suggested by position in the NJ tree such as in a multigene analysis (COI, EF1alpha, 28S).

[7–8] *Notholoba schausi* (Warren, 1908): Barcoding data from other Chilean localities suggesting the existence of two sister species.

[9–11] *Triptiloides* sp. 2 (cf. *laeta*): Usually with less white marking on forewing than in *T. laeta*, on hindwing with broad purple fascia rather than with two narrow lines. However, rarely with conflicting character combinations. Minimum pairwise distance: 3.2% (mean intraspecific variation 0.16% and 0% resp.).

[12–16] *Triptiloides laeta* (Philippi, 1873): see remarks to 9–11.

[17–18] *Genus* AH5 sp. 1: Relationship to *Lagnyopteryx* suggested by position in the complete NJ tree of Chilean COI data (not shown).

[30–33; 223; 226–231] [genus *Hoplosauris*]: Genus concept and systematics requiring revision. COI data suggesting polyphyletic origin of the group currently assigned to *Hoplosauris*.

[31] *Hoplosauris multivirgulata* (Mabille, 1885), **comb. n.**: In Scoble (1999) combined with genus *Physoloba*. New generic combination recognized in current research of the junior author and confirmed by morphometric analysis, the males having hairy scales covering the anal margin of the hindwings, valvae of male genitalia curved with an elongated costal margin. Androconia formed by simple bristles plus some thick bristles.

[34–40] [Euphyiini]: Attribution to tribe according to the Palearctic concept. For doubts about generic assignment see under the three following species. Probably the species do not belong to Euphyiini. In a multigene analysis (COI, EF1alpha, 28S) the species are clustering together with members of the Cidariini (e.g., *Nebula* sp. 4).

[34–35] "*Euphyia*" sp. 2: Generic combination supported by wing pattern, suggested by position in NJ tree close to the following species. Generic and tribal attribution of all three species requiring revision as not clustering together with Palearctic Euphyiini in COI NJ tree.

[36–38] "*Euphyia*" *signata* (Butler, 1882): Generic and tribal attribution requiring revision as not clustering together with Palearctic Euphyiini in COI NJ tree. Type (BMNH) examined, well matching with this species (cf. following species). Genetically different from the sister species [39–40]: minimum pairwise distance: 5.0% (mean intraspecific variation 0.2% and 0.1% resp.), the latter usually larger and better marked.

