

Diversity and distribution of spiders (Arachnida: Araneae) in dry ecosystems of North Rhine-Westphalia (Germany)

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Abstract: The present study provides a robust data set for ecological planning and conservation of dry ecosystems in western Germany in general and North Rhine-Westphalia in particular. We summarised all available data from recent publications that dealt with spiders in dry ecosystems of North Rhine-Westphalia. Additionally, so far unpublished results of a detailed investigation regarding spiders in sand habitats of the Westphalian Bay that was conducted between 2006 and 2008 are presented. The analysis focussed on the habitat types according to Annex I of the EU Habitats Directive and related habitats. The investigation areas were scattered in the federal state of North Rhine-Westphalia. The data set comprised a total of 84436 individuals from 371 species and 28 families. Overall, an endangerment status is assigned to 68 species. Of these, 12 spiders are in imminent danger of becoming extinct. Two species, *Erigonoplus globipes* and *Meioneta simplicitarsis*, are believed to be extinct in North Rhine-Westphalia. Seven species (*Dictyna major*, *Mastigusa arietina*, *Micaria formicaria*, *Stylocetor romanus*, *Thanatus striatus*, *Theridion uhligi* and *Xysticus ferrugineus*) are new to the arachnofauna of North Rhine-Westphalia.

Keywords: biodiversity research, dry grassland, Flora-Fauna-Habitat directive, heathland, *Juniperus communis* heath, semi-dry grassland

In Germany, dry ecosystems, such as nutrient-poor sandy grasslands, dry heaths and semi-natural dry grasslands and scrubland facies on calcareous substrates are highly endangered (RIECKEN et al. 2006) and are listed in Annex I of the European Habitats Directive as priority habitat types (BALZER & SSYMANK 2005). Due to increasing cultivation, especially during the past 50 years, and the lack of disturbance (drifting sand, grazing, fire) the area of dry ecosystems has decreased considerably in northern and western Germany (DRACHENFELS 1996, VERBÜCHELN & JÖBGES 2000, JENTSCH et al. 2002, KRATOCHWIL 2004, PARDEY 2004).

Within the framework of conservation and ecological planning, updated and effective data sets concerning species inventories of endangered habitat types as well as distribution and ecology of habitat specialists are imperative. For example, stenotopic species are useful for the evaluation of the nature conservation status of a habitat and biotic communities and may render profuse management guidelines (cf. SCHNITTER et al. 2003). Furthermore, diversity studies and in particular diversity studies of arthropods

generally provide a wide spectrum of biogeographical and ecological probes for use in monitoring challenges (GARDNER 1991, KREMEN et al. 1993). In this context, spiders can play an important role since they are abundant, easy to record, occupy a wide array of spatial and temporal niches and respond immediately to habitat changes. Spiders provide robust data sets and statistical rigor within various kinds of ecological surveys (e.g. NEW 1999, SKERL 1999, SCHARFF et al. 2003, SCHMIDT et al. 2005, 2008, FINCH et al. 2007).

Information about the diversity and distribution of spiders in dry ecosystems of western Germany is poor (KREUELS et al. 2008). Thus, the aim of this study is to present a first complete catalogue of spiders that occur in dry ecosystems of North Rhine-Westphalia. For this purpose, we have summarised all available data from the recent literature and added previously unreleased results of detailed investigations concerning the ecology of spiders in sand habitats of the Westphalian Bay.

Study area

The investigation areas were scattered in the federal state of North Rhine-Westphalia that makes up part of the west and north-west of Germany (Fig. 1). The longest distance between areas was about 210 km (W-E) and 220 km (N-S). Most of the study areas were situated in the lowlands of North Rhine-Westphalia (Lower Rhine Valley, Westphalian Bay) with altitudes between 40 and 100 m a.s.l.. The climate

