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Autor: Germann, Christoph / Baur, Hannes

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Notes on the taxonomy and biology of *Dichotrachelus imhoffi*
Stierlin, 1857 (Coleoptera, Curculionidae) with the observation of a
length dimorphism of the aedeagus

CHRISTOPH GERMANN^{1,2*} & HANNES BAUR²

¹ Natur-Museum Luzern, Kasernenplatz 6, CH-6003 Lucerne

² Natural History Museum, Bern, Bernastrasse 15, CH-3005 Bern

* Corresponding author: Email: germann.christoph@gmail.com

A lectotype is designated for *Dichotrachelus seminudus* Tournier, 1879 and its name is synonymised with that of *D. imhoffi* Stierlin, 1857 (syn. n.). The first record of larvae of *D. imhoffi* and of their development in moss cushions (*Grimmia* sp.) on the Bernina Pass (Grisons, Switzerland) is presented. The examination of 50 males of *D. imhoffi* from its entire distribution range in Italy and Switzerland revealed a unique dimorphism in the length of the aedeagus.

Keywords: Cyclominae, taxonomy, new synonym, biology, genital morphology, length dimorphism.

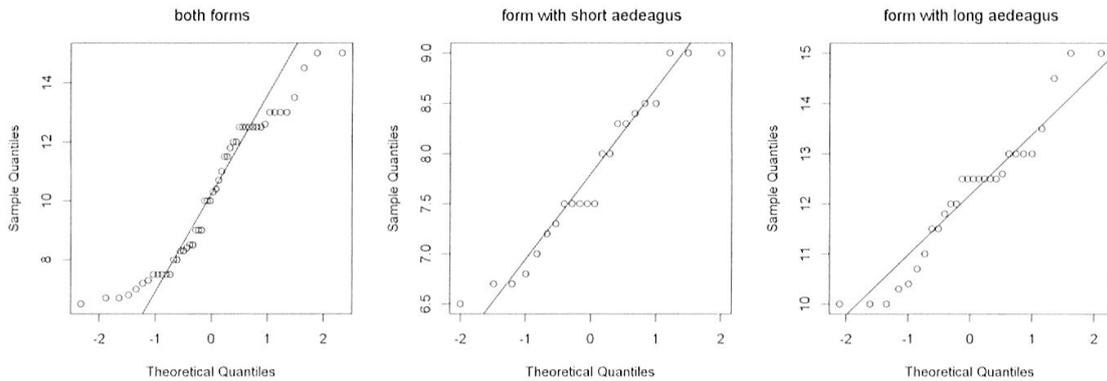
INTRODUCTION

The genus *Dichotrachelus* Stierlin, 1853 comprises 72 species and 13 subspecies in Europe and Northern Africa (Fauna Europaea 2010, Osella & Meregalli 2007, Germann 2009). The distribution area extends from the Transylvanian Alps to the Alps, the Tyrrhenian Isles, the whole of Italy and Sicily into Spain, Portugal, Morocco (Rif-Mountains, Jbel Tazzeka) and Algeria (Djurjura-Massiv). All species are restricted to mountainous regions at higher altitudes, with the exception of *Dichotrachelus rossettoi* Meregalli & Osella, 1975 (found at 500 m a.s.l.) and *D. deferreri* Meregalli & Alonso-Zarazaga, 1987 (50 m a.s.l.). Most species are restricted to small – presumably – refuge areas, and almost half of the species were described only after revisions of the genus by Osella (1970) and Meregalli (1987).

Little is known about the biology of the genus. Meregalli (1980) treated this aspect in detail and summarised the available information about adult and larval hostplants (Bryophyta, *Saxifraga* spp., probably also Crassulaceae and Caryophyllaceae), where larvae have not been reared from plants other than mosses though. Subsequent studies of the biology of several species, such as *D. dellabeffai* Meregalli, 1982 (Meregalli 1982), *D. rudeni* Stierlin, 1853 (Germann 2004), *D. venturiensis* Hustache, 1929 (Germann 2005), *D. koziorowiczi* Desbrochers, 1871 and *D. sardous* Solari & Solari, 1903 (Germann, unpublished data) as well as *D. imhoffi* Stierlin, 1857 as reported on here, have demonstrated that larvae exclusively breed in Bryophyta, spanning the genera *Bryum*, *Ceratodon*, *Dicranoweisia*, *Grimmia*, *Oligotrichum*, *Polytrichum*, *Racomitrium*, *Tortella* and *Tortula*. Often several species and/or genera of Bryophyta form conglomerates. The larvae of *Dichotrachelus* live exclusively in cavities excavated in these mostly very compact moss cushions (Germann 2004). As mosses are easy to cultivate, the rearing of *Dicho-*