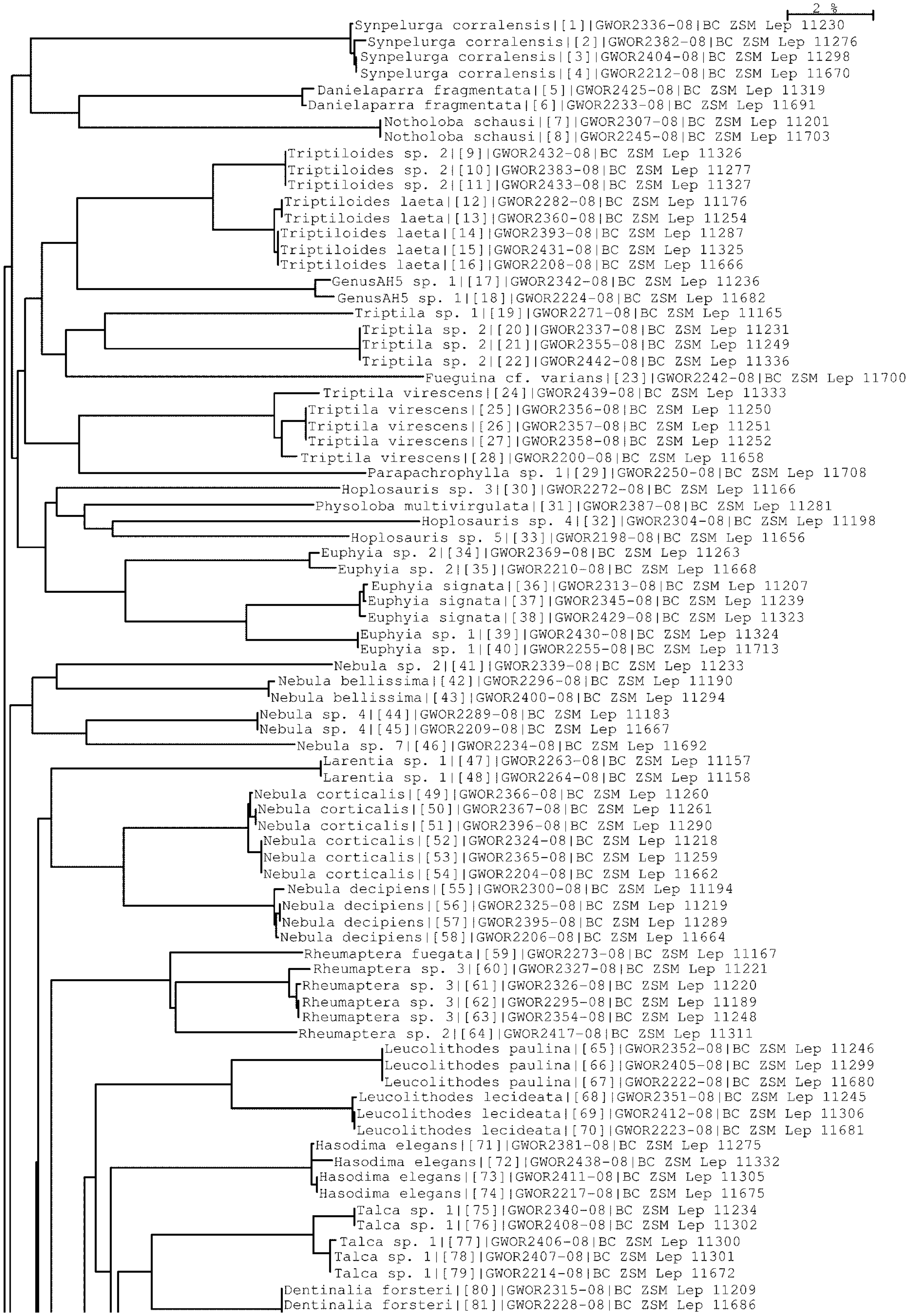

FIGURE 4a. Neighbor joining tree of Geometridae, collected at Huinay station, Chile from 4–14 January 2008; COI 5' barcoding fragment, 658 bp, Kimura 2 Parameter, from BOLD Data Systems (courtesy of Paul Hebert, CCDB Guelph, Canada) (continued).

