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Notes on the *Aphodius* (s.str.) *fimetarius*-complex – morphology, taxonomy, nomenclature and worldwide distribution (with emphasis on the Iberian Peninsula, Austria and Germany) (Scarabaeoidea: Scarabaeidae: Aphodiinae)

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A b s t r a c t: The world-wide distribution of *Aphodius* (s.str.) *fimetarius* (LINNAEUS, 1758) and *Aphodius* (s.str.) *cardinalis* REITTER, 1892 has been investigated, based on about 12,000 examined specimens of both species from a large number of museums and private collections. Special attention was paid to the distribution in the Iberian Peninsula, Austria and Germany, because from these areas we had a particularly large number of specimens at our disposal and, additionally, because these areas are among those in which the two species occur in sympatry, at least in some localities. Whilst we have not been able to find any regions in Austria or Germany exclusively preferred by one of the two species, it is evident from the records in the Iberian Peninsula that *A. cardinalis* prefers here more southern regions and occurs in the north mostly at lower altitudes, whereas *A. fimetarius* prefers more northern regions and occurs in the south at higher altitudes. Our data on the world-wide distribution of these species confirm those provided by other authors (e.g. MIRALDO et al. 2014) and expand considerably the number of countries from which both species are known. We show that both species can be correctly identified by classical methods, i.e. by external morphologic characters and particularly by the shape of the parameres. It seems to us that these results can be helpful to those colleagues who want to identify their material and have no possibility to apply non-classical methods or want to identify mounted specimens. The characters used are listed in a table, some of them are figured. Additionally, we provide details about the distribution of the var. *autumnalis* NAEZEN, 1792 of *A. fimetarius*, and pay attention to varieties with darkened elytra, which so far have been reported only for *A. fimetarius* from France and Austria. Similar varieties of *A. cardinalis* are reported here for the first time from the Iberian Peninsula and Mexico. The nomenclatural situation of the two species is discussed and our choice of their names is explained.

K e y w o r d s: Coleoptera, Scarabaeidae, Aphodiinae, *Aphodius* (s.str.), taxonomy, morphology, nomenclature, distribution, Palearctic, Nearctic, Australia, Mexico.

Introduction

LINNAEUS (1758) described 63 species in his genus *Scarabaeus*, seven of which stand currently in the genus *Aphodius* HELLWIG, 1798. *Aphodius fimetarius* (LINNAEUS, 1758) is one of them; moreover, it is the type species of that genus, designated by LATREILLE (1810). The genus includes more than 1,000 species world-wide, thus belonging to the most speciose genera of Scarabaeoidea (DELLACASA M. 1988). It has long been divided

into several subgenera, which today are often treated as valid genera (e.g. DELLACASA G. et al. 2001), a proceeding which is not accepted by all authors. Following the "Catalogue of Palaearctic Coleoptera" (DELLACASA M. & G. DELLACASA 2006), we treat *A. fimetarius* and its relatives in the nominate subgenus *Aphodius* (s.str.).

The species (as it has been formerly understood, i.e. *A. fimetarius* s.l.) has a vast distribution in the Palearctic, is usually rather common and occurs also in the Nearctic and in Australia (most probably introduced into both). Recently it has been also recorded in Mexico (DELLACASA M. & G. DELLACASA 2003), which belongs to the Neotropical zoogeographic region (sensu LÖBL & SMETANA 2006: 12). Due to its vivid red elytra and the contrasting black head and pronotum it is well-known to all dung-beetlers almost world-wide and can be called the archetype of the genus. Additionally, it is well-known to not only dung-beetlers, but also to other insect specialists, a fact which is underlined by a publication in which even a nickname is used: "Le Suisse" (see COSTANTIN 1893).

Since LINNAEUS (1758), numerous further names have been published treated today either as valid, as junior subjective synonyms or for (colour) varieties (see below in the respective section) of *A. fimetarius*. One of these names is of special interest because it was given to a species which at that time was known as distributed in the Mediterranean (i.e. *Aphodius cardinalis* REITTER, 1892). However, subsequently this name was treated mostly as a synonym of *A. fimetarius* and/or as an infrasubspecific name.

Recently, *A. fimetarius* was again split into two species. WILSON (2001) studied the chromosomes of *A. fimetarius* from populations living in England, France, The Netherlands and Cyprus and found evidence of the presence of two different species in her material. This finding slowly came to be known among a few specialists and seems to remain unknown to the majority of dung-beetlers to this day. WILSON'S results were later supported by molecular studies (MIRALDO et al. 2014) and are now widely accepted at least by those colleagues who have been informed about them. WILSON (2001) proposed to keep for one of these two species the name *A. fimetarius* and to use for the other one the name *Aphodius pedellus* (DE GEER, 1774). Additionally, she designated a lectotype for each of the two species. Unfortunately, she selected from the syntype series of *Scarabaeus fimetarius* LINNAEUS the only syntype which does not belong to that species, and in fact represents *Aphodius* (*Rhodaphodius*) *foetens* (FABRICIUS, 1787), a mistake which was suspected by the junior author in 2011. This was the start of an intensive and in part controversial discussion about the nomenclature of both species, which, however, will not be described here in detail. The reader may study the respective contributions of several authors in the Bulletin of the International Commission of Zoological Nomenclature (ANGUS et al. 2012, BALLERIO 2012, BARCLAY 2012, BELLMANN et al. 2012, BEZDĚK & KRÁL 2012, BRANCO 2012, DELLACASA M. & G. DELLACASA 2012, FERY 2012a, 2012b, 2013, FORSHAGE 2012, FROLOV 2012, ICZN 2014, KRELL & ANGUS 2012, MATÉ 2012, ROSLIN 2012, SCHMIDT et al. 2012, SOLODOVNIKOV 2012). Although the existence of two different species is generally accepted, the confusion has remained great since then, not only about the nomenclature, but also about the identity of both species. As we know today, one of the two species has a more northern distribution (this is the species called "with reddish elytra" in FERY 2012a) and the other one a more southern distribution (the species called "with yellowish-red elytra" in FERY 2012a; for details of the distribution see the respective sections below).

In December 2014 the International Commission of Zoological Nomenclature (ICZN)

published Opinion 2345 in which WILSON's lectotype designation of *Scarabaeus fimetarius* was set aside and a neotype was designated for this nominal taxon.

The text of Opinion 2345 is rather short and all information given about the neotype is "the specimen with the unique identification label BMNH{E}UIN990028 at the Natural History Museum, London is designated as the neotype". This specimen was proposed by ANGUS et al. (2012) for neotype designation; however, it was not selected from the former syntype series in the collection of LINNAEUS, but instead from material collected in 2000 in Kent (England) and of which the chromosomes have been studied by WILSON (2001). Thus, it is not at all obvious to dung-beetlers who have not studied the Application to the Commission by ANGUS et al. (2012) and all the Comments on this Application how to use the text of Opinion 2345 and its consequences in their practical work. MIRALDO et al. (2014) also do not clarify the situation, because on the one hand they refer several times to RÖSSNER's publication from 2012, but on the other hand do not mention at all that RÖSSNER uses the names *A. fimetarius* and *A. cardinalis* for what is called by MIRALDO et al. (2014) *A. pedellus* and *A. fimetarius* (sensu WILSON 2001), respectively.

This is why we want to demonstrate the consequences of Opinion 2345 in some more detail. As a result of this Opinion, now we have the following situation:

(1) According to the Opinion, the species with the more northern distribution should be called *Aphodius pedellus* (DE GEER, 1774) (a taxon described by DE GEER from specimens collected in Sweden), and

(2) the species with the more southern distribution should be called *Aphodius fimetarius* (LINNAEUS, 1758) (a species described by LINNAEUS, most probably also exclusively from specimens collected in Sweden).

In our opinion, this result is unsatisfactory for two different reasons:

(a) We have now the bizarre situation that the former syntype series of *Scarabaeus fimetarius* contains not a single specimen (sic!) which belongs to what now should be called *A. fimetarius*. All the specimens in LINNAEUS' collection should have the name *A. pedellus*, a name which has never been used as valid after its publication, but instead was treated as a junior subjective synonym of *A. fimetarius* for almost 250 years.

(b) *Aphodius* specialists have ever understood *A. fimetarius* as a species with a mainly northern, central and eastern European distribution and only additionally as a species with expansions to the Mediterranean. As mentioned under (2), the species which mainly occurs in the Mediterranean should now have the name *A. fimetarius*, and its type locality is Deal in East Kent (England) (cf. ANGUS et al. 2012: 32; in MIRALDO et al. 2014: 538 it is specified as "Great Mongeham", a village and civil parish in East Kent, on the outskirts of Deal).

In contrast to MIRALDO et al. (2014), RÖSSNER (2012) used the name *A. fimetarius* for the species with the more northern distribution and the name *Aphodius cardinalis* REITTER, 1892 for the species with the more southern distribution. FERY (2012a) designated a neotype for *A. cardinalis*. The book about the "Scarabaeoidea of Eastern Germany" (RÖSSNER 2012) attracted much attention among Scarabaeoidea specialists and is widely distributed not only among German entomologists, but also in other countries. Thus, we can assume that the view of RÖSSNER has been already become known to a large part of the Scarabaeoidea community.

Since the start of the discussion about the identity and nomenclature of the two species in

2012, some papers have been published which use the names in the sense of Opinion 2345 (e.g. WILSON & ANGUS 2004, KRELL & ANGUS 2014, MIRALDO et al. 2014), but also others which follow RÖSSNER's view (ČÍLA & KRÁL 2012, BÄSE 2013, RÖSSNER 2015). We want also to point to a paper by AKHMETOVA & FROLOV (2014) in which the authors use the name *A. fimetarius* for Russian populations, although FROLOV (2012) wrote a Comment on Case 3579 in which he supported the view of ANGUS et al. (2012) and thus should have used instead the name *A. pedellus* for these populations (the name *A. pedellus* is not used at all in AKHMETOVA & FROLOV 2014, although only the more northern species occurs in European as well as in Asian Russia; see Tab. 2). Thus, it cannot be excluded that supporters of the Application of ANGUS et al. (2012) have misunderstood the situation and that the opinion of the Commission was partly based on misunderstanding.

The decision of the Commission has been approved by some dung-beetlers, but found little sympathy among others. We know of many colleagues who have no intention to use in the future the names in the sense of ANGUS et al. (2012) for the two species in question. All these facts make us doubt whether a large part of the dung-beetler community will follow Opinion 2345. It is not unlikely that the use of the name *A. fimetarius* for the more northern species and the name *A. cardinalis* for the other species will prevail. This is why we ask all colleagues – no matter from which side – to form their own judgement and then to publish their results and to label their specimens in an unmistakable manner (an example is given below). Only then it will be possible to use the results of their work in future studies. Authors may also explain the reasons for their choice of the names. In time it will become clear which of the two opinions is preferred by the dung-beetler community and – if necessary – the case can be again submitted to the Commission. We hope that the reader will understand our choice to use in the present work the names *A. fimetarius* and *A. cardinalis* in the sense of RÖSSNER (2012).

The aims of our work are (1) to illustrate those morphological characters by which the two species can be identified without the use of karyological or molecular methods; (2) to present the distribution of both species based on our examination of about 12,000 specimens from about 3,500 collecting sites world-wide; and (3) to give the results of our especially intensive distributional studies of populations from the Iberian Peninsula, Austria and Germany.