Quantile-quantile plots of aedeagus length and body length for *D. imhoffi*

A: aedeagus length



B: body length

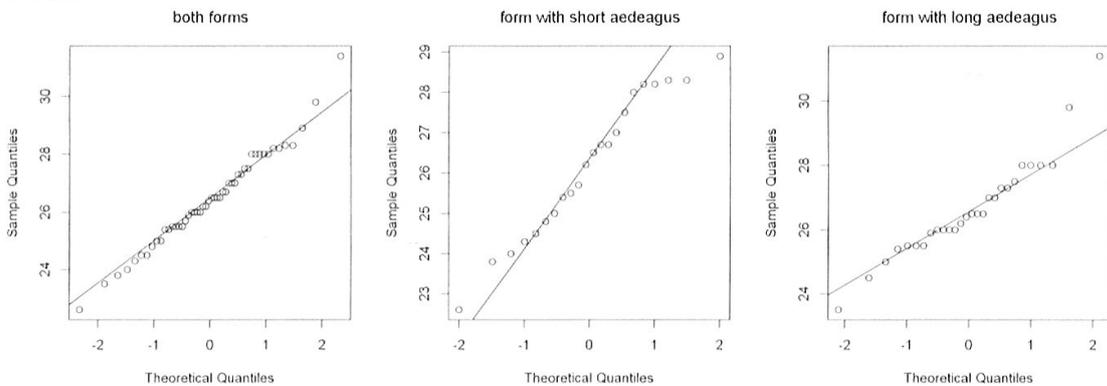


Fig. 1. Quantile-quantile plots of body and aedeagus length of *Dichotrachelus imhoffi*. The plots make it clear that the data significantly depart from a normal distribution whether the data are considered in their entirety or split according to forms. Note also the presence of multiple tied observations.

trachelus larvae is rather unproblematic, despite their specialised high-altitude habitats.

In this paper we report the first record of the larvae of *D. imhoffi* feeding in cushions of the moss genus *Grimmia* and their partial rearing in captivity. We also synonymise the names *seminudus* Tournier, 1879 and *imhoffi* Stierlin, 1857 (syn. n.) and report a marked intraspecific dimorphism in the length of the aedeagus of the species at both its type locality (Bernina Pass) and throughout its entire range.

MATERIALS AND METHODS

Larvae were bred in moss cushions kept humid. Preimaginal stages were preserved in 70 % ethanol. Pictures were taken with a 5-megapixel digital camera (Leica DFC 420) mounted on a binocular microscope (Leica MZ16), and image stacks were combined using the Auto-Montage Version 8 software (Imagic Image Access). The aedeagi (aedeagus = penis of male insects) of the specimens examined were macerated in 10 % KOH and mounted dry on the cards beside the corresponding specimens. Dry-mounted aedeagi and bodies of 50 males of *D. imhoffi* were measured indirectly, on unprocessed pictures taken with the above-mentioned