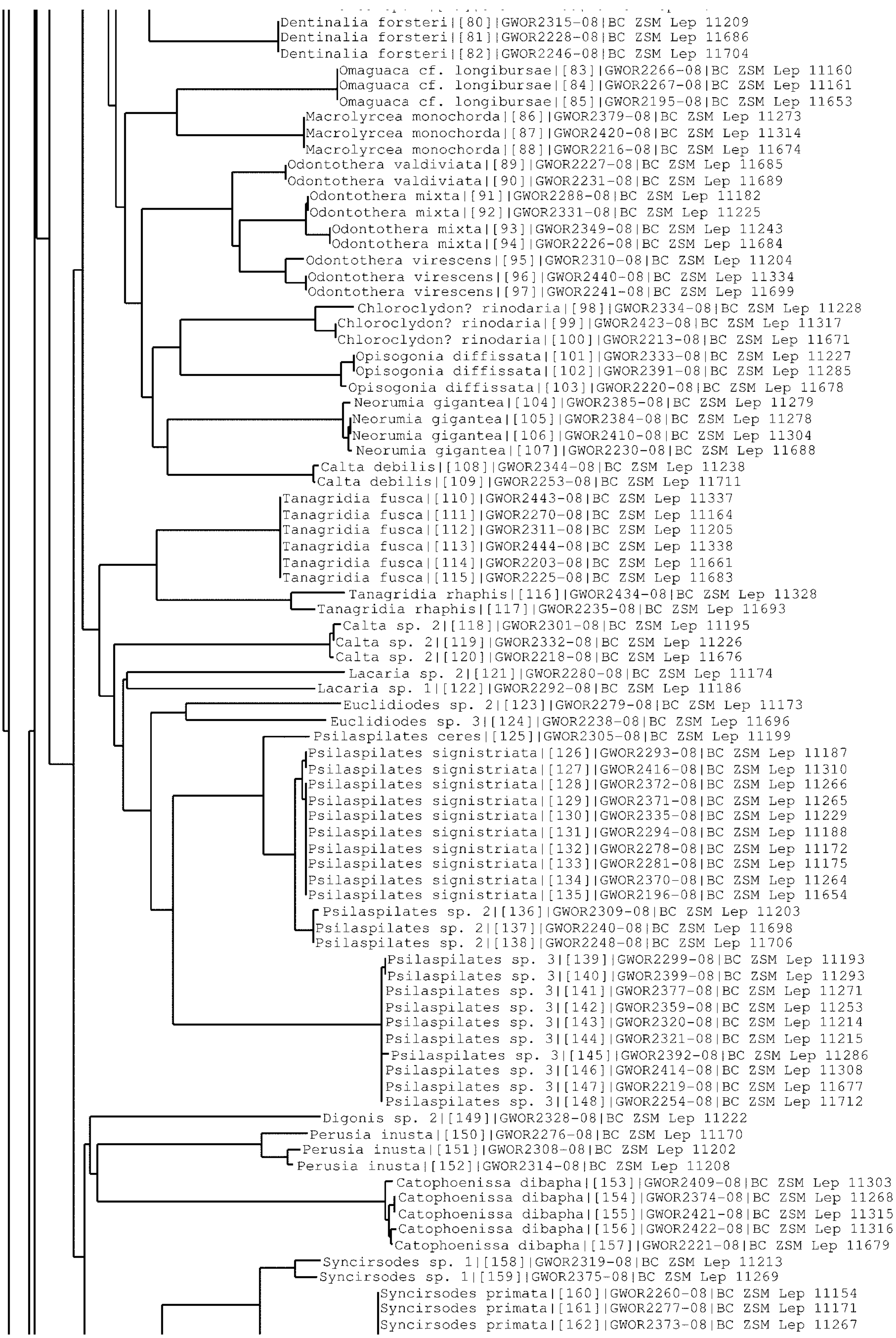

FIGURE 4b. Neighbor joining tree of Geometridae, collected at Huinay station, Chile from 4–14 January 2008; COI 5' barcoding fragment, 658 bp, Kimura 2 Parameter, from BOLD Data Systems (courtesy of Paul Hebert, CCDB Guelph, Canada) (continued).