The Iberian Peninsula is insofar of special interest, because:

- Andalusia belongs to the type locality originally given by REITTER (1892) for *A. cardinalis* (after the designation of a neotype, the type locality of this species is specified as Vejer de la Frontera, Cádiz Province, which is situated in Andalusia, Spain).
- The Peninsula has quite diverse types of landscapes and vegetation zones, from regions with low altitudes to large flat areas of higher altitudes, and mountain ranges of moderate and high altitudes, and thus some ecological preferences of each species can be worked out.
- *Aphodius cardinalis* is much more abundant here than *A. fimetarius*, in contrast to more northern countries.
- It is one of those regions in which the distribution areas of both species clearly overlap.

Austria and Germany are also of great interest because:

- We have studied especially rich material from these two countries.
- The landscapes are less diverse than those of the Iberian Peninsula.
- *Aphodius fimetarius* is much more abundant here than *A. cardinalis*.
- The distribution areas of both species also considerably overlap in Germany, but for Austria we have only few records of *A. cardinalis* from some quite restricted areas.

Material and methods

We have studied about 12,000 specimens from about 3,500 localities (see Tab. 2; inexact localities like "Andalusia" are not included here). The institutions and private collections from which material was examined are listed below. Codens of the private collections are only given if these are cited in the text.

HNHM.....Hungarian Natural History Museum (Hungary, Budapest; O. Merkl)

MNCN.....Museo National de Ciencias Naturales (Spain, Madrid; M. París)

NME.....Naturkundemuseum Erfurt (Germany, Erfurt; M. Hartmann)

NMP.....National Museum Prague (Czech Republic, Prague; J. Hájek)

NHMW.....Naturhistorisches Museum Wien (Austria, Vienna; H. Schillhammer)

OLML.....Oberösterreichisches Landesmuseen/Biologiezentrum, Linz (Austria, Linz; F. Gusenleitner)

SDEI.....Senckenberg Deutsches Entomologisches Institut Müncheberg (Germany, Müncheberg; L. Behne)

SMFM.....Senckenberg Forschungsinstitut und Naturmuseum Frankfurt am Main (Germany, Frankfurt a. M.; D. Kovac, A. Hastenpflug-Vesmanis)

SMNS.....Staatliches Museum für Naturkunde Stuttgart (Germany, Stuttgart; W. Schawaller)

SMTD.....Senckenberg Naturhistorische Sammlungen Dresden, Museum für Tierkunde (Germany, Dresden; O. Jäger)

UMJG.....Universalmuseum Joanneum (Austria, Graz; W. Paill, U. Hausl-Hofstätter)

ZMFK.....Zoologisches Museum und Forschungsinstitut Alexander Koenig, Bonn (Germany, Bonn; D. Ahrens)

ZMHB.....Zoologisches Museum der Humboldt-Universität Berlin (Germany, Berlin; J. Frisch, J. Willers)

ZSM.....Zoologische Staatssammlung München (Germany, Munich; M. Balke, L. Hendrich)

Private collections (the country is Germany unless specified otherwise):

Apfel, W. (Eisenach); Bäse, W. & K. (Reinsdorf); Baumann, H. (Düsseldorf); Bellmann, A. (Bremen) (cAB); Bezděk, A. (Czech Republic, Česke Budějovice); Brunk, I. (Dresden); Buse, J. (Landau); Dellacasa, G. (Italy, Genova) (cGD); Eifler, M.

(Pinneberg); Esser, J. (Berlin); Fery, H. (Berlin, property of the ZSM) (cHF); Flossmann, S. (Jena); Frenzel, D. (Sonneberg); Fresneda, J. (Spain, Llesp, El Pont de Suert) (cJF); Gollkowski, V. (Oelsnitz/Vogtland); Grimm, H. (Seehausen); Gürlich, S. (Buchholz); Hadulla, K. (Bonn); Heinig, U. (Berlin); Heise, H. (Vastorf); Hengmith, K. (Hamburg); Hillert, O. (Schöneiche) (cOH); Hoffmann, W. (Hoyerswerda); Holzer, E. (Austria, Anger) (cEH); Kalz, H. (Schlabendorf); Kopetz, A. (Amt Wachsenburg); Langer, M. (Lichtenwalde) (cML); Lehmann, T. (Oranienbaum); Link, A. (Austria, Haid/ Ansfelden); Malchau, W. (Schönebeck/Elbe); Müller, H. (Zittau); Peschel, R. (Chemnitz); Richter, W. (Oderwitz); Rohwedder, D. (Bonn) (cDR); Rösner, C. (Erfurt); Rössner, E. (Schwerin) (cER); Schönfeld, J. (Sinzig) (cJS); Schulze, W. (Bielefeld); Sieber, M. (Großschönau); Skale, A. (Hof/Saale); Sparmberg, H. (Erfurt); Strobl, P. (Stendal) (cPS); Teuscher, M. (Neustrelitz); Tschimmel, A. (Zwickau); Wagner, T. (Koblenz); Weipert, J. (Plaue); Ziani, S. (Italy, Meldola/Forli) (cSZ); Ziegler, W. (Rondeshagen).

The material was studied in part with a Zeiss GSM and in part with an Olympus SZX16 stereomicroscope. Parameres were studied wet. Stacks of photos of the habitus and other taxonomically important details were made with a Nikon Coolpix 995 digital camera attached to the stereomicroscope. These stacks were processed with CombineZP image stacking software and afterwards tuned up with Photoshop CS5.

A list of the data of all ca. 12,000 specimens studied seems unnecessary and would go beyond the scope of our work. However, these data are stored in a database, and details can be provided on request. Moreover, data of a large part of the German material are listed in RÖSSNER (2012). The majority of the material studied (mainly from museums) is rather old and mostly labelled without dates. Thus, it was impossible to get any information about the changes in geographical ranges of the two species during the last few centuries or about the phenology of the two species. Here the reader is referred to the interesting results given in MIRALDO et al. (2014: 535-536) for two localities in Colorado (USA).

The maps (Figs 10-12) were prepared using Microsoft Encarta World Atlas 2000.

To label the material in an unmistakeable manner, we used such label texts as "*Aphodius fimetarius* (LINNAEUS) [= *pedellus* (DE GEER, 1774) sensu WILSON (2001)]" or "*Aphodius cardinalis* REITTER [= *fimetarius* (LINNAEUS, 1758) sensu WILSON (2001)]". We recommend dung-beetlers to proceed in a similar way, although other unambiguous label texts are also conceivable.

Morphology (Tab. 1)

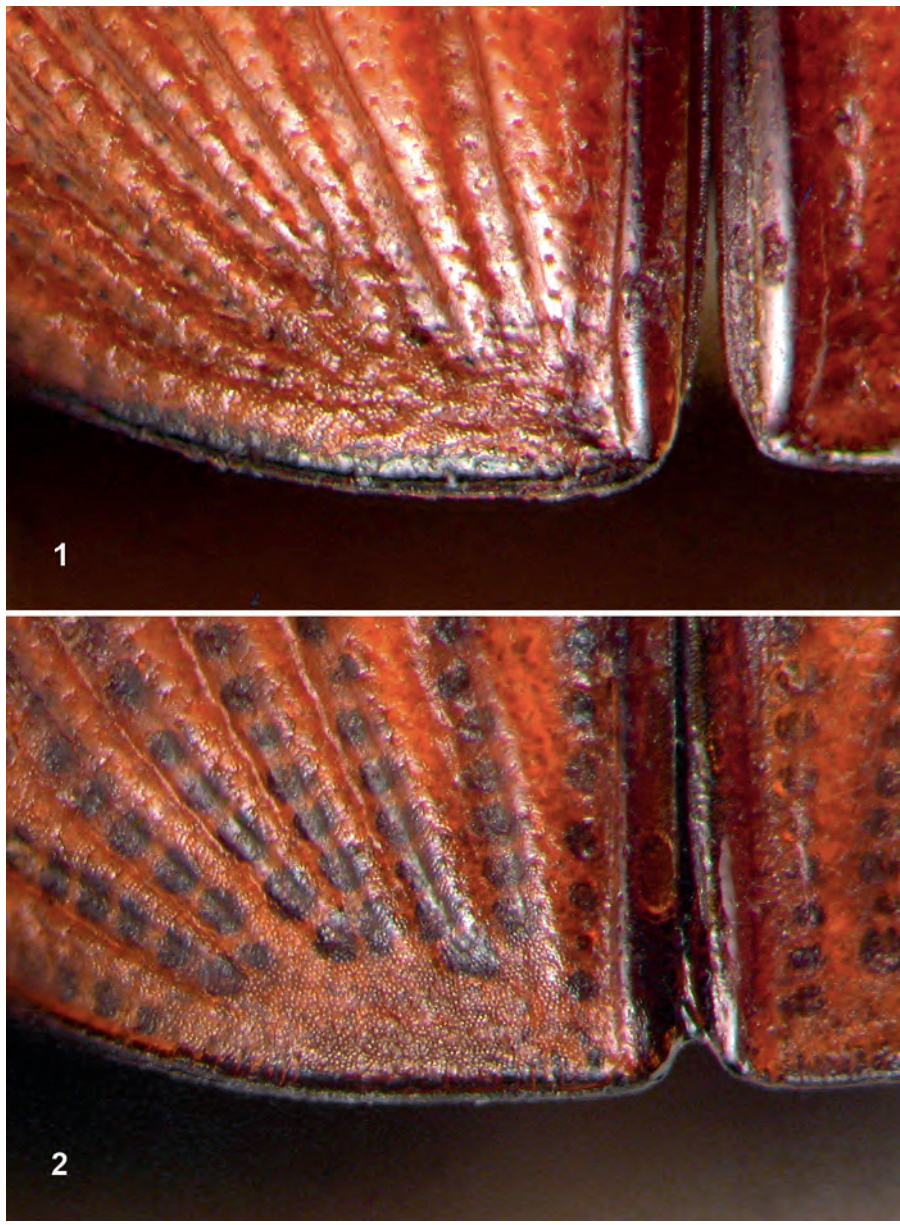
The characters which can be used to separate the two species are given in Tab. 1. Here we distinguish between "strong" characters, which hold for most specimens, and "weak" ones, which do not hold true for all. A "weak" character should never be trusted alone, but such characters can be helpful nevertheless, because together with other characters they can make it possible to identify a particular specimen. In addition to the explanations in Tab. 1, we provide below more information on some of such features.

Table 1: Morphological characters that can be used to distinguish between *Aphodius fimetarius* and *A. cardinalis* (listed in decreasing order of importance)

	character	*Aphodius fimetarius*	*Aphodius cardinalis*
strong	surface structure of elytral apex	matt in part, but generally more shiny; reticulate surface interspersed with wrinkles and/or small raised shiny areas (Fig. 1)	distinctly matt; mostly without wrinkles or small raised areas; if wrinkles or raised areas present, then these very sparse, flat, small and not shiny (Fig. 2)
	shape of parameres in lateral view (males)	apex relatively weakly bent (Figs 3 and 5)	apex more distinctly bent (Figs 4 and 5)
weak	lateral lobes of head	distinctly rounded and protruding eyes; rarely weakly subparallel	mostly weakly developed, almost sub-parallel; not or only weakly protruding eyes
	elytral colouration	mostly distinctly red, less frequently yellowish red	rarely distinctly red, often yellowish red
	shape of 4th elytral interval before apex	mostly shortened, because 3rd and 4th elytral striae connected subapically	mostly not shortened, because 3rd and 4th elytral striae not connected subapically
	habitus	in dorsal view appearing stocky; maximum width of elytra at mid-length or in anterior half (Fig. 6a)	in dorsal view appearing more or less subparallel (Fig. 6c)
	shape of elytral intervals on disc in cross-section	mostly flat or only weakly vaulted; rarely distinctly convex in cross section	mostly weakly to distinctly vaulted, convex in cross section
	median tubercle of frontal suture (males)	distance between tubercle and clypeal carina appearing more or less same as distance between clypeal carina and anterior margin of clypeus (Fig. 8)	distance between tubercle and clypeal carina often appearing smaller than distance between clypeal carina and anterior margin of clypeus (Fig. 9)
	pronotal punctation	coarser and more impressed; in females on disc mostly denser and more evenly distributed	smaller and less impressed; in females on disc less numerous and less evenly distributed

E l y t r a l a p e x: The most important external distinguishing character is the surface structure of the elytral apices, which was first studied in detail by RÖSSNER. The results were published in RÖSSNER (2012: 138, 140), but they were already sent earlier to interested colleagues as unpublished communication (cf. ANGUS et al. 2012: 34). KRELL & ANGUS (2014: figs 7D and 8B) published photos of the elytral apices of the lecto- and paralectotype of *Aphodius nodifrons* RANDALL, 1838 (a junior subjective synonym of *A. fimetarius*, given by these authors under the name *A. pedellus*), but did not deal with *A. cardinalis*. Respective photos of both species were provided by MIRALDO et al. (2014: fig. 5; same figures in ROSLIN et al. 2014: 194), but these are rather difficult to interpret. The same authors gave in their tab. 3 (p. 540) some explanations; however, a more precise description seems to be necessary to help the user understand. This is why below we pay special attention to these structures (Figs 1 and 2).