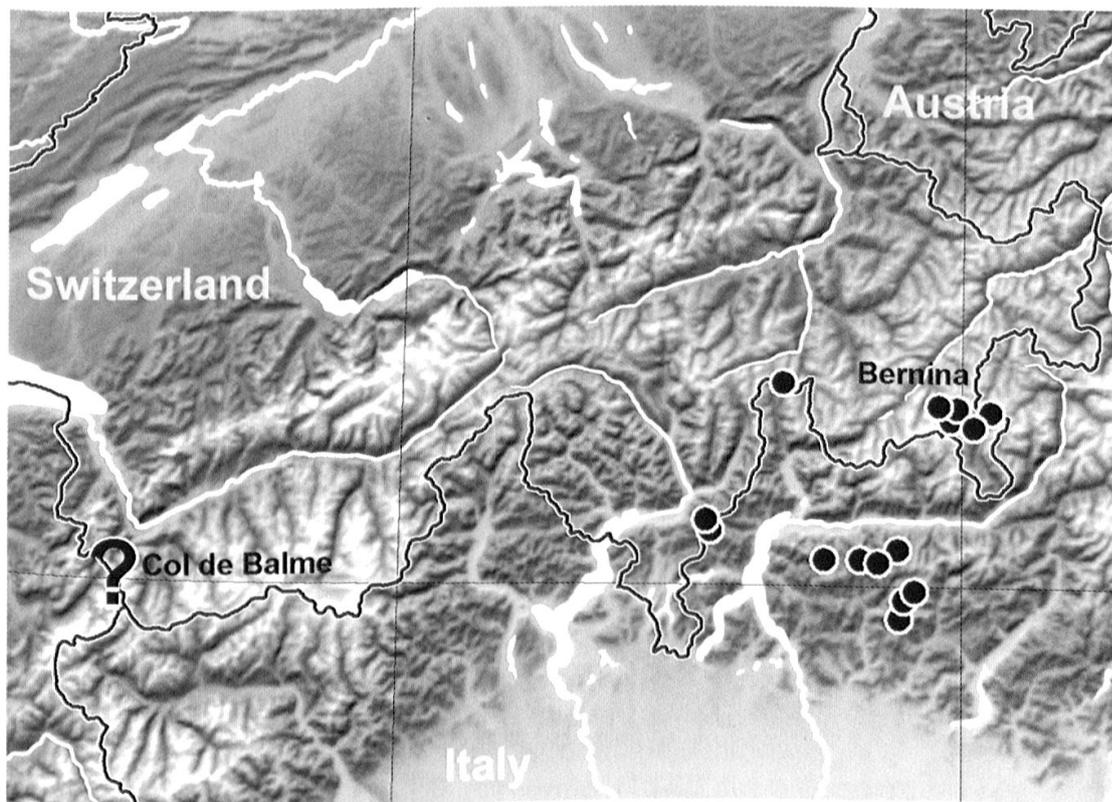


Fig. 2. Map showing distribution records of *Dichotrachelus imhoffi* specimens used in the study.

camera and viewed with Photoshop version 10.0.1 (Adobe Systems Incorporated) using the ruler option (cm) at zoom level 33.3 %. Body length was measured in dorsal view from the front margin of the pronotum to the apex of the elytra. The apical, spoon-shaped part of the aedeagus was measured in lateral position (Fig. 6E) from its basis at the kink in the aedeagus straight to the apex (as in Fig. 6E). Label data of type specimens are cited verbatim, a double slash (//) denoting different labels on the pin of a specimen. Statistical analyses were performed and graphs drawn with the R statistical software 2009 (R Development Core Team 2009). The data contain multiple tied observations and deviate from normality also in their distribution (see quantile-quantile plots, Fig. 1), hence only non-parametric methods (for cases of related samples or repeated measurements) were used for the statistical analysis. To account for the ties (tied data points) in the data, a Wilcoxon rank-sum test using the function «wilcox.exact» from the package «exactRankTests» was performed (R Development Core Team 2009).

The collections housing the specimens examined are abbreviated as follows:

DEI	Deutsches Entomologisches Institut, Müncheberg
MHNG	Muséum d'histoire naturelle de Genève
NMBA	Naturhistorisches Museum Basel
NMBE	Naturhistorisches Museum Bern
TLMF	Tiroler Landesmuseum Ferdinandeum, Innsbruck
cCG	Sammlung Christoph Germann, Thun