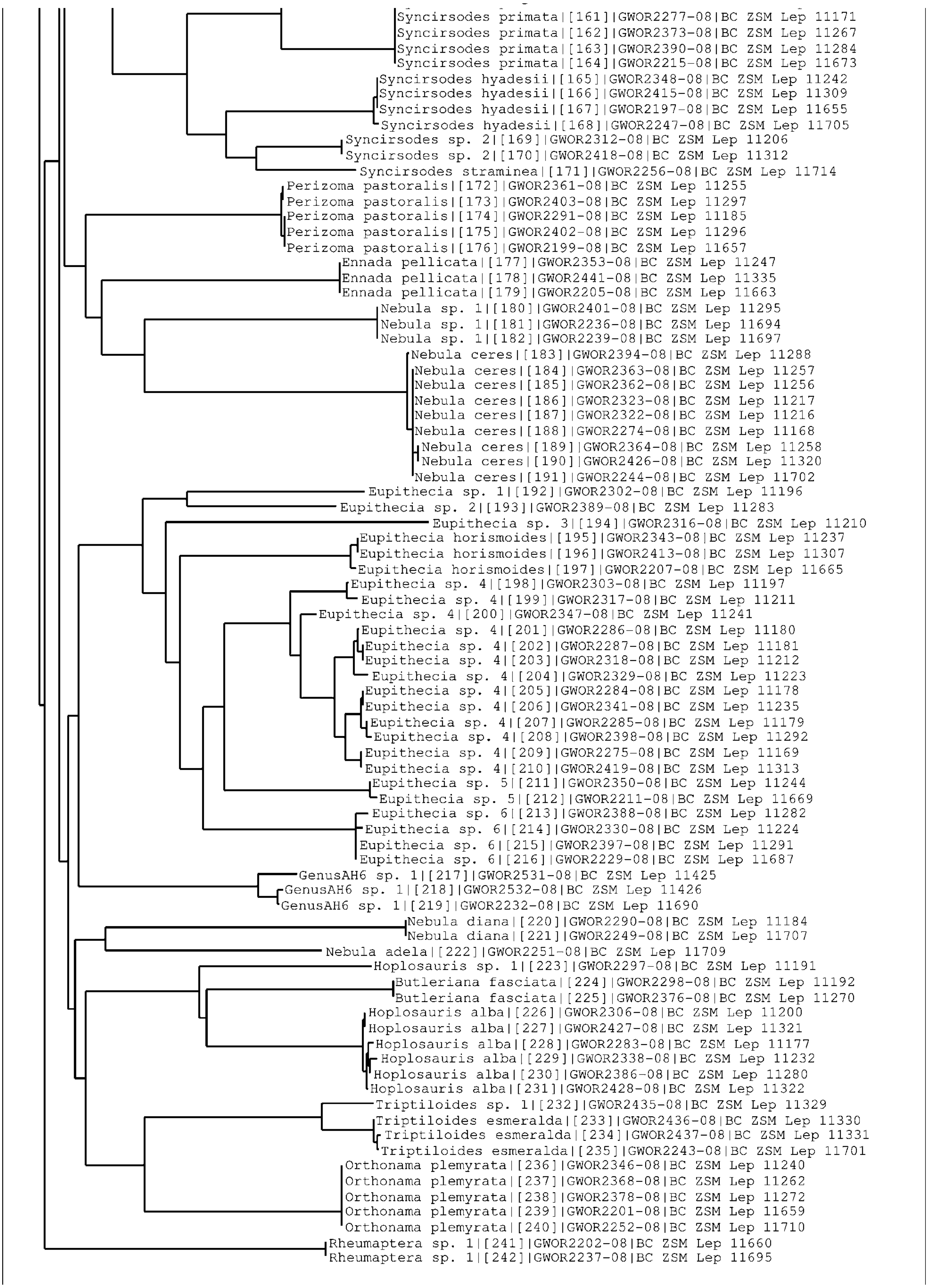

FIGURE 4c. Neighbor joining tree of Geometridae, collected at Huinay station, Chile from 4–14 January 2008; COI 5' barcoding fragment, 658 bp, Kimura 2 Parameter, from BOLD Data Systems (courtesy of Paul Hebert, CCDB Guelph, Canada).

[39–40] *“Euphyia”* sp. 1 *(*cf. *signata)*: Generic and tribal attribution requiring revision. Generic and tribal attribution requiring revision as not clustering together with Palearctic Euphyiini in COI NJ tree. Genetically different from the sister species [36–38]: minimum pairwise distance: 5.0% (mean intraspecific variation 0.2% and 0.1% resp.), *E. signata* usually being smaller, more reddish and with weaker pattern in the median area.

[41–46; 49–58; 180–191; 220–222] [genus *Nebula*]: Attribution to tribe Cidariini according to the Palearctic concept of genus *Nebula*. Generic assignment of the Chilean species to *Nebula* doubtful and urgently requiring revision though some species (e.g., *N. bellissima* [42–43]), in their COI data, reveal certain relationships with Palaearctic species of the genera *Nebula* and *Coenotephria*. Both COI data and multigene analysis (COI, EF1alpha, 28S) suggesting polyphyly of Chilean species currently assigned to *Nebula*.

[47–48] *Ennada flavaria* (Blanchard, 1852) (on fig. 4a as *'Larentia* sp. 1'): Both data referring to L3–4 larvae, beaten from fern (Pteridophyta). Nearest neighbour in COI analysis *Larentia irma*. Host-plant unusual for Larentiinae.

[59–64; 241–242] [genus *Rheumaptera*]: Molecular analysis (COI) suggesting relationships to “*Xanthorhoe*” *chiloena* (possibly to be transferred to *Rheumaptera*) such as to Palaearctic species of the genus *Rheumaptera* [59–64], except for [241–242], see below.

[Ennominae]

[65–70] [genus *Leucolithodes*]: Possibly rather a boarmiine than a nacophorine genus (the latter suggested by Pitkin 2002), cf. the New Zealandian boarmiine genus *Pseudocoremia*, which is similar in habitus.

[71–88; 98–103; 153–157] [Nacophorini]: Chilean “nacophorines”, according to the concept of Pitkin (2002) not well clustering together in the COI NJ tree and in the multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown). Deep phylogeny relationships and tribal systematics requiring more extensive studies with an integrative approach of morphological and molecular techniques.

[75–79] *Talca* sp. 1: COI NJ tree with shallow split of 1.4% maximum divergence between both branches. However, without corresponding differential feature in habitus.

[83–85] *Euangerona valdiviae* Butler, 1882 (on fig. 4b as '*Omaguaca cf. longibursae*'): Larvae of different development stages beaten from *Nothofagus dombeyi*. Nearest neighbour in COI analysis is *Macrolyrcea monochorda* with a comparatively low sequence divergence (6.3%). Larval morphology well corresponding to that of *Euangerona longibursae* Parra, 1984 (central Chile), feeding on *Nothofagus obliqua*. However, coloration of larva quite different.

[89–109; 110–148] [Lithinini]: Chilean “lithinines”, according to the concept of Pitkin (2002), clustering together in two clades of the COI NJ tree. In the multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown), however, *Psilaspilates*, *Tanagridia* and *Caltha* sp. 2 grouped together with Tasmanian Nacophorini. Deep phylogeny relationships and tribal systematics requiring more extensive studies with an integrative approach of morphological and molecular techniques.