In both species the elytral apices are reticulate (at least in part) and the lines of reticulation include more or less roundish cells, which are very small (diameter about 8 µm), vaulted (convex), smooth and shiny. These lines are rather deeply engraved in *A. cardinalis* (Fig. 2) and the sum of the shiny inner areas of the cells is comparable to the sum of the areas of the non-shiny engraved lines. Thus, the whole apical area is appearing matt, although the cells themselves are shiny. A similar, but still finer surface structure can be seen in *Aphodius* (*Bodilopsis*) *sordidus* (FABRICIUS, 1775).



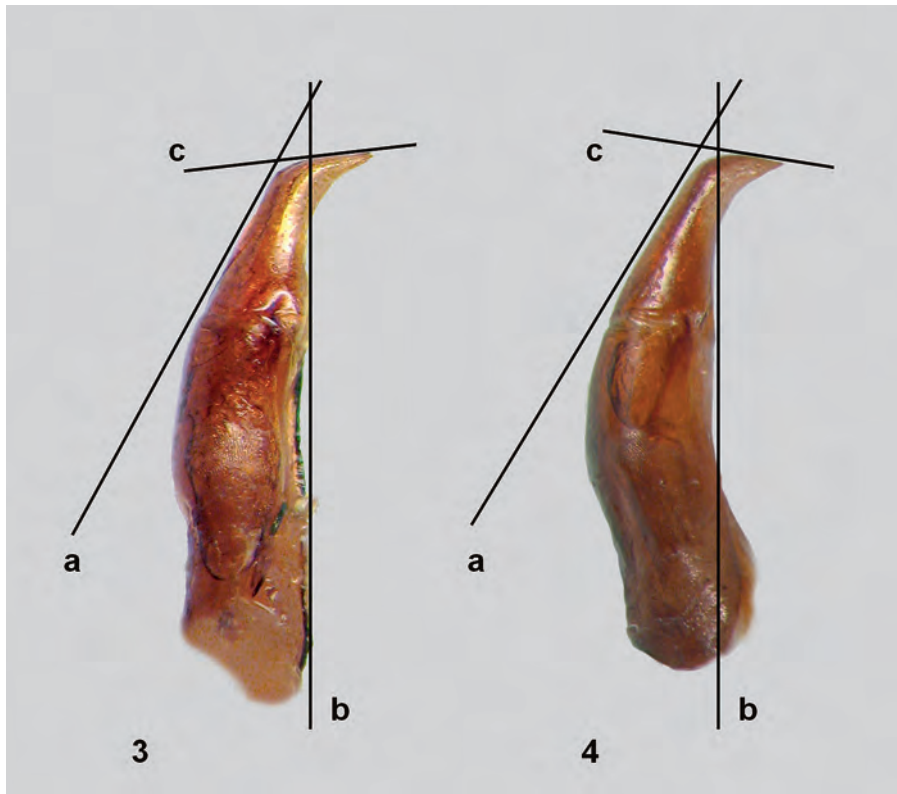
Figs 1-2: Elytral apex of (**1**) *Aphodius fimetarius* (♂, El Pont de Suert, Spain; cHF) and (**2**) *Aphodius cardinalis* (♂, idem).

In *A. fimetarius* the lines of reticulation are less deeply engraved or even partially absent (Fig. 1). Additionally, the cells are slightly less vaulted and thus larger parts can reflect the light. That is one reason why the apices of *A. fimetarius* are shinier as a whole than those of *A. cardinalis*, although basically the reticulation is the same in both species. There is another effect responsible for the overall shinier surface of the apices in *A. fimetarius*: whilst in *A. cardinalis* this area is almost evenly reticulated and only rarely interspersed by superficially elevated parts (see below), it is more uneven in *A. fimetarius*, and in the elevated parts the lines of reticulation are less deeply engraved or even absent, so that the surface here is becoming much more shinier. The surface of the apices in the latter species is generally much more irregularly and diversely structured (also among specimens of the same population) and always interspersed with wrinkles and spots of varying size. In some cases the reticulation cells are deformed and have a more oblong shape and/or the whole surface can be very roughly structured and cleft and restrain the reticulation over large parts.

In *A. cardinalis* the surface structure of the apices is generally only little varying and the reticulation cells are almost equal in shape and size, and only rarely a few cells are slightly deformed. Exceptionally, however, the apices of *A. cardinalis* can also have some elevated parts. However, these are always very flat and not shinier than the rest. It can also happen that two or rarely three reticulation cells are combined, and the surface here is locally slightly shinier.

P a r a m e r e s: MIRALDO et al. (2014: 536) write "... aedeagal characters ... seem to fail when more material from the whole range is studied." Here we cannot follow these authors. On the contrary, we are sure that the shape of the parameres is one of the best aids for identification, which only fails in very rare ambiguous cases. We have dissected about 400 males from diverse regions and found distinct, but largely constant differences between the two species in the shape of the parameres in lateral view (extent of bend of the apical part). In Fig. 5 parameres of specimens of both species from diverse regions are illustrated. It can be seen that in *A. cardinalis* the apex of the parameres is distinctly more bent than in *A. fimetarius*. We must concede, however, that the human eye can easily be deceived when estimating angles between surfaces or lines and – depending on the orientation of the parameres – different students may come to different results. To avoid these difficulties at least in part, we show photos of the parameres in lateral view of an *A. fimetarius* from Germany (Fig. 3) and of the neotype of *A. cardinalis* from Spain (Fig. 4). We have added three straight lines, one line parallel to the ventral (convex) surface of the parameres (a), a second one parallel to the dorsal (concave) surface (b) and a third one parallel to the bent ventro-apical part (c). The angles between lines (a) and (c) are about 122° in *A. fimetarius* and about 103° in *A. cardinalis*; the difference between the two angles is about 14° and both angles are distinctly greater than 90°. The angles between lines (b) and (c) are about 96° in *A. fimetarius* and about 82° in *A. cardinalis*; the difference between the two angles is again about 14°. As can be seen in Fig. 5, in all *A. fimetarius* the angle between the two lines is mostly distinctly greater than 90°, whereas in *A. cardinalis* it is mostly distinctly smaller than 90°. The deviations of the respective angles from the right angle vary; however, we did not find any *A. fimetarius* with an angle smaller than 93° or any *A. cardinalis* with an angle greater than 90°. In Fig. 5 we have added the values of both angles below each paramere. The users of this character may decide for themselves the angle between which lines they prefer. If,

nevertheless, the identification of a specimen by estimation of the respective angle seems to be ambiguous, a study of the surface structure of the elytral apex and also of other characters will help in almost all cases.



Figs 3-4: Parameres in lateral view of (**3**) *Aphodius fimetarius* (Oldendorf near Celle, Germany; cHF) and (**4**) *A. cardinalis* (neotype; Vejer de la Frontera, Cádiz, Spain; ZSM). Lines **a**, **b** and **c** include angles the values of which are given for several specimens in Fig. **5**.

According to our data, the situation is as follows:

- All dissected males with an unambiguous structure of the elytral apex had parameres which agree with the shape of the respective species – and vice versa.
- The very few males which showed no absolutely clear surface structure of the elytral apex (i.e. very small raised – but nevertheless matt – areas in *A. cardinalis* or strongly reduced – but more or less shiny – wrinkles or raised areas in *A. fimetarius*) could be clearly identified by the shape of the parameres plus the use of the "weak" characters given below.
- As an example, we have studied all mounted Iberian specimens of both species from the MNCN. Most of them were identified by J. MATÉ (most probably by those characters given in WILSON 2001 and WHITEHEAD 2006, i.e. shape of

lateral lobes of head, punctation of pronotum in females, and colour of elytra; specimens not dissected). Among them we found a small number of both species which had the "wrong" elytral apex. We identified these specimens preliminarily and afterwards dissected the males – all males with matt elytral apex had the parameres relatively strongly bent (*A. cardinalis*) and all males with wrinkled elytral apex had the parameres distinctly less bent (*A. fimetarius*).

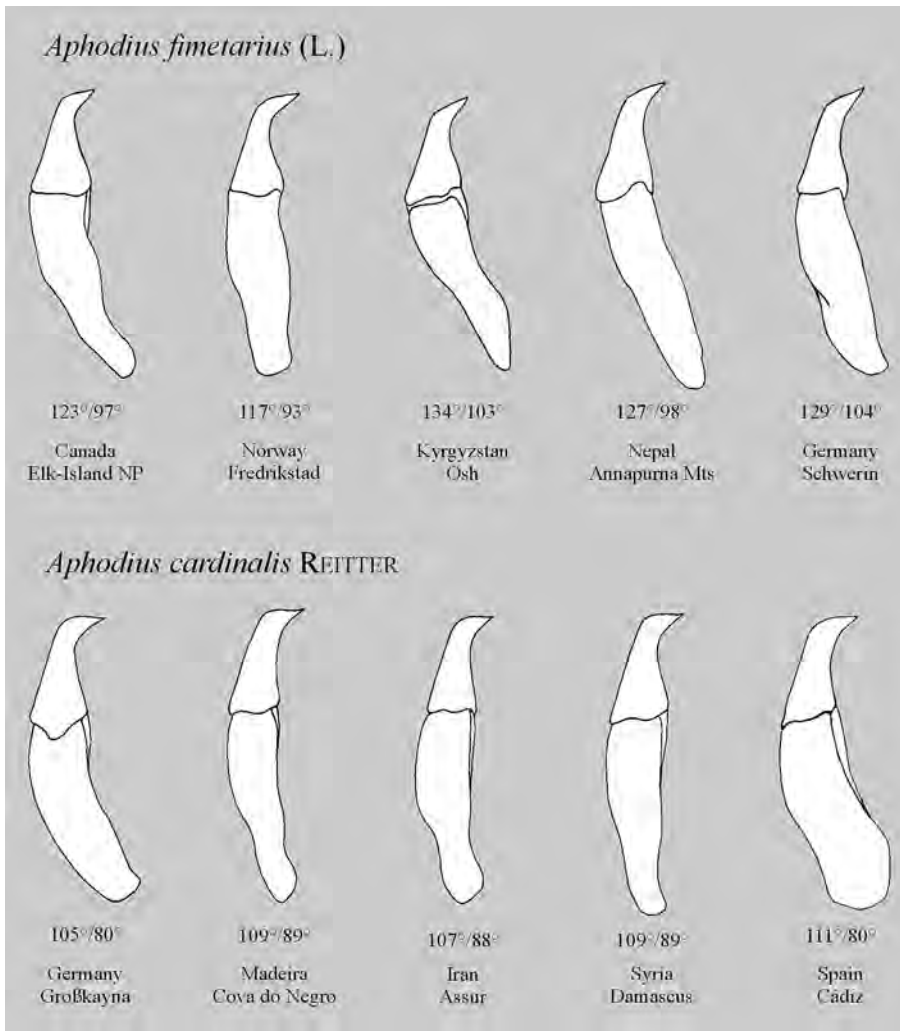


Fig. 5: Parameres in lateral view of *Aphodius fimetarius* (upper row) and *A. cardinalis* (lower row) from diverse localities. Ventral sides of all parameres oriented in the same direction. Given angles are measured between lines **a**/**c** and **b**/**c** respectively (cf. Figs **3**-**4**).