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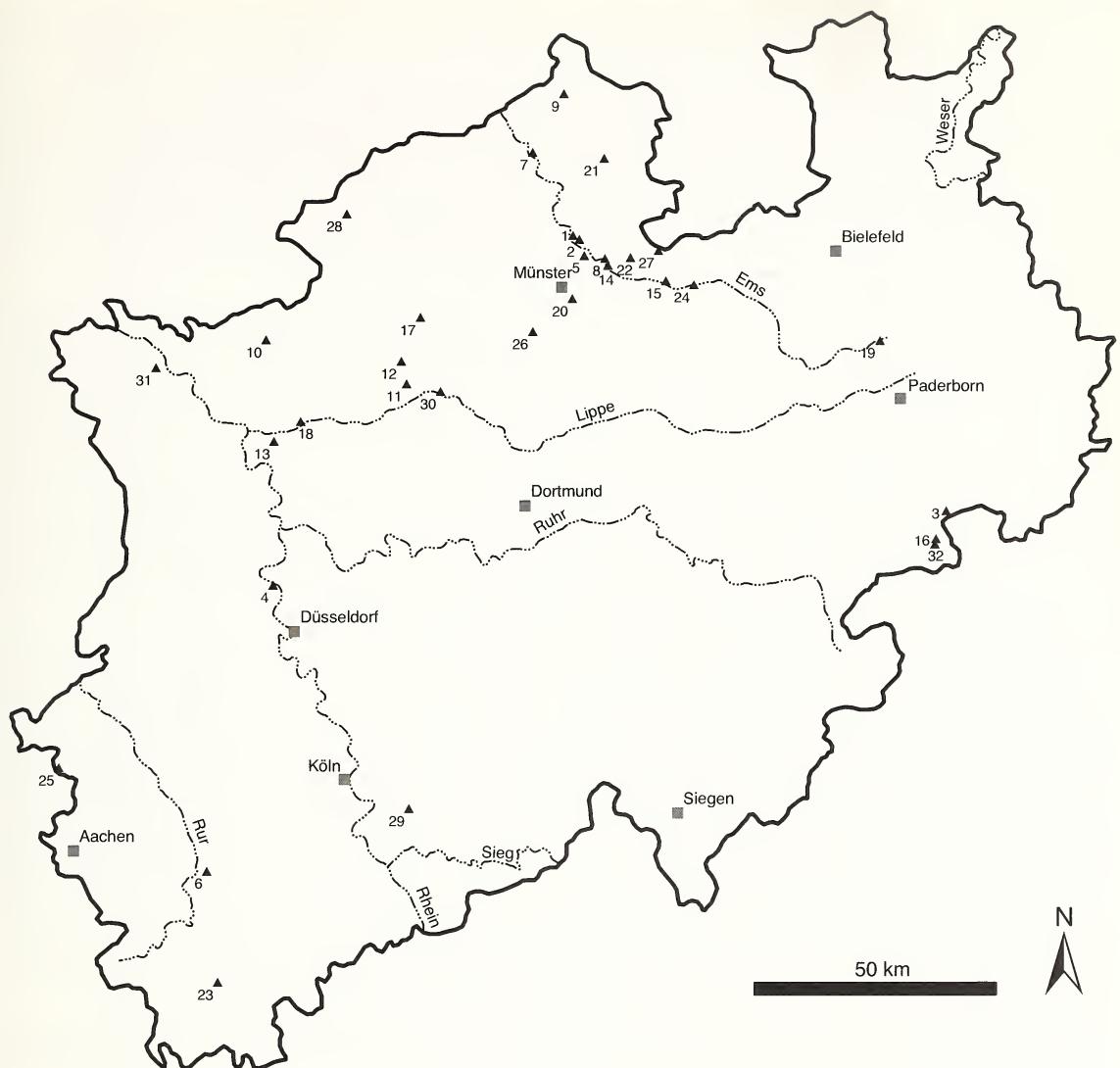


Fig. 1: Location of the investigation areas in North Rhine-Westphalia Geographical explanations: 1 = Bockholter Berge (TK25 3912-1), 2 = Boltenmoor (3912-1), 3 = Dahlberg (4419-3), 4 = Die Spey (4606-3), 5 = Dorbaum (3912-3), 6 = Drover Heide (5205-3), 7 = Elter Sand (3711-3), 8 = Emsaue (3912-4), 9 = Heiliges Meer (3611-2), 10 = Hohenhorster Berge (4105-4), 11 = Holtwicker Wacholderheide (4208-2), 12 = Hüstener Wacholderheide (4208-2), 13 = Kaninchenberge (4306-3), 14 = Klatenberge (3912-4), 15 = Kooksheide (4013-2), 16 = Kregenberg (4519-3), 17 = Letter Wacholderheide (4109-1), 18 = Loosen Berge (4306-2), 19 = Moosheide (4118-1/3), 20 = Münster (4011-4), 21 = Osterklee (3712-4), 22 = Schirlicheide (3913-3), 23 = Stolzenburg (5405-3), 24 = Talgraben (4014-1), 25 = Teverener Heide (5002-1/3), 26 = Venner Moor (4111-1), 27 = Vinnenberg (3913-4), 28 = Wacholderheide Hörsteloe (3907-1), 29 = Wahner Heide (5108/5109-1), 30 = Westruper Heide (4209-3), 31 = Wisseler Dünen (4203-2), 32 = Wulsenberg (4519/3).

is sub-Atlantic with a mean annual temperature of 9.5 to 10 °C and mean annual precipitation of 700 to 750 mm. Further study areas were located in the geographic region of the Eifel (Stolzenburg) and the Süder mountains (Hochsauerland: Dahlberg, Kregenberg, Wulsenberg) at an elevation of 450 m a.s.l.

and about 345 m a.s.l., respectively. Both regions are characterised by mean annual temperatures below 7 °C and more than 1000 mm of annual precipitation. For further detailed information on the landscape and natural regions of North Rhine-Westphalia see DINTER (1999) and LÖBF (2005).