[89–97] [genus *Odontothera*]: In Pitkin (2002) as Lithinini genus. Both COI NJ tree and multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown) showing a clade including *Chloroclydon*,*“Opisogonia”*, *Neorumia*, *Macrolyrcea*, *Euangerona* and *Odontothera*. Therefore the hypothesis should be tested, that *Odontothera* may be a Nacophorini genus. Hostplants are unknown for genus *Odontothera.*

[91–94] *Odontothera mixta* (Butler, 1882): Molecular analysis (COI) revealing specific difference (sequence divergence 3.3%; mean intraspecific variation 0.4% and 0% resp.) from *Odontothera valdiviata,* but some specimens [91] similar to the latter.

[98–100] *Chloroclydon ? rinodaria* (Felder & Rogenhofer, 1875). In Scoble (1999) as larentiine moth. In Pitkin (2002) not included. In the COI NJ tree and multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown) grouped with *“Opisogonia”*, *Neorumia*, *Macrolyrcea*, *Euangerona* and *Odontothera*. Therefore, preliminarily, attributed to Nacophorini sensu Pitkin (2002).

[101–103] *Opisogonia ? diffissata* Felder & Rogenhofer, 1875: According to Pitkin (2002) the generic combination with *Opisogonia* is incorrect and the species may be attributed to Nacophorini. In the COI NJ tree and multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown) grouped with *Chloroclydon*, *Neorumia, Macrolyrcea, Euangerona* and *Odontothera*.

[104–107] *Neorumia gigantea* Bartlett-Calvert, 1883 (Fig. 3): According to Pitkin (2002) possibly a nacophorine or lithinine moth, the former supported in the COI NJ tree by the position in the clade together with *Chloroclydon*, *"Opisogonia"*, *Macrolyrcea, Euangerona* and *Odontothera*.

[108–109] *Calta debilis* (Butler, 1882), **comb. n.**: Morphology (current research of junior author) and position in COI NJ tree suggesting a separate genus from *Odontothera* where it was currently placed (Pitkin 2002). Male antennae lamellate, anellus process long, thin, with a tuft of apical setae as long as length of anellus. Position in Lithinini not supported by position in COI NJ tree, where it groups together with some putative nacophorine genera such as *Chloroclydon*, *"Opisogonia"*, and *Neorumia*. COI data from other seasons (not shown in the tree) suggesting two different species, possibly.

[110–117] [genus *Tanagridia*]: In Pitkin (2002) as Lithinini genus, but in the multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown) grouped together with the genera *Psilaspilates, Euclidiodes, Lacaria* and the species "*Calta*" sp. 2 and well clustering to a large set of Tasmanian Nacophorini genera. Tribal systematics and position of *Tanagridia* requiring more extensive studies with an integrative approach of morphological and molecular techniques.

[116–117] *Tanagridia rhaphis* (Rindge, 1986): COI data (barcoding fragment) suggesting two different species, possibly (sequence divergence 1.9%).

[118–120] *”Calta”* sp. 2: Generic combination very tentatively. See remarks to [110–117]. *”Calta”* sp. 2 groups especially close to the Tasmanian *Capusa senilis* with which it shares also the narrow forewings.

[121–122] [genus *Lacaria*]: See remarks to [110–117].

[123–124] [genus *Euclidiodes*]: See remarks to [110–117].

[125–148] [genus *Psilaspilates*]: See remarks to [110–117]. In the multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown) interestingly at a close position to the Australian genus *Amelora* (Nacophorini), with which it shares a close similarity in habitus.

[125] *Psilaspilates ceres* (Butler, 1882): Sequence divergence from *P. signistriata* 1.7%, intraspecific variation of the latter 0.06%. Correlated with differences in habitus e.g., darker ground colour, transverse fascia almost absent.

[136–138] *Psilaspilates* sp. 2 (cf. *signistriata*): COI data showing a shallow split to *P. signistriata*. Though being small (0.6%) the sequence divergence is correlated with particular wing pattern. Mean infraspecific variation is 0.06% and 0.1% respectively.

[153–157] [genus *Catophoenissa*]: see remarks to Nacophorini [71–88; 98–103; 153–157]. In the multigene analysis (COI, EF1alpha, 28S; 1914 bp; not shown) *Catophoenissa* comes out as sister genus of *Hasodima*, however.

[158–159] *Syncirsodes* sp. 1 (cf. *primata*): COI data suggesting clear specific difference from *S. primata* and the other three members of the genus, collected at Huinay. Variable in habitus.