The following characters are considered "weak" because they can vary to some extent and none of them can be used alone for a reliable identification.

Colour: As mentioned also by MIRALDO et al. (2014: 536), differences in elytral colour can only be considered a "weak" character. On average the elytra of *A. fimetarius* are darker and more reddish and those of *A. cardinalis* lighter and more yellowish-red (cf. Figs 6a and 6c). Although colour was used as central character in WHITEHEAD (2006) and was also mentioned in ANGUS et al. (2012: 33) and FERY (2012a), we must concede that the elytral colouration is rather variable and only slightly helpful in making identifications more reliable.

Body shape: Males of *A. fimetarius* have often a rather stocky habitus in dorsal view and the maximum width of the elytra is situated at their mid-length or in anterior half (Fig. 6a), whereas males of *A. cardinalis* are mostly more parallel-sided (Fig. 6c). We have not studied any *A. cardinalis* with a stocky habitus as in Fig. 6a and in our experience if a male has a stocky habitus and if additionally the surface of the elytral apex is matt and even, then it is undoubtedly *A. fimetarius*. We have sporadically dissected such males and have never found any of them to be *A. cardinalis*. Unfortunately, not all *A. fimetarius* are so stocky; in particular, smaller specimens are not so, and thus erroneously can be thought to belong to *A. cardinalis*.

Fig. 6: Habitus of (**a**) *Aphodius fimetarius* (♂, Kumisi near Tbilisi, Georgia; cER), (**b**) *A. fimetarius* var. *autumnalis* (♂, Schwerin, Germany; cER) and (**c**) *A. cardinalis* (♂, Hisarönü, near Marmaris, Turkey; cER) (photos reproduced from RÖSSNER 2012).

Structure of median tubercle on head: This feature can be helpful especially in larger males. For recognising this character, the head must be studied in perpendicular and/or in (oblique) lateral view. In *A. fimetarius* the distance between the tip of the median tubercle of the frontal suture and the transversal clypeal carina is subequal to the distance between that carina and the anterior margin of the head (Fig. 8).

In *A. cardinalis* the distance between the median tubercle and the clypeal carina is in fact not (or not much) smaller than the distance between the clypeal carina and the anterior margin of the head (Fig. 9), but it appears smaller because in this species the median tubercle is anteriorly less abruptly ascending than in *A. fimetarius* (Fig. 8).

Pronotal punctation: This character is applicable mainly to females and was given by WILSON (2001: 138) as an important one, although not fitting all of the specimens studied by her (see also WHITEHEAD 2006 and RÖSSNER 2012). In *A. cardinalis* the punctation is generally smaller and less impressed and on pronotal disc of females less numerous and more irregularly distributed. We agree with MIRALDO et al. (2014: 536) that there are many specimens with which this character is of little help.

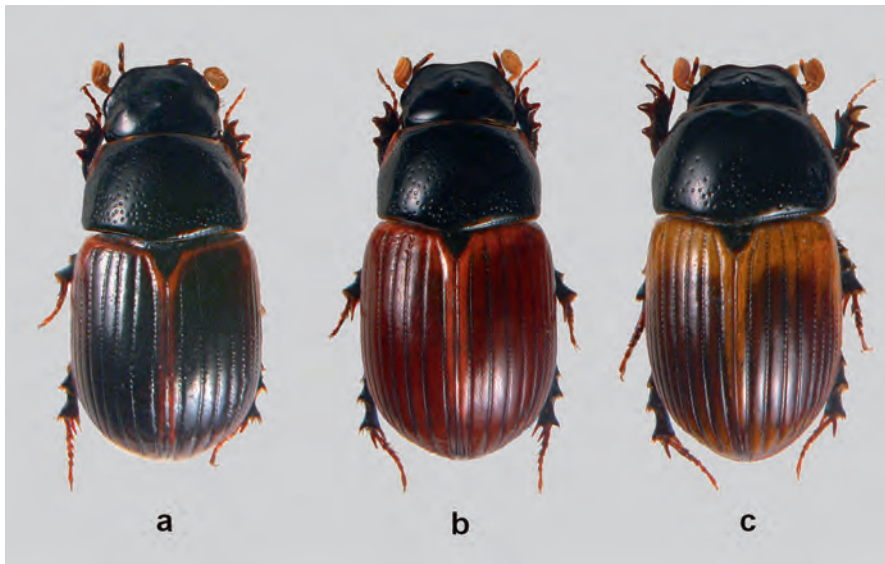
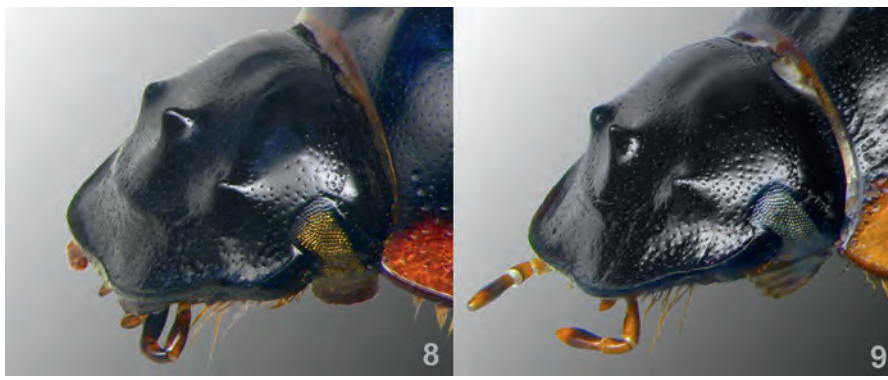


Fig. 7: Colour varieties of (**a**) *Aphodius fimetarius* (♀, Ischgl, Austria; cHF), (**b**) (♀, idem) and (**c**) *A. cardinalis* (♂, Torre, Serra da Estrela, Portugal; cHF).



Figs 8-9. Structure of head of male in oblique lateral view of (**8**) *Aphodius fimetarius* (Berlin, Germany; cHF) and (**9**) *A. cardinalis* (Barro, near Llanes, Spain; cHF).

Other characters: MIRALDO et al. (2014: 540) propose three further characters as useful: shape of the lateral lobes of the head, shape of the elytral intervals in cross-section on disc, and shape of apical ends of these intervals. We can confirm that these characters may support an identification (cf. Tab. 1), but we found in several specimens states of these characters which are by no means clear. Thus, we count these three characters also among the "weak" ones. In particular, detailed description of the shapes of the lateral lobes (in other publications called also "genae" or "cheeks") in MIRALDO et al. (2014) seems to be rather difficult, and we found no possibility to prove whether such short curved lines have a semi-oval, semi-parabolic, semicircular or hyperbolic contour. We have also studied specimens with different shapes of the left and the right lobe.

As already mentioned above, none of the "weak" characters can be used alone to produce a reliable identification. However, if these characters are applied in combination with "strong" characters in any doubtful case, then reliable identification will be impossible only in a tiny number of specimens. The reader may be surprised that we concede the possibility that in some cases specimens (in particular females) of both species cannot be identified. However, this is known to be true of several other pairs of morphologically closely related species, such as the following three examples: *Aphodius* (*Agrilinus*) *ater* (DE GEER, 1774) and *Aphodius* (*Agrilinus*) *convexus* ERICHSON, 1848; *Aphodius* (*Euorodalus*) *coenosus* (PANZER, 1789) and *Aphodius* (*Euorodalus*) *paracoenosus* BALTHASAR & HRUBANT, 1960; *Aphodius* (*Biralus*) *satellitius* (HERBST, 1789) and *Aphodius* (*Biralus*) *mahunkaorum* (ÁDÁM, 1983) (see RÖSSNER & FERY 2014).

Observation: Among smaller specimens of *A. fimetarius* we found some in which several characters show tendencies to states that belong to *A. cardinalis*: habitus less stocky, elytral intervals more convex, lateral lobes of head smaller, elytral apices with uneven areas less prominent. Such specimens were found especially among material from South Tyrol (Gröden, St Ulrich, Ortler Mts.; NHMW). Males should be dissected in such cases to make the identification more reliable.

Concluding remarks: At the end of this section we want to give some additional hints and to point to circumstances which can complicate or even prevent reliable identification:

- Specimens must be carefully cleaned, in particular the elytral apices (cf. also MIRALDO et al. 2014: 536). The apices must also be dry; otherwise a matt but wet surface appears shiny, and thus a specimen of *A. cardinalis* can be incorrectly identified as *A. fimetarius*.
- Sometimes one elytral apex has a somewhat ambiguous surface structure; in such cases the study of the other apex can often yield the correct result.
- In very few of the specimens studied the elytral intervals end only shortly before the hind margin of the elytra. Thus, the matt and/or wrinkled area on the elytral apex is unusually strongly reduced and the identification is considerably complicated.
- Old material tends to alter the elytral colour considerably, mostly to more yellowish; thus, specimens of *A. fimetarius* might be mistaken at first glance for *A. cardinalis*.
- Worn out specimens may have strongly reduced lateral lobes of the head; such specimens of *A. fimetarius* can also be mistaken at first glance for *A. cardinalis*.

In most cases, however, such specimens can be reliably identified with the help of other characters.

Distribution of both species

The results of our investigation on the distribution of *A. fimetarius* and *A. cardinalis* are summarised in Tab. 2. Those for the Iberian Peninsula, Austria and Germany are illustrated in even more detail in three maps (Figs 10-12).

It must be noted that the records given in these maps certainly do not represent the actual complete distribution of both species in the three countries. For instance, we have few records from Portugal and no record from the Spanish Badajoz Province, as well as only a single one from the Seville Province. Other gaps exist in the Ebro valley, in the plain north of the "Cordillera Central" (which comprises mainly the Sierra de Guadarrama and Sierra de Gredos) and in the Sierra Morena. Such gaps exist also in north-western Germany and some small parts of Austria; however, they are far less pronounced. It is possible that both species actually do not occur in some of these regions; however, lack of material may also be due to little collecting activities in such eventually "unattractive" areas.

Distribution on the Iberian Peninsula (Fig. 10)

According to the material studied, both species are distributed rather unevenly.

Aphodius fimetarius is distinctly less frequent and seems to be absent in south-western Spain and southern Portugal. It seems to be absent also on the Balearics, the Canary Islands and Madeira. Records of *A. fimetarius* are chiefly concentrated in the mountains: the Pyrenees, the Cantabrian Mountains (Cordillera Cantabrica), the Central System (mainly Sierra de Guadarrama and Sierra de Gredos), the Iberian System (mainly Sierra de Demanda and Sierra de Albarracin) and the Baetic System (Sistema Bético with Sierra Nevada, Sierra de los Filabres etc.). Records from the southern half of the peninsula are especially rare. The species occurs mainly at altitudes from 700 to 1,800 m, reaching 2,200 m in the Sierra Nevada (Pico del Veleta; NME) and 1,825 m in the Pyrenees (Aigüestortes, near Barruera, Lleida province, 1.X.1983, Fresneda leg.; cJF). It avoids the Mediterranean coast (only one record from near Cartagena; MNCN). From Portugal we know of only one specimen collected in the Serra da Estrela at Penhas Douradas (ca. 1,300 m; cJF). From Andorra we have only records of *A. fimetarius*. We ourselves collected the species at excrements of cows, horses and donkeys, but only rarely at those of sheep (the same observation holds for *A. cardinalis*).