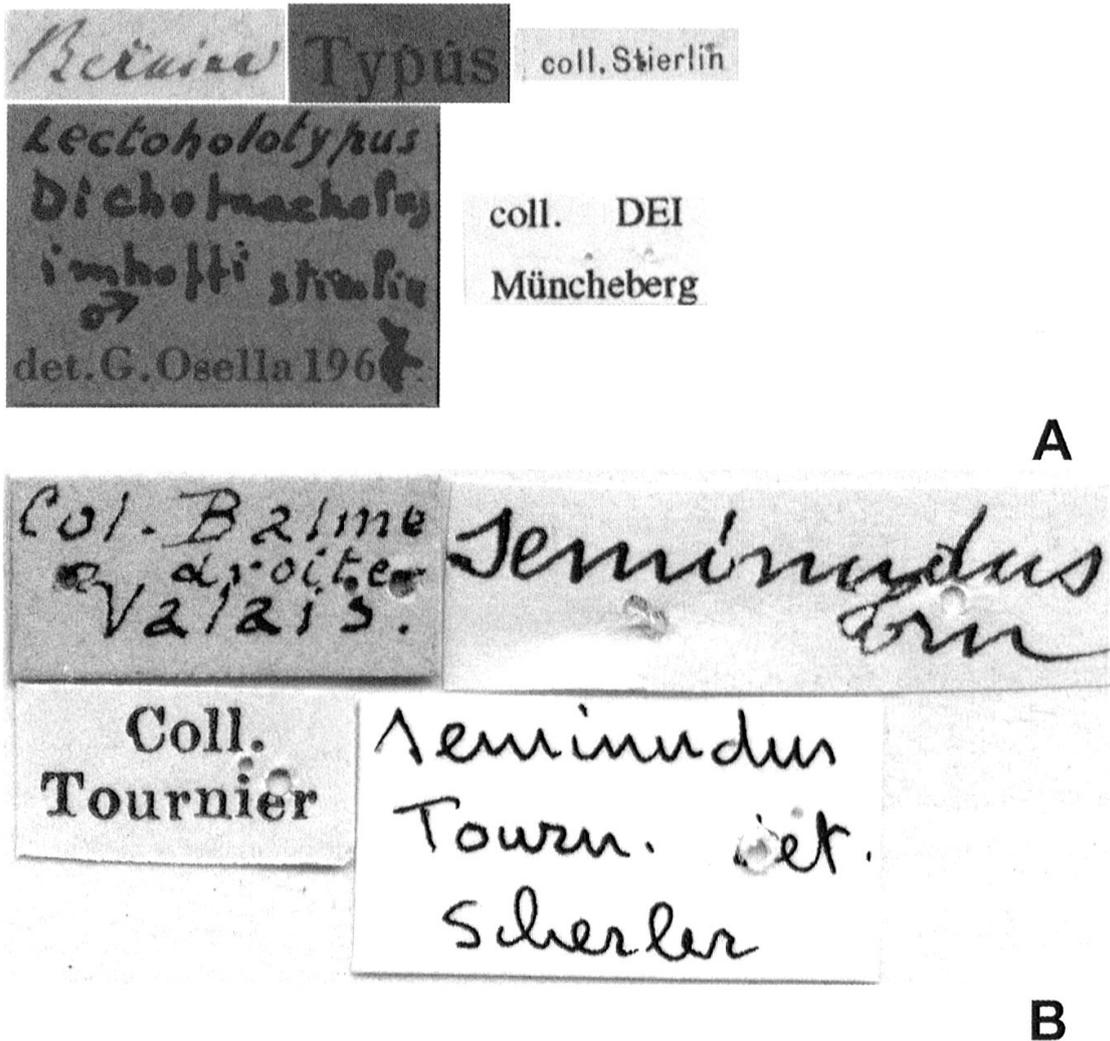


Fig. 3. Lectotype labels of *imhoffi* Stierlin, 1857 (A) and *seminudus* Tournier, 1879 (B).

RESULTS

Taxonomy

As mentioned by Germann (2009), the status of some species of *Dichotrachelus* is problematic in that they are known only from unique type specimens. One such species is *D. seminudus* Tournier, 1879, of which only one additional record (in the R. Oberthür collection) was supposed to exist (Hoffmann 1954, Osella 1970). Our examination of its type specimen, housed in the MHNG, revealed that it is a male of *D. imhoffi*, which occurs in Switzerland and Italy from Val Viola and the Bernina massif in the north-east to the Orobian and Bergamask Alps in the south and the Alpi Mesolcine in the west (Fig. 2). The distinctive shape of the aedeagus (Fig. 6C), and the comparison with the lectotype specimen of *D. imhoffi* led us to this conclusion. A lectotype was designated for *D. imhoffi* by Osella (1967). The synonymy of *D. imhoffi* is therefore as follows:

Dichotrachelus imhoffi Stierlin

Dichotrachelus imhoffi Stierlin, 1857 (Stierlin 1857: 63–64).

Dichotrachelus seminudus Tournier, 1879 (Tournier 1879: 115), lapsus.

Dichotrachelus seminudus Tournier, 1879 (Tournier 1879: 118–119), syn. n.

Dichotrachelus concavirostris Stierlin, 1898 (Stierlin 1898: 270), nomen nudum (Osella 1970: 473).

Dichotrachelus insubricus Barajon, 1946 (Barajon 1946: 118; 124), syn. (Osella 1967: 383).

Material examined. Types: *D. imhoffi*: lectotype male (labels Fig. 3A) «Bernina [in Stierlin's hand] // coll. Stierlin // Typus // coll. DEI Müncheberg // Lectoholotypus [sic!] *Dichotrachelus imhoffi* Stierlin male det. G. Osella, 1967 // vid. C. Germann 2010» (DEI); paralectotype female «Bernina [in Stierlin's hand] // coll. Stierlin // Typus // *D. Imhoffi* Stierl. [in Stierlin's hand] Lectoparatypus [sic!] *Dichotrachelus imhoffi* Stierlin female det. G. Osella, 1967 coll. DEI Müncheberg // vid. C. Germann 2010» (DEI); *D. seminudus*: 1 male (labels Fig. 3B) «Col. Balme a droite Valais. [in Tournier's hand] // Coll. Tournier // seminudus Trn. [unknown handwriting] // seminudus Tourn. dét. Scherler // Lectotype *Dichotrachelus seminudus* Tournier, 1879 des. C. Germann 2010 // *Dichotrachelus imhoffi* Stierlin, 1857 (= *D. seminudus* Tournier, 1879) det. C. Germann 2010» (MHNG, coll. G. Toumayeff). Other specimens: see records in Appendix 1.

Notes. The claw segment of the left hind leg and the right fore tarsus of the lectotype of *D. imhoffi* are missing. Tournier (1879) did not mention any type specimens in his description of *D. seminudus*, but the label data of the specimen in the Toumayeff collection agree completely with his description. We therefore here designate this specimen as the lectotype of *D. seminudus*, in agreement with Recommendation 73F of the ICZN (2000). As there is a considerable distance between the type localities of *D. seminudus* (Col de Balme on the Swiss-French border) and *imhoffi* (Bernina) and no records are known from the area between them, it is very likely that the specimen on which Tournier based his description of *D. seminudus* was mislabelled. Support for this assumption is provided by a specimen of *D. imhoffi* from Bernina in the MHNG, which is labelled by Tournier and mounted in a similar way on a card as the lectotype of *D. seminudus*. Furthermore, mislabelled specimens are well known from Tournier (e.g. C. Besuchet, pers. comm. 2005, and Caldera 1995). Doubts about the status of *D. seminudus* have already been expressed before, Hoffmann (1954: 557) suggesting that it could be a geographical race of *D. imhoffi* («Cette espèce n'est probablement qu'une race géographique de *imhoffi* ...»), Germann (2009) treating it as «problematic» and Germann (2010) listing it as a probable synonym of *D. imhoffi*. Problematic remains the unique record of a supposed *D. seminudus* from Mt. Buet in the R. Oberthür collection, as reported by Hoffmann (1954). Despite a thorough search in the Museum A. König, Bonn, where a major part of the Oberthür collection is housed, no corresponding specimen could be located (K. Ulmen, pers. comm. 2005).