[160–164] *Syncirsodes primata* (Walker, 1862): One of the records, BC 11154, referring to a L4 larva, beaten from *Luma apiculata* (Myrtaceae) and identified through DNA barcoding.

[165–168] *Syncirsodes hyadesii* (Mabille, 1882): COI data suggesting clear specific difference from the other four members of the genus, collected at Huinay. Variable in habitus.

[169–170] *Syncirsodes* sp. 2: COI data suggesting clear specific difference from *S. primata* and the other three members of the genus, collected at Huinay. Variable in habitus.

[171] *Syncirsodes straminea* (Butler, 1882): COI data suggesting clear specific difference from *S. primata* and the other three members of the genus, collected at Huinay. Variable in habitus

[Larentiinae 2]

[172–176] [Perizomini]: Attribution to tribe according to the Palearctic concept (Mironov 2003). For doubts about generic assignment see under *P. pastoralis*. Probably the species is related to *Ennada* and certain "*Nebula*" species e.g., *N. ceres* (Larentiini?, see below) and does not belong to Perizomini. Multigene analysis

(COI, EF1alpha, 28S) shows these three branches (*Perizoma pastoralis*, *Ennada* and *Nebula ceres*-group) united.

[172–176] *Perizoma pastoralis* (Butler, 1882)

[177–179] *Ennada pellicata* (Felder & Rogenhofer, 1875): The position in the tribe Larentiini is well supported by habitus and genitalia structure. See remarks to [172–176]. The status of both forms with and without the projection of medial area towards the termen as infrasubspecific, infrapopulational forms is confirmed by COI data.

[180–191] "*Nebula*" sp. 1 and "*Nebula*" *ceres* (Butler, 1882): See remarks to [172–176].

[198–210] *Eupithecia* sp. 4: Difficult group with variable habitus, probably including *Eupithecia spurcata* (Warren, 1904). COI data revealing a heterogenous pattern of different haplotypes, mean "intra"specific variation 1.7%, maximum pairwise distance 3.4%. Probably corresponding to several different species.

[217–219] *Genus* AH6 sp. 1: Possibly an eupitheciine genus, as tentatively suggested by position in the NJ tree. In the multigene analysis (COI, EF1alpha, 28S) however rather grouping with *Perizoma pastoralis* than with Eupitheciini.

[220–222] "*Nebula*" *diana* (Butler, 1882) and "*Nebula*" *adela* (Butler, 1893): For polyphyly of the genus "*Nebula*" and doubtful generic combination(s) see remarks [41–46; 49–58; 180–191; 220–222].

[223; 226–231]: see remarks to genus *Hoplosauris* [30–33; 223; 226–231]

[232] *Triptiloides* sp. 1 (cf. *esmeralda*): Molecular analysis (COI) suggesting species diversity from *T. esmeralda* [233–235]: minimum pairwise distance: 2.3% (mean intraspecific variation of the latter 0.2%).

[236–240] *Orthonama plemyrata* (Felder & Rogenhofer, 1875): In Scoble (1999) as synonym of *Orthonama obstipata* (Fabricius, 1794). Separated from Old world sister species in Hausmann & Hebert (2008).

[241–242] *Rheumaptera* sp. 1 (cf. "*Larentia*" *irma*): see remarks to genus *Rheumaptera* [59–64; 241–242]. Tribal and generic relationships awaiting revision. Molecular analysis (COI) not revealing close relationship to Palaearctic species of the genus *Rheumaptera*.

[#] *Hoplosauris valeria* Butler, 1893: specimen not yet barcoded; unnamed genus according to Scoble (1999), but assignment to *Hoplosauris* probable.

Discussion

The area of Huinay in northern Patagonia proved to be a remarkable hotspot of geometrid biodiversity. For comparison, at Aysén (central Patagonia) the junior author collected about 80 species of Geometridae in two weeks (October). At Concepción the total for Geometridae is approximately 130 species. This area is another transitional zone between faunistic elements of the sclerophyllous and temperate forests of central and southern Chile. By extrapolation, since the Huinay assessment so far is incomplete as to different seasons, habitats and altitudinal distribution, the total geometrid species number at Huinay could be expected to be perhaps 180 species (i.e., approximately 60% of the known Chilean fauna). Given the fact that geometrids are valuable bioindicators for diversity patterns (see introduction), this part of northern Patagonia may generally be a hotspot for arthropods resp. primary consumers.