Aphodius cardinalis is generally much more frequent than *A. fimetarius*; only in the Pyrenees it is less abundant. The areas where it has been found are distributed over the entire peninsula, from sea level (e.g. Cádiz province) to rather high altitudes (e.g. Castellon, Els Monllats, 1,100 m; Pyrenees, Lleida, Gotarta, near El Pont de Suert, 1,210 m, 31.V.1984, Fresneda leg.; cJF); no preference for any special part of the peninsula is visible. At higher altitudes it is almost exclusively found together with *A. fimetarius*. The distribution area of the species is continued in North Africa, on the other side of the Mediterranean Sea.

N o t e s: From the Balearics and Madeira we have exclusively records of *A. cardinalis*. Records from the Canary Island are unknown.

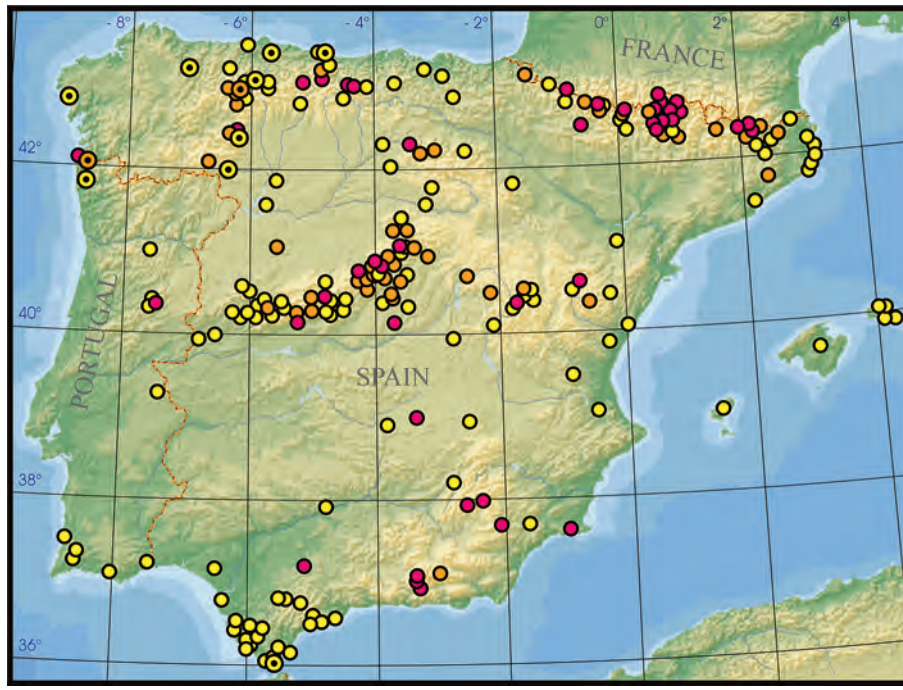


Fig. 10: Distribution of *Aphodius fimetarius* (red circles) and *A. cardinalis* (yellow circles) on the Iberian Peninsula; orange circles indicate localities where both species have been found together; larger circles with a dot in the centre indicate localities where specimens with darkened elytra have been found together with normally coloured specimens.

Distribution in Austria (Fig. 11)

Aphodius fimetarius is distributed more or less all over the entire country and has been found in almost all altitude zones. The species occurs in all types of landscapes, from the steppe-like plains at Lake Neusiedel in the east (altitude ca. 100 m) to the west with the high Alps in the Rätikon and regions near the borders with Switzerland and Liechtenstein. In the Stubai Alps (Serleskamm, ca. 2,200 m; SDEI) the species was found slightly below the nival altitude zone. Lacking records in a few parts are certainly due to lack of collecting activities. The species accepts all kinds of mammalian excrements, at high altitudes including those of chamois, ibex and marmot.

Aphodius cardinalis is very rare in Austria. This may be due to the generally high altitudes of most areas of the country. The species occurs in the colline and submontane altitude zones and avoids distinctly higher altitudes. Its distribution area extends mainly along the valleys of the big rivers Danube and Mur. According to the preference of this species for warmer regions with lower altitudes, its occurrence around Lake Neusiedel is likely, although respective records remain lacking. Specimens from the following sites have been studied: near Linz (Upper Austria, altitude ca. 300-500 m), Vienna and its surroundings (altitude ca. 150-300 m), two records from near Graz (Styria, altitude ca. 300-700 m), one record from Weißenbach, Attersee (Upper Austria, ca. 500 m), and Kitzbühel (Tyrol, ca. 800 m). The species was mainly found together with *A. fimetarius*.

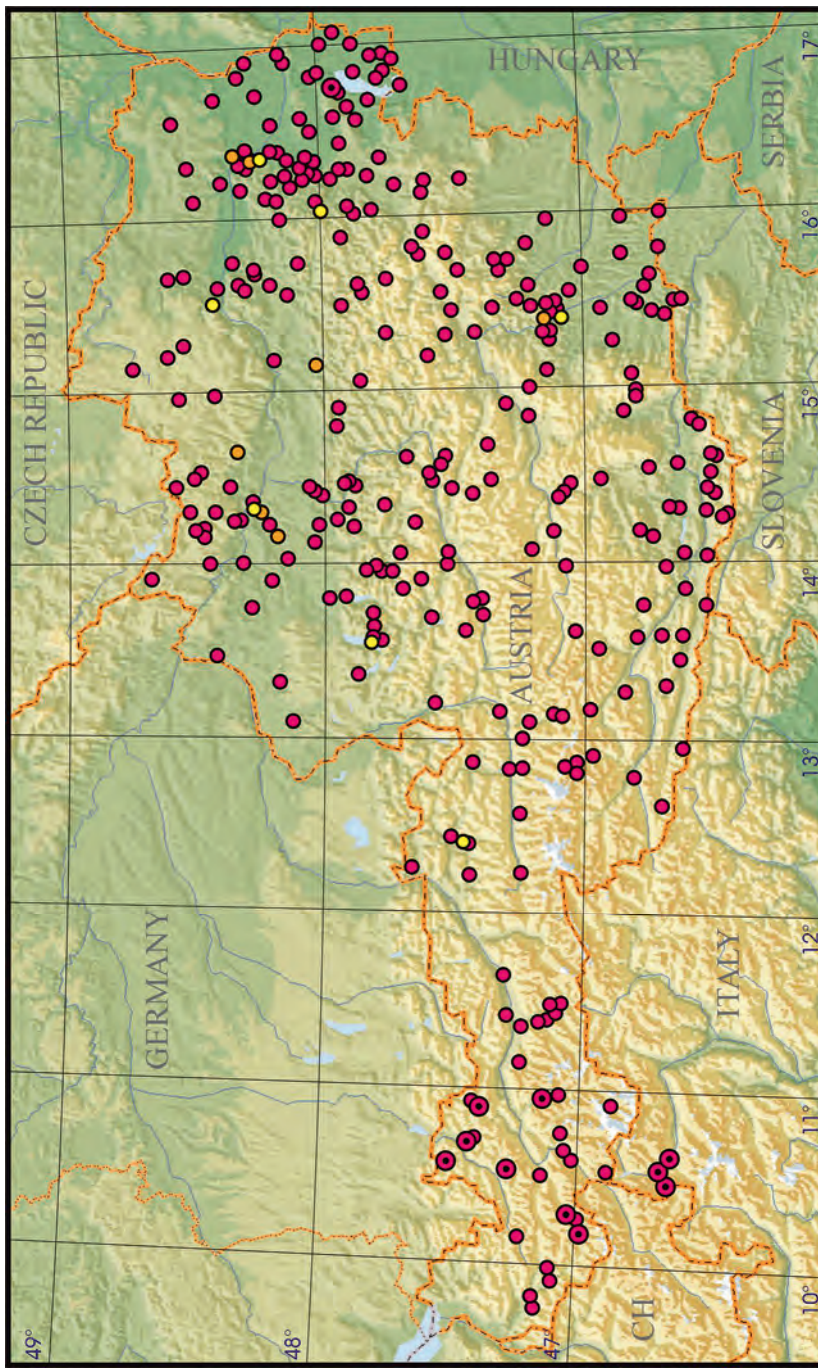


Fig. 11: Distribution of *Aphodius fimetarius* (red circles) and *A. cardinalis* (yellow circles) in Austria; orange circles indicate localities where both species have been found together; larger circles with a dot in the centre indicate localities where specimens with darkened elytra have been found together with normally coloured specimens. Italian records of specimens with darkened elytra have been added to give a better overview of the complete distribution of this variety in the region.

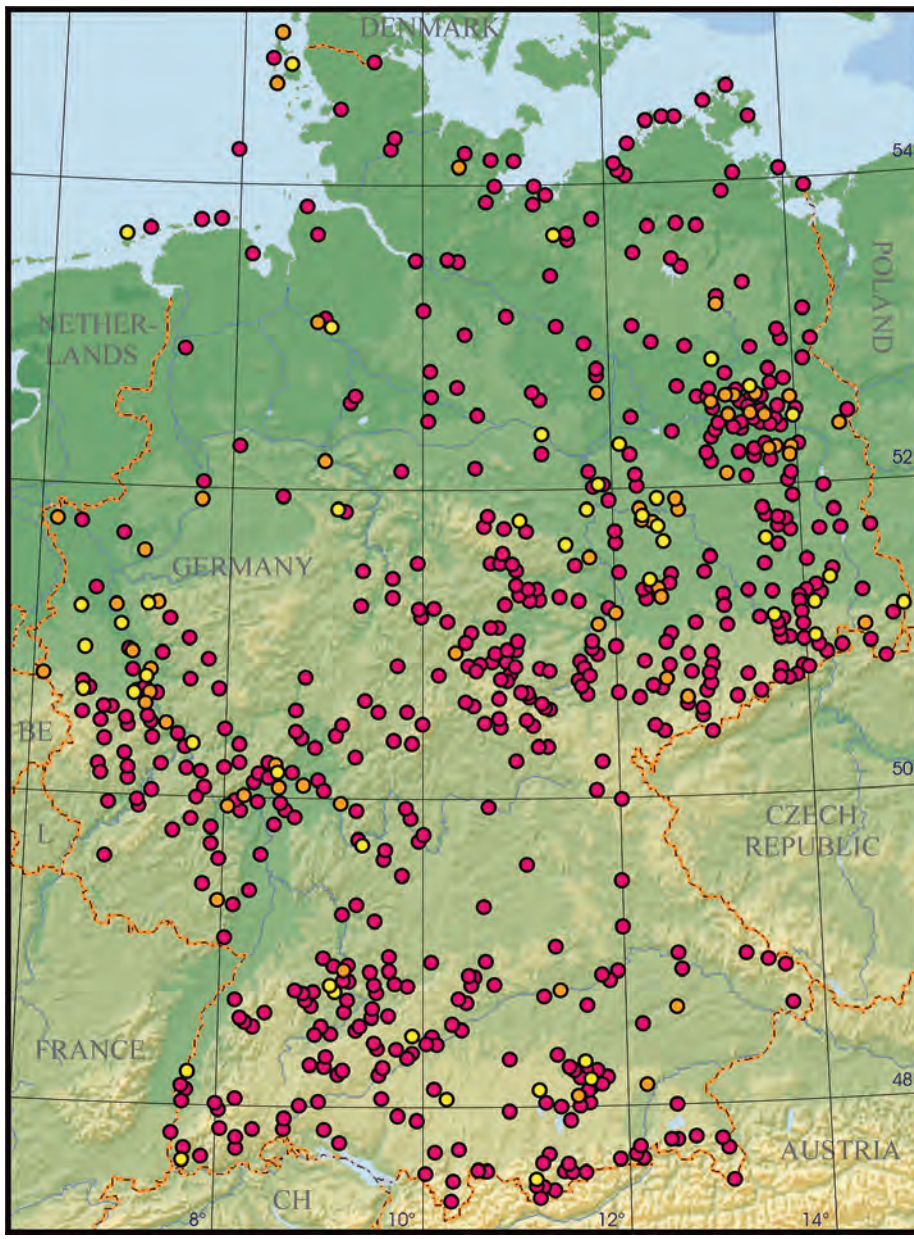


Fig. 12: Distribution of *Aphodius fimetarius* (red circles) and *A. cardinalis* (yellow circles) in Germany; orange circles indicate localities where both species have been found together.