Biology

On 8 November 2005 an excursion was conducted in the Val dal Cambrena (Fig. 5), west of the Bernina Pass (Grisons), with the aim of finding larvae of *D. imhoffi*. Compact moss cushions of the genus *Grimmia* growing on stones and on



Fig. 4. Lectotype male of *seminudus* Tournier, 1879, dorsal habitus.

rocks protruding from the snow layer (300–500 mm deep) were examined. Three larvae of *D. imhoffi* were found, one in the first instar and the others in the second. The larvae were collected together with their moss cushions and reared in these cushions at home at room temperature. On 15 November two larvae had reached the third instar and the third had pupated. Another four larvae were collected at the same locality on 19 August 2007, one in the first instar and three in the third, together with three pupae and a freshly emerged imago.

With this discovery of larvae, pupae and a teneral imago and the partial rearing of larvae in moss, it is established that *D. imhoffi* also develops in mosses, like other species of the genus. Nothing was hitherto known about the biology of *D. imhoffi*, and Meregalli (1980) hypothesized that larger species of *Dichotrachelus* may rather develop on/in *Saxifraga* (Saxifragaceae), *Sempervivum* (Crassulaceae) or Caryophyllaceae. However, Meregalli has in the meantime also collected larvae of *D. imhoffi* from moss cushions (pers. comm., 2009). The discovery of different larval instars in autumn and winter also provides first information about the life history of the species. The occurrence of first-instar larvae in August and November, together with a teneral imago in August, suggests that the species may overwinter in the adult but perhaps also in the larval stage. This may indicate considerable plasticity of the life cycle and all developmental stages, possibly an important adaptation to the harsh alpine climate to which the species is exposed.



Fig. 5. Habitat of *Dichotrachelus imhoffi* in the Val dal Cambrena at 2400 m a.s.l. (Switzerland, Grisons), where larvae were found in moss cushions (photo: C. Germann).

Genital dimorphism

Huber (2003) recently raised the question of the constancy of genital structure as a species-specific trait. Evidence for bi- or polymorphic genital development is extremely scarce. In Coleoptera, to the authors' knowledge, not a single case of such a striking dimorphism as presented here has been reported.

Among six males of *D. imhoffi* collected under stones in the Val dal Cambrena on 24 August 2001, two on dissection showed an aedeagus considerably longer than in the others, even though the specimens were otherwise identical. We consequently examined 50 specimens from four geographically isolated populations of *D. imhoffi* (Bergamask Alps, Passo dello Spluga, Bernina area and Ticino canton) spanning the known distribution range of the species. The results (Tab. 1) confirm the occurrence of two distinct aedeagus sizes (Fig. 7), a shorter one (form I, Fig. 6A) and a longer one (form II, Figs. 6B–D). The sizes of these two forms do not deviate significantly in relation to body size, with minimal differences in the respective medians (Wilcoxon rank-sum test: $W = 280.5$, $p = 0.5969$; see Fig. 8 and Table 1). No intermediate sizes were found. The ratios of these two forms in the four populations are as follows: Bergamask Alps – I: 47.4 % / II: 52.6 % ($N = 19$); Bernina area – I: 36.4 % / II: 63.6 % ($N = 22$); Passo del Spluga – I and II each 50 % ($N = 2$); Ticino canton – I: 57.1 % / II: 42.9 % ($N = 7$). The possibility of these discrete aedeagus sizes reflecting sympatric, cryptic species can be dismissed, as