Methods

All available data from recent publications that dealt with spiders in dry ecosystems of North Rhine-Westphalia were condensed into this study. Here, we analyse mainly the investigation sites representing the habitat types according to Annex I of the EU Habitats Directive (2310 - Dry sand heaths with *Calluna* and *Genista*; 2330 - Inland dunes with open *Corynephorus* and *Agrostis* grasslands; 4030 - European dry heaths; 5130 - *Juniperus communis* formations on heaths or calcareous grasslands; 6210 - Semi-natural dry grasslands and scrubland facies on calcareous substrates) (cf. BALZER & SSYMANIK 2005) and related habitats like semi-dry grasslands, dry *Avenella*-grasslands as well as ruderalised dry grasslands and heathlands. Investigation sites that could not be clearly assigned to one of the above listed habitat types were excluded from the analysis. Furthermore, so far unpublished results of a detailed investigation of spiders in sand habitats of the Westphalian Bay that was conducted between 2006 and 2008 are presented. A detailed overview of the investigated sites, study periods and methods is given in Tab. 1. Due to the differences in methodology, sampling intensity and investigation period, this study should only provide a qualitative description of the species inventories. All information on distribution and status of endangerment spiders of North Rhine-Westphalia were taken from KREUELS & BUCHHOLZ (2006) and KREUELS et al. (2008).

Results

A total of 84436 individuals from 371 species and 28 families were summarised (Table 2). Altogether, for 67 species a status of endangerment is given. Apart from 22 species of category V (endangerment may be assumed), 22 endangered (category 3) and 9 highly endangered (category 2) species, 12 spiders are in imminent danger of becoming extinct (category 1). Furthermore, the linyphiid spiders *Erigonoplus globipes* and *Meioneta simplicitarsis* are now considered extinct in North Rhine-Westphalia (category 0). The records of seven species (*Dictyna major*, *Mastigusa arietina*, *Micaria formicaria*, *Styloctetor romanus*, *Thanatus striatus*, *Theridion ubligi* and *Xysticus ferrugineus*) new to the arachnofauna of North Rhine-Westphalia are noteworthy. Further faunistically interesting species discovered during this study were *Agnyphantes expunctus*, *Diplocephalus connatus*, *Halorates reprosus*, *Hypselites jacksoni* and *Linyphia tenuipalpis*, all of which are extremely rare in North Rhine-Westphalia and Germany.

Discussion

Seven species have been recorded for the first time for the arachnofauna of North Rhine-Westphalia: According to STAUDT (2009), the rare *Dictyna major* is mainly distributed in northern Germany, for example in dune habitats (HEYDEMANN 1964, SCHULTZ & PLAISIER 1995) and dry grasslands (BOCHMANN 1941, MERKENS 2002). This species also seems to inhabit dry *Pinus* forests (SCHAEFER 1980, SIMON 1995).

Mastigusa arietina has so far only been recorded in southern and eastern Germany (STAUDT 2009). The biology and ecology of this rare species is rather unclear. According to MARTIN (1983) *Mastigusa arietina* is a myrmecophil spider that occurs exclusively in nests of *Formica rufa* ants. However, SIMON (1995) and KIELHORN & BLICK (2007) found this species at trees and on treetops, respectively. These records may explain the scarcity of this spider since pitfall traps seem to be an inappropriate method to study these strata.

The gnaphosid *Micaria formicaria* is classified as a xerophilous species that inhabits mainly dry and semi-dry grasslands and *Juniperus* heaths (HAUK 1996, PLATEN et al. 1999) but also occurs in open pastures (HÄNGGI & BAUR 1998) and dry forest edges (BAUCHHENSS 2002). According to BAUCHHENSS (1995) and BAUR et al. (1996), *Micaria formicaria* inhabits sandy substrates as well as calcareous soils. This species is distributed mainly in the south-western regions of Germany (LEIST 1978, BAEHR & BAEHR 1984, HAUKE 1996) but is also found in eastern Germany (PLATEN et al. 1999, STAUDT 2009).