Distribution in Germany (Fig. 12)

As in Austria, *Aphodius fimetarius* is distributed more or less all over the country, although we have less numerous materials from north-western and south-eastern Germany, possibly due to little collecting activities. It can be found in almost all kinds of landscapes and at almost all altitudes. It occurs on the islands of the North and Baltic seas, in the northern German lowlands and further south in the low mountain ranges and until the Alps. It is recorded in dry and warm German landscapes (such as Kaiserstuhl or the southern slopes of the Kyffhäuser Mountains) as well as in humid and rather cold regions of the Alps where it can be found even in the alpine zone. In the Harz it occurs in the subalpine zone of the Brocken (1,140 m) and in the Alps it was found at 2,200 m in the Wetterstein Mountains. The species has a high ecological potency and avoids neither urban zones nor anthropogenically degraded landscapes. It can be found at all kinds of mammalian excrements and is also found at rotting plants and occasionally also at cadavers. At the collecting sites the species is often very abundant (up to more than 100 specimens at a single locality).

Aphodius cardinalis is relatively rare in Germany, but distributed over large parts of the country. The northern-most records in Germany are from the islands Amrum, Föhr and Sylt. Here the species lives on sandy grounds which are rapidly heated by sunlight. These islands are characterised by an above-average sunlight duration and mild humid winters. We know of only very few more northern records from Denmark, which form part of the northern border of the range of this species. Other regions with relatively high numbers of records belong to the planar and colline altitude zones and mostly have rather warm climates with low precipitation. The species usually does not occur in the alpine zone, but along river valleys it can invade montane altitude zones (e.g. Kleiner Inselsberg, 500-600 m, in Thuringia (SDEI) and Warmberg, ca. 1,000 m, near Garmisch-Partenkirchen in the Bavarian Alps (cER)). At the collecting sites *A. cardinalis* is often found together with *A. fimetarius*, but the former is usually much less abundant than the latter. The species has been found at excrements of cows, horses and sheep, as well as at rotting plants.

Distribution in other countries (Tab. 2)

Records from other regions than Austria, Germany and the Iberian Peninsula are briefly summarised in Tab. 2, where we provide the numbers of localities ("locs") and specimens ("exs") studied accompanied in many cases by a few remarks. The results of MIRALDO et al. (2014) largely agree with our results. We can, however, provide more detailed information for several countries for which these authors provide only records of *A. fimetarius* sensu lato (seemingly taken from the literature).

Our results support the attribution of both species to their respective areal types in RÖSSNER (2012: 138, 141): *Aphodius fimetarius* is an Asiatic-European and *A. cardinalis* a European-Mediterranean areal type (inside the Palearctic zoographic region; here we exclude regions into which the species apparently have been introduced by human activities) (cf. VIGNA TAGLIANTI et al. 1992).

Special attention must be paid to some records from Mexico. We have studied three

specimens of *A. fimetarius* from Reynosa, State of Tamaulipa (ZMFK), and three specimens of *A. cardinalis* (among these a totally black male: ab. *paradoxus* HOFFMANN, 1929) from Tehuacán, Estado de Puebla, 1,600 m, 23.VIII.1980, ZUNINO leg. (cGD). Both are the southern-most localities for the two species known to us. MIRALDO et al. (2014: 543) cite also records from Puebla (NAVARRETE-HEREDIA 2006), but add "*the species identity of these records has yet to be determined*". NAVARRETE-HEREDIA's records relate to the specimens of *A. cardinalis* mentioned above and already mentioned without detailed data in DELLACASA M. & G. DELLACASA (2003: 182). Latter authors communicated privately also the data of another finding of *A. cardinalis* in Mexico: 10 exs, State of Baja California, Municipio Ensanada, Llano Colorado, 1,100 m, 7.V.1968. All the data given above confirm the occurrence of both *A. fimetarius* and *A. cardinalis* in Mexico.

N o t e s: The collection of the NHMW houses a male of *A. cardinalis* with a single printed label "Nagasaki". Judging by the outward style of the label, we suspect that the specimen was collected and labelled before the middle of the twentieth century. Since no other material from Japan has ever been recorded, we assume that the specimen was mislabelled. If not so, the species has been undoubtedly introduced to Japan.

N o t e s: Records from North Africa (e.g. BARAUD 1985: 182, AHRENS & ZORN 1996: 11, HOLLANDE & THÉROND 1999: 101, DELLACASA M. & G. DELLACASA 2006: 113) of *A. fimetarius* (sensu lato) relate no doubt chiefly to *A. cardinalis*. We have not seen any material of *A. fimetarius* (sensu stricto) undoubtedly originating from North Africa and cannot exclude that the few specimens studied are mislabelled; thus, we want to state that the occurrence of *A. fimetarius* in North Africa urgently requires confirmation.

Table 2: Distribution of *Aphodius fimetarius* and *A. cardinalis* (world-wide)

region/ country	species	n_1 (locs)	n_2 (exs)	diverse comments, indications of remarkable records
EUROPE				
Albania	*fimetarius*	3	9	occurring in mountainous regions
	cardinalis	-	-	so far no records; occurrence in coastal regions likely
Andorra	*fimetarius*	2	5	near Port d'Envalira at 2,200 m (SMNS)
	cardinalis	-	-	no records
Armenia	*fimetarius*	10	10	occurring up to 2,300 m near Sevan (SMNS)
	cardinalis	-	-	no records
Austria	*fimetarius*	374	1,364	evenly distributed and abundant, including high mountain regions, e.g. Stubai Alps (Serleskamm) at 2,200 m (SDEI)
	cardinalis	13	24	rare; records only from Tyrol, Upper and Lower Austria and Styria
Azerbaijan	*fimetarius*	4	7	without comments
	cardinalis	-	-	no records
Belgium	*fimetarius*	3	4	most probably more frequent than *A. cardinalis*
	cardinalis	1	1	single specimen from Dourbes, near Viroinval (ZSM)
Belarus	*fimetarius*	-	-	no material studied; given in DELLACASA M. & G. DELLACASA (2006)
	cardinalis	-	-	no records; occurrence unlikely
Bosnia and Herzegovina	*fimetarius*	11	20	records from Dinarian Mts, Makljan Prolaz, 1,120 m (cSZ)
	cardinalis	1	8	without comments

region/ country	species	n_1 (locs)	n_2 (exs)	diverse comments, indications of remarkable records
Bulgaria	*fimetarius*	62	176	rather evenly distributed and abundant
	cardinalis	5	5	scattered collecting sites, mostly near coast of Black Sea
Croatia	*fimetarius*	37	107	preferring mountainous regions; Monte Maggiore in Istria, 1,200 m (ZMHB), Velebit Mts, 1,100 m (SMTD); rare on Dalmatian islands: Krk (cDR)
	cardinalis	24	78	abundant at Adriatic coast and on Dalmatian islands; also in Istria; sporadically found in inner Croatia: Zagreb (NMP)
Czech Republic	*fimetarius*	133	363	rather evenly distributed and abundant
	cardinalis	2	2	Giant Mts (ZMHB) and in Hrubý Jeseník Mts ("Altvatergebirge: Hochschar"), 1,350 m (SMFM)
Denmark	*fimetarius*	7	21	without comments
	cardinalis	2	2	species' northern-most collecting sites: Apenrade (NMP) and Lolland (ZMFK)
Estonia	*fimetarius*	1	3	without comments
	cardinalis	-	-	species absent in Estonia; see also MIRALDO et al. (2014)
Finland	*fimetarius*	4	4	widespread and rather abundant (MIRALDO et al. 2014)
	cardinalis	-	-	species absent in Finland; see also MIRALDO et al. (2014)
France	*fimetarius*	115	254	rather evenly distributed and abundant, including high mountain regions (e.g. Savoy Alps, 2,600 m) **Corsica**: many collecting sites
	cardinalis	32	64	sparsely in Vosges Mts, near Paris, until Pyrenees (Val d'Ariège at Luzenac; SMNS); rather abundant at Riviera **Corsica**: few collecting sites (Forêt d'Ospedale; ZSM)
Georgia	*fimetarius*	18	35	coast of Black Sea (Suchumi; SMFM), also in mountains: Manglisi (ZMHB) and Kasbek (ZMFK)
	cardinalis	1	1	coast of Black Sea: Batumi (cAB)
Germany	*fimetarius*	1,081	3,779	many collecting sites and very abundant; from lower regions in north (e.g. East-Frisian Islands, Juist; SMFM) to Alps in south (e.g. Bavaria, Wetterstein Mts, 2,200 m; ZSM)
	cardinalis	135	274	distinctly rarer than *A. fimetarius*; rather evenly distributed in central and southern regions; rare in north; northern-most collecting sites on North-Frisian Islands (Sylt, Amrum, Föhr)
Great Britain	*fimetarius*	3	11	distributed in south, but also in more central regions (cf. also data in WILSON 2001, WHITEHEAD 2006 and MIRALDO et al. 2014)
	cardinalis	2	14	distributed more in south-east (cf. also data in WILSON 2001, WHITEHEAD 2006 and MIRALDO et al. 2014)
Greece	*fimetarius*	25	48	mostly in mountainous regions (Pindos, Pieria, Parnass, Taygetos), up to 1,700 m; also on Corfu (Vatos; cDR); lacking on Aegean Islands
	cardinalis	23	82	mostly in Mediterranean coastal regions; Taygetos Mts: Profitis Ilias, 2,200 m (see RÖSSNER 2012); also on Corfu (Nissaki; cEH)
Hungary	*fimetarius*	35	92	rather evenly distributed
	cardinalis	7	9	scattered collecting sites
Ireland	*fimetarius*	2	4	collecting sites in Cork and Clare counties (cSZ)
	cardinalis	1	1	collecting sites near north-western-most part of distribution area: Cork, Clonakilty (cSZ)
Italy	*fimetarius*	169	495	from Southern Tyrol (Außerraschötz near St. Ulrich, 2,100 m; SMNS) to Sicily; in Mediterranean parts preferring mountainous regions **Sardinia**: numerous collecting sites
	cardinalis	66	133	from Southern Tyrol (Bolzano) to Sicily; especially abundant near Mediterranean coast; on Elba and Sicily; highest record: Lago Scuro near Parma, 1,500 m (cSZ) **Sardinia**: so far no records