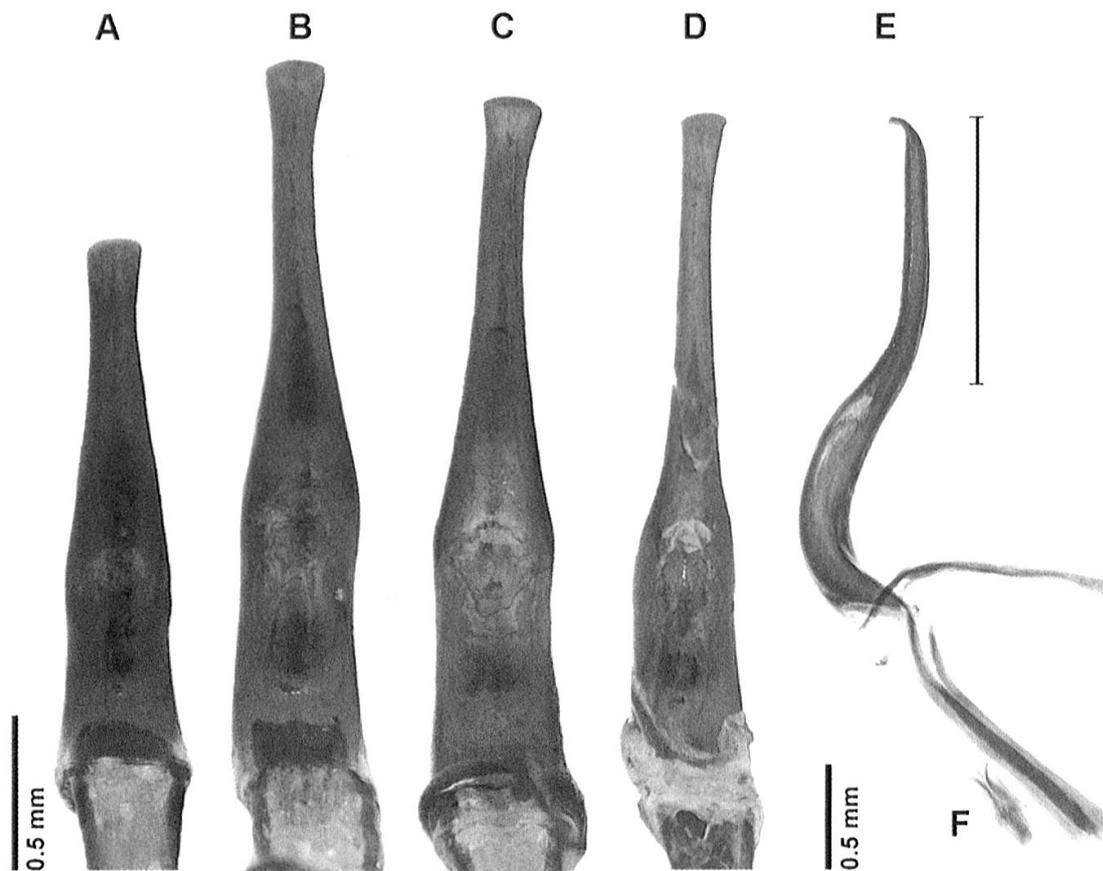


Fig. 6. Aedeagi of *Dichotrachelus imhoffi*, showing short form I (A) and long form II (B–E). A and B – Bernina (type locality of *D. imhoffi*); C – Col de Balme (lectotype of *D. seminudus*); D – Monte Gazzirolo (apical part partly broken); E – lateral view of C showing armature of internal sac; line indicating apical part as measured; F – internal sac.

Table 1. Range, lower and upper quartile and median for sizes of apical part of aedeagus and body length for short (N=22) and long (N=28) aedeagus forms; note that units used in measurements of aedeagi and body lengths are different.

character	form	minimum	lower quartile	median	upper quartile	maximum
aedeagus length	short	6.5	7.225	7.5	8.375	9
aedeagus length	long	10	11.375	12.5	13	15
body length	short	22.6	24.85	26.35	27.875	28.9
body length	long	23.5	25.8	26.45	27.35	31.4

characters of the external morphology, female genital organs (spermatheca, 8th sternite, ovipositor) as well as the internal sac (Fig. 6G) of the aedeagus are identical (data not shown) – although this should be ideally corroborated with molecular data. All studied types of the species (*D. imhoffi* and *D. seminudus*) have aedeagi of form II, and while the type of *D. insubricus* was not examined in this regard, the illustration of its aedeagus by Barajon (1946, Figure 9) suggests that it also represents form II.

From an evolutionary point of view, the presence of a length dimorphism of the aedeagus is remarkable. As this dimorphism occurs throughout the whole distribution area of the species known so far, it can be postulated that this dimorphism is highly conserved in the genome of all populations under investigation, as both forms obviously coexist. The coexistence of two forms may be either explained by two specific – equally successful – mating strategies, or by the fact that the trait simply might not be under any selective pressure, and – purely hypothetical – a sort of epistatic threshold size regulation may be the cause for the two well-separated forms. However, just to toy with the idea, within evolutionary timescales, the present case could lead to a sympatric speciation event, mainly driven by sexual selection.