Southern temperate forests exhibit an extraordinary species diversity as a product of (1) mixture between diverse biotas originating from different biogeographic zones and of (2) position between central Chile with seasonal climate and southern Chile with non-seasonal climate. For the flora, the highest species richness is recorded between 40° and 43° S, where the forest is seen as the product of the intersection of two major sources of biota, with the retention of many temperate genera and with tropical relict flora present (Arroyo *et al*. 1996). Seasonal rain forest seems not to have suffered strongly from glaciation in the Pleistocene, where the species have persisted in relict populations in ice-free areas (Villagrán *et al*. 1996). Thus, the high species richness of geometrids in Huinay can be interpreted as the product of multiple historical influences of these biotic (e.g., floral) and abiotic (e.g., climatological) parameters. Today there is a complete overlap between

Valdivian fauna elements (e.g., *Catophoenissa*, *Nebula*, *Orthonama*) which find their southern distribution limits here, and typical representatives of the Patagonian (Magellanian) fauna e.g., *Rheumaptera*, *Fueguina,* some species of *Euclidiodes* and *Hoplosauris* (e.g., *E. meridionalis*, *H. multivirgulata*, along with others), which are at their northern limit of distribution.

Studies in the tropical Andes have revealed outstanding levels of species richness in Geometridae and other families of Lepidoptera, qualifying these areas as a reservoir of biodiversity at global level (Brehm *et al*. 2005). Therefore, conservation of forests associated with the Andes is of vital importance, especially now that many of these forests are being destroyed at an alarming rate. At Huinay station, the undisturbed habitats are largely free of human influence (the site is not accessible by road) and this certainly plays a major role in offering ideal conditions for terrestrial animals.

The combination of morphological and molecular approaches helped in accelerating biodiversity assessments. Conflicts between morphospecies grouping and molecular species grouping were rare and usually pointed to undetected species variation or new, cryptic species. Such an integrated approach is especially relevant for faunas with insufficiently known taxonomy, with large elevated numbers of polymorphic and variable species (such as Chile), with many sexual dimorphic species, and for unambiguous identification of immature stages. Insect biodiversity of the southern regions of Chile is still poorly studied, but extended sampling will undoubtedly provide more concrete data on species richness in this area.

Acknowledgments

We thank the Huinay team, Reinhard and Soledad Fitzek, Günter (‘Fossi’) Forsterra, Vreni Häussermann, Josh Biro and Michelle Marcotte, for their valuable help in the assessment of Huinay Geometridae. Josh Biro and Gerald (‘Roddy’) Forley carried a heavy generator up to the camp at 800 m altitude through the arduous slopes of the wet rainforest, which was a dangerous and extremely challenging enterprise. Tilla Roy and Reinhard Fitzek collected at light for many weeks when the authors left the station. Roland Melzer and Roland Meyer from the ZSM performed additional collecting during their expeditions. Thomas Greifenstein (Pfaffenhofen, Germany) and Norbert Flauger (Valencia, Venezuela) accompanied the authors on the January 2008 expedition, and Greifenstein mounted most of the geometrids. Sonja Knölke (ZSM) made dissections and digital photographs of the genitalia. Satoshi Yamamoto (Kyoto, Japan) helped by some tree-reconstructions on the base of nDNA data. Jeremy D. Holloway (London, U.K.), John Dugdale (New Zealand), Peter McQuillan and Cathy Young (both Hobart, Tasmania) offered discussions of biogeographical patterns and phylogenetic relationships. Thomas Greifenstein and Günter Forsterra provided authorization for publishing Figs. 2 and 3 of this paper. Paul Hebert (CCDB, Guelph, Canada) provided competent, quick and gratis DNA barcoding. The German Research Foundation (Deutsche Forschungsgesellschaft; DFG) financed the expedition and the work with grant no. HA 1806/7-1. The Dirección de Investigación of the Universidad de Concepción financed the publication of this study. This is publication nr. 37 of Huinay Scientific Field Station.

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Appendix: Systematic Account of Huinay Geometridae

Continuously updated version of this list is at http://www.zsm.mwn.de/lep/huinay.htm