region/ country	species	n_1 (locs)	n_2 (exs)	diverse comments, indications of remarkable records
Latvia	*fimetarius*	14	30	without comments
	cardinalis	-	-	absent in Latvia; see also MIRALDO et al. (2014)
Lithuania	*fimetarius*	3	4	without comments
	cardinalis	-	-	absent in Lithuania; see also MIRALDO et al. (2014)
Luxemburg	*fimetarius*	2	5	without comments
	cardinalis	-	-	no records
Macedonia	*fimetarius*	5	9	Šar Planina near Popova Šapka, 2,000 m (ZMHB)
	cardinalis	-	-	no records
Moldavia	*fimetarius*	4	9	without comments
	cardinalis	-	-	no records
Montenegro	*fimetarius*	13	24	mostly in mountainous regions: Bjelasnica Planina (ZSM); near Prekornica and Žabljak up to 1,500 m (ZMHB, NMP)
	cardinalis	1	1	single specimen from Budva (UMJG)
Netherlands	*fimetarius*	4	4	without comments
	cardinalis	-	-	no material studied, but records published by WILSON (2001)
Norway	*fimetarius*	14	59	records from south (near Kornsjö; ZMHB) up to Lofoten (cSZ)
	cardinalis	-	-	species absent in Norway; see also MIRALDO et al. (2014)
Poland	*fimetarius*	28	107	rather evenly distributed and abundant; also in Giant Mts (Schneekoppe; Karpacz, 1,500 m; cER); in Tatra, 1,600 m; NME)
	cardinalis	1	1	single specimen from near north-eastern-most border of distribution area: Jugów (= Hausdorf) in Lower Silesia (SMFM)
Portugal	*fimetarius*	1	1	single specimen from Serra da Estrela
	cardinalis	16	106	few collecting sites, mainly in Algarve **Madeira**: 50 exs from six localities
Romania	*fimetarius*	19	33	widespread and most probably rather abundant
	cardinalis	1	1	single specimen from near north-eastern-most border of distribution area: Bușteni (SMFM)
Russia (including Asian part)	*fimetarius*	36	118	widespread and abundant in European Russia, including Caucasus; Asian Russia: southern Taiga region and southern mountains; selected colleting sites: **Southern European Russia**: coast of Black Sea: Sotschi (cER); Caucasus: Itkol region, 2,300 m (SMTD); Dagestan, Kurusch, 2,200-2,400 m (SMNS); Woronesch (ZMHB) **Central European Russia**: Nischni Nowgorod (ZMFK); Odinzowo (ZSM); Swenigorod, W Moscow (ZMHB) **Western Siberia**: Jenissej Mts N Krasnojarsk; Tomsk (SMFM); Nowosibirsk (SMNS); Altai, Shebalino (cSZ); Eastern-Altai, Tscholesman (ZMFK) **Eastern Siberia**: Minusinsk (SMFM); Tuwa, Khorumnung-Tayga Mts, 1,000 m (SMTD); Selenga Valley (ZMHB)
	cardinalis	-	-	species absent in entire Russia
Serbia	*fimetarius*	4	7	without comments
	cardinalis	-	-	so far no records, but occurrence rather likely
Slovakia	*fimetarius*	1	9	without comments
	cardinalis	-	-	no records
Slovenia	*fimetarius*	20	66	rather evenly distributed collecting sites
	cardinalis	-	-	so far no records, but occurrence rather likely

region/ country	species	n_1 (locs)	n_2 (exs)	diverse comments, indications of remarkable records
Spain	*fimetarius*	116	517	preferring more northern and mountainous regions **Balearics**: absent **Canary Islands**: absent
	cardinalis	196	1,457	preferring more southern and less mountainous regions **Balearics**: several records **Canary Islands**: absent
Sweden	*fimetarius*	8	18	occurring especially in south and on Gotland
	cardinalis	-	-	species absent in Sweden; see also MIRALDO et al. (2014)
Switzerland	*fimetarius*	24	81	evenly distributed and rather abundant
	cardinalis	2	2	rare; records from Uri (Unterschächen, Brunnital, 1,050 m; ZMHB) and Wallis (Binii, near Savièse, 1,050 m; cPS)
Ukraine	*fimetarius*	21	68	occurring until Kharkov in east and Crimea in south; many records from Carpathian Mts (e.g. Boržava Polonia: Veliky Vrh, 1,300 m)
	cardinalis	-	-	no records
NORTH AFRICA				
Algeria	*fimetarius*	1	3	two males and one female from "Alger" (ZMHB)
	cardinalis	8	30	occurring only in northern parts, not in desert
Egypt	*fimetarius*	1	1	one female from Lake Mairout, Nile Delta (SMFM)
	cardinalis	-	-	records of *A. fimetarius* (sensu lato) in DELLACASA M. & G. DELLACASA (2006) relating most probably to *A. cardinalis*, at least in part
Libya	*fimetarius*	-	-	no records; see below under *A. cardinalis*
	cardinalis	-	-	records of *A. fimetarius* (sensu lato) in DELLACASA M. & G. DELLACASA (2006) relating most probably to *A. cardinalis*
Morocco	*fimetarius*	-	-	no records
	cardinalis	17	53	highest collecting site near Azrou, 2,000 m (SMTD)
Tunisia	*fimetarius*	-	-	no records
	cardinalis	13	26	without comments
ASIA				
Afghanistan	*fimetarius*	4	6	preferring northern mountainous regions; Hindukusch, Walang in Salang valley; Nuristan, Bashgul valley, 1,100 m (ZMFK)
	cardinalis	-	-	no records
China	*fimetarius*	6	19	records from western and north-western provinces: Xinjiang (Sinkiang): Dsungarian Alatau, Djergalanka valley(ZMHB); Kuldscha [= Gulja]; Xizang (Tibet): Gartok [= Garyarsa] (SMTD)
	cardinalis	-	-	no records
Cyprus	*fimetarius*	-	-	no records
	cardinalis	8	13	cf. also record in WILSON (2001)
India	*fimetarius*	9	72	occurring only in great altitude in northern states: Jammu and Kashmir: Gurais (ZMHB); Ladakh, 3,700 m (cSZ); Pahalgam, 2,600 m (SMTD); Tangmarg, 2,600 m (SMNS); Himachal Pradesh: Jagatsukh, 2,800 m (cSZ); Keylong, 3,100 m (cAB, cOH); Kullu (SMTD); Uttarakhand: Mussoorie [= Masurie] (NMP)
	cardinalis	-	-	no records

region/ country	species	n_1 (locs)	n_2 (exs)	diverse comments, indications of remarkable records
Iran	*fimetarius*	17	33	records from northern and north-western mountains belonging to southern-most parts of distribution area; Alburz (Elburs) Mts: Gach Sar; Karaj Mts; Tacht-I Suleimar: 2,000-3,000 m; Azarbayjan-e Gharbi: Jolfa; Gilān: Masouleh near Fooman [Fuman], 1,400 m (all cSZ); Gichob (ZMHB); Rudbar, 1,100 m (NME); Qazvin: Ibrahim Abad, Talran, 2,300 m (NME); Māzandarān: Amir Kabir dam, 2,000 m; Chalus; Namak Abrood Mts, 1,050 m; Pole Sefid: 550 m (all cSZ); Nowshahr, Dozdc, at sea level (NME);
	cardinalis	-	-	no records
Iraq	*fimetarius*	-	-	no records
	cardinalis	2	2	records only in northern regions: Assur and Mossul (ZMHB)
Israel	*fimetarius*	-	-	no records
	cardinalis	19	130	without comments
Kazakhstan (including European part)	*fimetarius*	14	39	preferring southern mountainous regions: Alma Ata (NMP); Taraz (ZMFK); Narykol (SMFM); Tarbagatay Mts, Kirova [= Karatuma], 1,100 m; Ketmen Mts, Podgornoe, 1,800 m (all SMNS); Dsungarian Alatau, Koyandytau/Keskenterek (cSZ); Ili-region (ZMHB)
	cardinalis	-	-	no records
Kyrgyzstan	*fimetarius*	18	50	many records: Chichkan Valley, Toktogul (cDR); Talas Valley, ca. 1,250 m (ZMHB); Ferganskij Chrebet, Kara-Shoro National Park, 2,500 m (cAB); Ferganskij Alatau, Zailijskij Alatau; Upper Sussamyr Valley, 2,800 m (all SMNS)
	cardinalis	-	-	no records
Lebanon	*fimetarius*	-	-	no records
	cardinalis	5	7	without comments
Nepal	*fimetarius*	40	182	collecting sites with greatest altitude so far known, mostly between 2,000 and 3,000 m; eastern Nepal, Junbesi, Trognosa, 3,800 m (NME); Annapurna Mts, Manang, 4,000-4,500 m (SMNS) (cf. AHRENS & STEBNICKA 1997)
	cardinalis	-	-	no records
Pakistan	*fimetarius*	16	71	occurring up to more than 3,000 m: Dir: Lawarai pass, 2,700-3,300 m (cJS); Kāgān-Tal, Shogran, 2,300–3,000 m (cJS); Punjab: Lalla Marghina, E Faisalabad (ZMFK); Rawalpindi (ZSM); Muree-Mchata, 1,500 m; Muree-Sandhian; Swat: Kalam, 2,000 m; N Mingora; Kashmir: Rawalakot, Banjosa Lake (all cSZ)
	cardinalis	-	-	no records
Syria	*fimetarius*	-	-	no records
	cardinalis	12	21	without comments
Tajikistan	*fimetarius*	4	29	occurring in mountainous regions: Romet-valley near Dushanbe, 1,300 m (cER); Pamir, Kuliab (ZSM)
	cardinalis	-	-	no records
Turkey (including European part)	*fimetarius*	61	151	occurring especially in mountainous regions: near Black Sea (Trabzon; Aygir-pass, near Rize, 1,800 m; SMFM); Kars and Erzurum provinces; near Mediterranean Sea (Taurus, Antalya, 1,400 m; cDR)
	cardinalis	30	55	occurring along coasts of Black Sea and Mediterranean Sea; in part also in mountainous regions
Turkmenistan	*fimetarius*	12	23	occurring near Caspian Sea and in mountainous regions: Krasnowodsk [= Türkmenbaşy], ca. 30 m (cOH); Ashgabad (cER); Lake Kaiyndy: 2,000 m (NME); Langar Waschia: 2,640 m; Wachia, Dora-i-Charon: 2,500 m (ZMHB)
	cardinalis	-	-	no records

region/ country	species	n_1 (locs)	n_2 (exs)	diverse comments, indications of remarkable records
Uzbekistan	*fimetarius*	9	63	occurring in mountainous regions: Fergana (NMP); Chimgan, near Chirchiq, Melovoi pass: 1,500 m (cER)
	cardinalis	-	-	no records
NEARCTIC REGION				
Canada	*fimetarius*	5	43	Alberta: Elk-Islands-National Park (ZMHB); Montreal (ZMFK); Ontario: Dunnville; Windsor (SMTD)
	cardinalis	-	-	without comments
USA	*fimetarius*	17	43	Alaska: Chilkat-region; Massachusetts (ZMHB); Missouri: St. Louis; Buffalo; Pennsylvania: Wilmerding (ZMFK); New Mexico: Willard (NMP); New York (ZSM); Ohio (SMTD, ZMFK); Philadelphia (SMTD); Tennessee: Deer Lodge (SMFM); Texas: Dallas (cJS), Nacogdoches (cJS); Cedar Hill (cJS); Wyoming: Twin Lakes, 3,170 m (SMNS) (cf. also MIRALDO et al. 2014)
	cardinalis	2	14	Arizona: Yavapai (Dewey Fain Road) (SMNS); California: Warner, Hot Springs, San Diego (ZSM) (cf. also MIRALDO et al. 2014)
NEOTROPICAL REGION				
Mexico	*fimetarius*	1	3	State of Tamaulipa, Reynosa (ZMFK)
	cardinalis	1	3	southern Mexico, State of Puebla, Tehuacán (one specimen with elytra totally black; cGD)
AUSTRALIAN REGION				
Australia	*fimetarius*	-	-	no records
	cardinalis	4	5	Victoria, near Keith West (cML); North-Kangaroo Island (cML); Western Australia, near Bunbury (cAB); most probably introduced **Tasmania**: 2 exs from Freycinet Peninsula (cSZ); most probably introduced
sum		**3,324**	**11,436**	sum of localities and specimens studied of both species

Notes on the aberration *A. autumnalis* (NAEZEN, 1792)

NAEZEN (1792: 167) described *Scarabaeus autumnalis* as a valid species from Sweden. In the description he compared his new species with *A. fimetarius*; he called both rather similar, but emphasised that *A. autumnalis* has the pronotum ("thorax"), elytra, abdomen and legs testaceous. This aberration is on the one hand indeed rather similar to *A. fimetarius*; on the other hand, however, a collector who does not know this aberration might easily take it for another species, mainly due to the lack of the light red colour on the elytra (Fig. 6b). Generally it can be stated that its body length is smaller (5.0-5.6 mm) and the head, pronotum, scutellum, elytra, entire ventral surface, legs and antennae are yellowish brown to yellowish red-brown, but head and pronotum are mostly a little darker; the aberration is not uniformly coloured, but the contrast between differently coloured parts is rather small. To our knowledge, this aberration occurs only in late summer to early autumn. It appears mostly together with the nominate form and is found only in small numbers. N o t e s: The variety *imperfectus* MULSANT (1842: 187) seems to be the same as the ab. *autumnalis*.