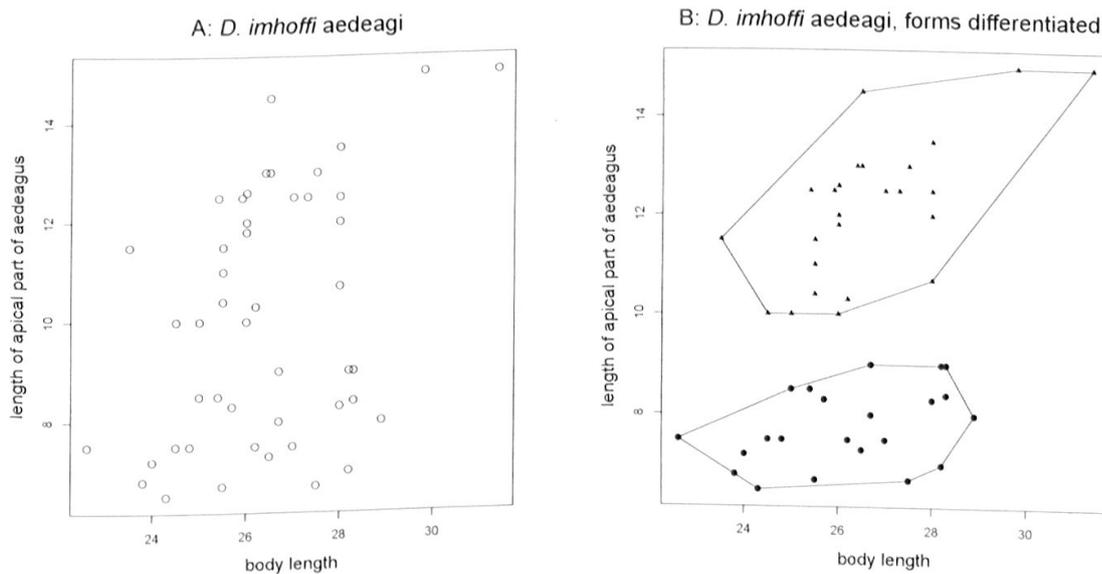


Fig. 7. Undifferentiated (left) and differentiated (right) scatterplots of length of aedeagal apex in relation to body size.

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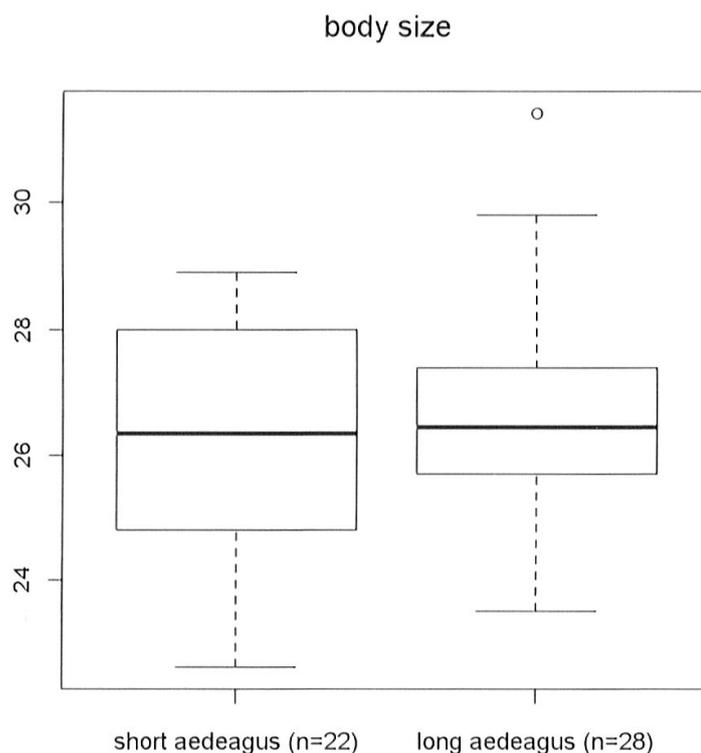


Fig. 8. Boxplot of short and long aedeagal forms in relation to body size, showing almost completely overlapping size ranges (difference in medians not significant; $W = 280.5$, $p = 0.5969$ in Wilcoxon rank-sum test).

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Appendix 1. Collecting data of males of *Dichotrachelus imhoffi* used for measurements of aedeagal and body size (Nr. = sample number (type specimens indicated by asterisk); locality stating country, canton/district, place (uncertain or doubtful ones in brackets); coordinates in either Swiss (NYYY/EXXX) or international convention; altitude in m a.s.l.; depositories abbreviated as in Material and Methods).