- Larentiinae
  - Xanthorhoini
  - *Orthonama plemyrata* (Felder & Rogenhofer, 1875)
  - *Ennada flavaria* (Blanchard, 1852)
  - Larentiini
  - *Ennada pellicata* (Felder & Rogenhofer, 1875)
  - Cidariini
  - *“Nebula” diana* (Butler, 1882)
  - *“Nebula” bellissima* (Butler, 1883)
  - *“Nebula” corticalis* (Butler, 1882)
  - *“Nebula” decipiens* (Butler, 1882)
  - *“Nebula” ceres* (Butler, 1882)
  - *“Nebula”* sp. 1
  - *“Nebula”* sp. 2 (*cf. diana*) (specimen not yet barcoded)
  - *“Nebula”* sp. 4 (*cf. emilia*)
  - *“Nebula” adela* (Butler, 1893)
  - *“Nebula”* sp. 5 (specimen not yet barcoded)
  - *“Nebula”* sp. 6
  - *“Nebula”* sp. 7 (specimen not yet barcoded)
  - “Euphyiini”
  - *“Euphyia” signata* (Butler, 1882)
  - *“Euphyia”* sp. 1 *(cf. signata)*
  - *“Euphyia”* sp. 2
  - Rheumapterini
  - *Rheumaptera* sp. 1 *(cf. "Larentia" irma)*
  - *Rheumaptera* sp. 2
  - *Rheumaptera* sp. 3 *(cf. exacta)*
  - *Rheumaptera fuegata* (Staudinger, 1899)
  - *Rheumaptera exacta* (Butler, 1882) (specimen not yet barcoded)
  - Trichopterygini
  - *“Hoplosauris”* sp. 1
  - *“Hoplosauris” alba* (Butler, 1882)
  - *“Hoplosauris”* sp. 3
  - *“Hoplosauris”* sp. 4
  - *“Hoplosauris”* sp. 5
  - *“Hoplosauris“ valeria* (Butler, 1893) (specimen not yet barcoded)
  - *Hoplosauris multivirgulata* (Mabille, 1885), comb. n.
  - *Butleriana fasciata* (Butler, 1882)
  - *Fueguina* sp. 1 *(cf. varians)*
  - *Triptiloides laeta* (Philippi, 1873)
  - *Triptiloides* sp. 2 *(cf. laeta)*

Triptiloides esmeralda (Bartlett-Calvert, 1883)
Triptiloides sp. 1 *(cf. esmeralda)*
Triptiloides sp. 2 *(cf. esmeralda)* (specimen not yet barcoded)
Triptila virescens (Philippi, 1873)
Triptila sp. 1 *(cf. virescens)*
Triptila sp. 2
Parapachrophylla sp. 1
Notholoba schausi (Warren, 1908)
Genus 5 sp. 1 *(cf. Lagnyopteryx?)*
Danielaparra fragmentata (Dognin, 1906), comb. n.
Synpelurga corralensis (Butler, 1882)
“Perizomini”
Perizoma pastoralis (Butler, 1882)
Eupitheciini
Eupithecia horismoides Rindge, 1987
Eupithecia sp. 1
Eupithecia sp. 2
Eupithecia sp. 3
Eupithecia sp. 4
Eupithecia sp. 5
Eupithecia sp. 6
Genus 6 sp. 1

Ennominae (tribal systematics according to Pitkin 2002)
Nacophorini
Catophoenissa dibapha (Felder & Rogenhofer, 1875)
Hasodima elegans Butler, 1882
Leucolithodes lecideata (Felder & Rogenhofer, 1875)
Leucolithodes paulina (Ureta, 1956)
Talca sp. 1
Dentinalia forsteri Heimlich, 1960
Euangerona valdiviae Butler, 1882
Macrolyrcea monochorda Prout, 1916
Neorumia gigantea Bartlett-Calvert, 1883
Opisogonia ? diffissata Felder & Rogenhofer, 1875
Chloroclydon ? rinodaria (Felder & Rogenhofer, 1875)
Lithinini
Psilaspilates signistriata (Butler, 1882)
Psilaspilates ceres (Butler, 1882)
Psilaspilates sp. 2 *(cf. signistriata)*
Psilaspilates sp. 3 *(cf. stygiana)*
Euclidiodes sp. 2
Euclidiodes sp. 3
Lacaria sp. 1
Lacaria sp. 2 *(cf. aracaunaria)*
Calta debilis (Butler, 1882)
“Calta” sp. 2
Odontothera valdiviata (Felder & Rogenhofer, 1875)
Odontothera mixta (Butler, 1882)
Odontothera virescens (Butler, 1882)
Tanagridia rhaphis (Rindge, 1986)
Tanagridia fusca Butler , 1882
Ourapterygini
Perusia inusta (Felder & Rogenhofer, 1875)

Digonis sp. 2 *(cf. cuprea)*
Uncertain position
Syncirsodes hyadesii (Mabille, 1882)
Syncirsodes primata (Walker, 1862)
Syncirsodes sp. 1 *(cf. primata)*
Syncirsodes sp. 2
Syncirsodes straminea (Butler, 1882)