The junior author has studied specimens from almost all German states (except Bremen, Hamburg, Hessen and Saarland; for the eastern German states see RÖSSNER 2012). Other localities in Europe are as follows: A u s t r i a: Damberg, Leonstein, Losenstein, Zell bei

Zellhof (all OLML), Michelbach, Herzogenburg, Neuhaus a. D., Ober-Radlberg, Ennstal (all NHMW), Fiss (ZSM), Gastein (SMFM), Waidisch (SMNS); Croatia: Lipik (SMTD), Plitvice (cJS); Czech Republic: Bechovice (NMP), Běleč nad Orlicí (NMP), Brno (SMFM), Harrachov (ZSM), Hlubočepy (NMP), Opatovice (NMP), Strakonice (NMP); Denmark: Grønnestrand bei Fjerrits (cJS); France: Faillefeu (ZSM), Hte. Saône (ZMFK), Col du Lautaret (ZMFK); Italy: Klausen (= Chiusa) (SMFM), Sankt Ulrich, Gröden (NHMW); Poland: West Prussia (SMFM); Slowenia: Wocheiner See (= Bohinjsko jezero) (ZSM); Spain: Cañizares (Cuenca province); Switzerland: Schaffhausen (SDEI), Tarasp (SMFM). One record from Asia has been already given in RÖSSNER (2012: 141): Nepal, Annapurna region, between Kutsuan and Thorung Phadi, 4,000-4,500 m (SMTD); another one is from Turkey, Adalia (SMFM). One specimen has been studied from the USA: Tennessee, Deer Lodge (SMFM).

Most interestingly, we have studied one Spanish female of *A. cardinalis* which shows the same aberrant characters as the ab. *autumnalis* of *A. fimetarius*: Muros, La Coruña province, 7.V.1990, Fery leg. (cHF).

Notes on colour varieties

Several colour varieties of *A. fimetarius* have been described by MULSANT (1842: 187) according to the extension and shape of the darkening of the normally reddish elytra:

- var. *maculipennis* (elytra with several black or blackish spots);
- var. *punctulatus* (each elytron with a large blackish macula of about three quarters of elytral length extended from the third to the sixth stria);
- var. *subluteus* (elytra yellowish red; this variety may be the same as *A. cardinalis*);
- var. *imperfectus* (seems to be the same as var. *autumnalis*, see above);
- ab. *paradoxus* HOFFMANN, 1929 (elytra totally black).

A variety with red abdomen (var. *hypopygialis* MULSANT, 1842) and another one which lacks the reddish anterolateral spots of the pronotum (var. *bicolor* MULSANT, 1842 = var. *bicolorellus* A. SCHMIDT, 1922) are not discussed here.

We want to emphasise that dark elytral spots are often pretended if the underside of the elytra is covered by grease and/or the hind wings are closely attached to the elytra etc. For instance, we have never studied specimens with several distinct black or blackish spots (var. *maculipennis*) and suspect that MULSANT (1842) described his variety from an artefact. However, specimens with one large spot on each elytron of variable extent and grades of black have been studied (see Figs 7a and 7b).

MULSANT (1842) did not give any hint on the collecting sites of his varieties. He lived in Lyon (France), and thus one might assume that he studied chiefly material from regions near that city, and maybe also from the Savoyan Alps, but we cannot be sure of this. We have not found any such specimens among our French material, but HOFFMANN (1929: 85) described his var. *paradoxus* with totally black elytra from Couzeix, Hte Vienne, in the south-western part of central France (altitude ca. 300-400 m). In Figs 10 and 11 we marked the respective collecting sites on the Iberian Peninsula and Austria by larger

circles with a dot in the centre. Here we did not care for the extension of the darkening and did not attribute the differently darkened specimens to any of the described varieties, because all transitions between these varieties can be found. According to our studies, such darker specimens occur always together with normally coloured specimens.

Among the examined material of *A. fimetarius* we have found dark varieties almost exclusively in the Austrian Alps (Northern Tyrol) and in the Italian Alps (Southern Tyrol): A u s t r i a: Biberwier, Gramais, Umhausen (all ZSM); Bludenz (NHMW); Galtür, Ischgl (all cHF); Grän, Trisanna (all SMNS), Weißenbach, Lechtal (cER); I t a l y: Mals (Vinschgau) (cJS), Spondinig (ZSM), Taufers (SMNS) (to give a more complete survey over the distribution of these dark varieties, we have included the Italian sites in Fig. 11). An exception from this alpine distribution is an almost totally black specimen from Winden am See, Burgenland, north-west of Lake Neusiedel (Austria). Specimens of *A. fimetarius* with darkened elytra from the Iberian Peninsula were not present in the material studied; however, to our great surprise we have found among the Iberian material of *A. cardinalis* the same kind of colour variety (see Fig. 7c) as in *A. fimetarius*, an observation which to our knowledge has never been reported before (also not under the name *A. fimetarius* sensu lato). These specimens have been found almost exclusively in the north-western part of the Iberian Peninsula: S p a i n : Asturias: Barro, near Llanes; La Coruña: Muros (cHF); León: Andiñuela, near Astorga (cHF), Villablino (MNCN); Lugo: Villardiaz, near Fonsagrada (cHF); Oviedo: Pto. de Ventana (MNCN); Pontevedra: Gondomar, near Tuy (MNCN); Zamora: Manzanal de Arriba (ZSM). P o r t u g a l: Minho: Viana, Serra de Arga (cHF); Guarda: Serra da Estrela, Torre (cJF, cHF). The only more southern record is a single specimen of *A. cardinalis* with darkened elytra found at Punta Arenas, Cádiz province, near Tarifa (cGD). N o t e s: A totally black male of *A. cardinalis* from Mexico is mentioned above in the section "Distribution in other countries".

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Zusammenfassung

Vielen Sammlern und vielleicht auch etlichen Spezialisten der Aphodien dürfte bisher entgangen sein, dass die bekannteste Art und gleichzeitig auch Typusart der Gattung *Aphodius* HELLWIG, 1798 von WILSON (2001) anhand chromosomaler Untersuchungen in zwei Arten aufgespalten wurde. Die vorliegende Arbeit beinhaltet überwiegend Ausführungen zur Morphologie, Taxonomie und Verbreitung dieser beiden Arten: *Aphodius* (s.str.) *fimetarius* (LINNAEUS, 1758) und *Aphodius* (s.str.) *cardinalis* REITTER, 1892. In der Einleitung wird außerdem darauf eingegangen, dass die Benennung der beiden Arten nicht unumstritten ist. Um unsere Wahl der Namen zu begründen, wird auch die augenblickliche Situation der Nomenklatur beider Arten dargestellt.

Die Verbreitung der beiden Arten wurde anhand von Material aus nahezu sämtlichen Ländern, von denen sie bekannt sind, untersucht. Dabei wurden etwa 12.000 Exemplare von etwa 3.500 Fundorten aus zahlreichen Museen und Privatsammlungen gesichtet. Den Schwerpunkt bildete dabei Material von der Iberischen Halbinsel, aus Österreich und Deutschland, weil wir einerseits von dort besonders viele Exemplare vorzuliegen hatten, und andererseits, weil diese Länder mit ihren verschiedenartigen geographischen Gegebenheiten und wegen des zum Teil sympatrischen Vorkommens beider Arten besonderes Interesse verdienen. Für die Verbreitung auf der Iberischen Halbinsel (Fig. 10) zeigt sich klar, dass *A. cardinalis* die häufigere Art ist und mehr südliche Regionen bevorzugt, sowie weiter im Norden solche mit vergleichsweise geringer Höhe (bis zu 1000 m in den Pyrenäen). Die andere Art dagegen ist eher im Norden anzutreffen und ansonsten meist in größerer Höhe (z. B. um 2000 m in der Sierra Nevada und in den Pyrenäen). *Aphodius cardinalis* kommt in Deutschland (Fig. 12) sehr viel weniger häufig vor als *A. fimetarius*, in Österreich (Fig. 11) ist er sogar ausgesprochen selten. Hier lassen sich kaum Regionen angeben, die von *A. cardinalis* eindeutig bevorzugt werden. Die Art ist jedoch auch in diesen Ländern meist nur in deutlich niedrigeren Lagen (planar bis submontan) zu finden. Dabei scheint es allerdings so, dass sie sich entlang der Täler größerer Flüsse ausbreitet und dabei auch in zum Teil montane Lagen vordringt (z. B. Warmberg, bei Garmisch-Partenkirchen, ca. 1000 m). *Aphodius fimetarius* dagegen steigt bis in alpine Höhen an (z. B. in Österreich auf 2200 m, Stubaier Alpen, Serleskamm oder auf gleiche Höhe in Deutschland, im Wetterstein-Gebirge, südlich von Garmisch-Partenkirchen). Unsere Untersuchungen der Verbreitung beider Arten bestätigen einerseits die von MIRALDO et al. (2014), andererseits kann die Anzahl der Länder, aus denen beide Arten identifiziert wurden, erheblich erweitert werden.

Es wird weiterhin gezeigt, dass beide Arten anhand extern- und genital-morphologischer Merkmale sicher bestimmt werden können. Die betreffenden Merkmale werden nach "starken" und "schwachen" unterschieden, ausführlich beschrieben, zum Teil durch Fotos illustriert sowie tabellarisch erfasst. Dies dürfte für die Mehrheit der Dungkäfer-Sammler von großem Interesse sein, denen keine Möglichkeiten zur Verfügung stehen, ihr frisch gesammeltes Material mit nicht-klassischen Methoden (d. h. molekulare und chromosomale Untersuchungen) zu bestimmen. Auch älteres Material (z. B. aus Museen) kann so sicher determiniert werden. Wie bei etlichen anderen nahe verwandten Art-Paaren kann es selbstverständlich – obwohl sehr selten – Exemplare geben, bei denen eine gewisse Unsicherheit bleibt (insbesondere bei weiblichen Exemplaren).

Zusätzlich können wir neue Erkenntnisse zur Verbreitung der var. *autumnalis* NAEZEN, 1792 des *A. fimetarius* geben sowie zu Varietäten dieser Art mit verdunkelten Flügeldecken, die uns bisher lediglich aus Frankreich und Österreich bekannt waren. Interessanterweise können ähnliche Varietäten erstmals auch für *A. cardinalis* von der Iberischen Halbinsel und sogar für Mexiko angegeben werden.

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