Nr.	Country / region	Locality	Coordinates	Date	Collector	Depository	Alt.	
29	CH	Grisons	Bernina	798/143	- Kraatz	DEI	-	
30	CH	Grisons	Bernina	798/143	- Kraatz	DEI	-	
33*	CH	Grisons	Bernina	798/143	- Stierlin	DEI	-	
48	CH	Grisons	Bernina	798/143	- -	NMBA	-	
49	CH	Grisons	Bernina	798/143	- Seiler	NMBA	-	
34	CH	Grisons	Bernina	798/143	- Tournier	MHNG	-	
17	CH	Grisons	Passo dello Spluga	745/152	2.7.2008	Germann	cCG	2100
6	CH	Grisons	Val d' Arlas	796/144	31.7.1980	Scherler	NMBE	-
15	CH	Grisons	Val dal Cambrena	797/142	25.8.2005	Germann	cCG	2400
16	CH	Grisons	Val dal Cambrena	797/142	25.8.2005	Germann	cCG	2400
18	CH	Grisons	Val dal Cambrena	797/142	25.8.2005	Germann	cCG	2400
19	CH	Grisons	Val dal Cambrena	797/142	25.8.2005	Germann	cCG	2400
20	CH	Grisons	Val dal Cambrena	797/142	25.8.2005	Germann	cCG	2400
21	CH	Grisons	Val dal Cambrena	797/142	25.8.2005	Germann	cCG	2400
22	CH	Grisons	Val dal Cambrena	797/142	20.8.2011	Germann	cCG	2400
23	CH	Grisons	Val dal Cambrena	797/142	20.8.2011	Germann	cCG	2400
24	CH	Grisons	Val dal Cambrena	797/142	20.8.2011	Germann	cCG	2400
25	CH	Grisons	Val dal Cambrena	797/142	20.8.2011	Germann	cCG	2400
50	CH	Grisons	Val dal Cambrena	797/142	20.8.2011	Germann	cCG	-
2	CH	Grisons	Val Minor	797/146	23.7.1979	Scherler	NMBE	-
5	CH	Grisons	Val Minor	797/146	23.7.1979	Scherler	NMBE	-
11	CH	Grisons	Val Minor	797/146	23.7.1979	Scherler	NMBE	-
1	CH	Ticino	Camoghè	725/110	8.8.1974	Scherler	NMBE	-
4	CH	Ticino	Camoghè	725/110	8.8.1974	Scherler	NMBE	-
10	CH	Ticino	Camoghè	725/110	8.8.1974	Scherler	NMBE	-
3	CH	Ticino	M. Gazzirola	726/108	8.8.1975	Scherler	NMBE	-
7	CH	Ticino	M. Gazzirola	726/108	8.8.1975	Scherler	NMBE	-
8	CH	Ticino	M. Gazzirola	726/108	8.8.1975	Scherler	NMBE	-
9	CH	Ticino	M. Gazzirola	726/108	8.8.1975	Scherler	NMBE	-
35*	CH	(VS)	(Valais, Col de Balme, à droite)	(563/097)	-	Tournier	MHNG	-
45	I	Lombardia	Aviasco, Alp. occ.	46°01'15/9°51'49	-	Breit	NMBA	-
46	I	Lombardia	Aviasco, Alp. occ.	46°01'15/9°51'49	-	Breit	NMBA	-
47	I	Lombardia	Aviasco, Alp. occ.	46°01'15/9°51'49	-	Breit	NMBA	-
12	I	Lombardia	Bergamasker Alpen, Averara, Pso. San Marco	46°02'49/9°37'22	23.7.1996	Kahlen	TLMF	1970
32	I	Lombardia	Bergamasker Alpen, Pso. d' Aviasco	46°01'15/9°51'49	9.8.1899	Kraatz	DEI	-
13	I	Lombardia	Bergamasker Alpen, M. Arera	45°55'58"/9°48'48	21.7.1996	Kahlen	TLMF	2000
14	I	Lombardia	Bergamasker Alpen, M. Arera	45°55'58"/9°48'48	9.7.1994	Kahlen	TLMF	2050
26	I	Lombardia	Bergamasker Alpen, M. Arera	45°55'58"/9°48'48	21.7.1918	Künemann	DEI	-
27	I	Lombardia	Bergamasker Alpen, M. Arera	45°55'58"/9°48'48	21.7.1918	Künemann	DEI	-
28	I	Lombardia	Bergamasker Alpen, M. Arera	45°55'58"/9°48'48	21.7.1918	Künemann	DEI	-
39	I	Lombardia	Bergamasker Alpen, M. Arera	45°55'58"/9°48'48	-	Stolz	NMBA	-
38	I	Lombardia	Pso. d'Aviasco	46°01'15/9°51'49	10.7.1908	Stöcklein	NMBA	-
40	I	Lombardia	Pso. d'Aviasco	46°01'15/9°51'49	9.8.1899	Stöcklein	NMBA	-
42	I	Lombardia	Pso. d'Aviasco	46°01'15/9°51'49	10.7.1908	Stöcklein	NMBA	-
31	I	Lombardia	Lombardia (Bergamasker Alpen?)	-	-	Stierlin	DEI	-
37	I	Lombardia	Monte Spluga (Vapreppin?)	-	-	Apfelbeck	NMBA	-
36	I	Lombardia	M. Corte	45°57'28"/9°49'27	July	Nissl	NMBA	2000
41	I	Lombardia	M. Corte	45°57'28"/9°49'27	July	Nissl	NMBA	2000
43	I	Lombardia	M. Corte	45°57'28"/9°49'27	July	Nissl	NMBA	2000
44	I	Lombardia	M. Corte	45°57'28"/9°49'27	July	Nissl	NMBA	2000