The linyphiid *Styloctetor romanus* was recorded mainly in southern and eastern Germany (STAUDT 2009) but also seems to be distributed in northern Germany (MERKENS 2002). According to MARTIN & UHLIG (1986), SACHER & BREINL (1999), PLATEN et al. (1999), RATSCHKER (2001), SACHER (2001) and SCHNITTER et al. (2003), this species is a typical inhabitant of dry grasslands or dry ecosystems in general (for example dry fallow land), respectively. In contrast, GÖTZE (1992) found a single individual in a salt marsh of northern Germany.

On the other hand, up to now, *Thanatus striatus* has been found in a variety of different habitat types, such as dry and semi-dry grassland (HÖREGOTT 1958, HEYDEMANN et al. 1994, KUSCHKA 2004, AL HUSSEIN & LÜBKE-AL HUSSEIN 2007), heathlands (SCHMIDT & MELBER 2004), humid habitats (NENTWIG 1983, PLATEN et al. 1999, STAUDT 2000), salt

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Tab. 1: Overview of investigated sites, study periods and study designs. (*) = 20 % glycerin and 1% thymol added. (**) = according to RENNER (1982); ethanol + acetic acid + glycerin + water. (***) = hitherto unpublished data. Habitat types: A = bare sand, B = dry sand heaths with *Calluna* and *Genista* (FFH-code 2310), C = inland dunes with open *Corynephorus* and *Agrostis* grasslands (FFH-code 2330), D = European dry heaths (FFH-code 4030), E = *Juniperus communis* formations on heaths or calcareous grasslands (FFH-code 5130), F = semi-natural dry grasslands and scrubland facies on calcareous substrates (FFH-code 6210), G = *Avenella* dominated dry grassland, H = semi-dry grassland, I = ruderalised semi-dry and dry grassland.

no	area	Habitat types	TK25	N	E	M sites asl	traps per site	Investigation period	Preservation fluid	reference
1	Bockholter Berge	C	3912-1	52°03'30.21"	07°39'39.05"	50	3	4	08.2006-07.2008	4% formalin
2	Boltenmoor	C	3912-1	52°01'18.58"	07°41'10.12"	55	2	4	08.2006-07.2008	4% formalin
3	Dahlberg	F	4419-3	51°30'10.76"	08°54'19.24"	275	2	5	04.1991-10.1996	4% formalin
4	Die Spey	I	4606-3	51°20'10.01"	06°42'03.49"	25	4	3	06.1992-09.1992	80% ethanol (**)
5	Dorbaum	B, C, H	3912-3	52°01'23.06"	07°42'48.17"	50	5	5	04.2002-04.2003	3% formalin
6	Droven Heide	D	5205-3	50°43'58.07"	06°31'41.08"	205	5	1	05.2006-05.2007	unknown
7	Elter Sand	A, B, C, E	3711-3	52°13'27.45"	07°32'02.04"	55	5	3	05.2005-10.2005	4% formalin
8	Emsaue	C	3912-4	52°01'03.87"	07°46'22.35"	45	1	4	08.2006-07.2008	4% formalin
9	Heiliges Meer	A, B	3611-2	52°21'12.11"	07°38'02.91"	45	4	4	08.2006-07.2008	4% formalin
10	Hohenhorster Berge	C	4105-4	51°49'55.52"	06°39'17.98"	30	1	4	08.2006-11.2006	4% formalin
11	Holtwicker Wacholderheide	E	4208-2	51°45'00.04"	07°07'36.68"	90	1	4	08.2006-07.2008	4% formalin
12	Hüstener Wacholderheide	E	4208-2	51°47'52.03"	07°06'30.24"	80	1	4	08.2006-07.2008	4% formalin
13	Kaninchenthalberge	A, B	4306-3	51°37'39.13"	06°41'46.52"	25	4	3	06.1992-09.1992	80% ethanol (**)
14	Klatenberge	C	3912-4	52°01'16.73"	07°47'02.70"	60	1	4	08.2006-07.2008	4% formalin
15	Koeksheide	A	4013-2	51°58'13.99"	07°59'03.28"	60	1	5	05.1992-08.1992	unknown
16	Kregenberg	F	4519-3	51°26'25.64"	08°51'51.45"	330	4	5	04.1991-10.1996	4% formalin
17	Letter Wacholderheide	B, C	4109-1	51°53'12.09"	07°10'05.81"	75	1	4	08.2006-07.2008	4% formalin
18	Loosen Berge	A, I	4306-2	51°40'07.82"	06°46'40.70"	35	3	3	06.1992-09.1992	80% ethanol (**)
19	Moosheide	A, B, C, H	4118-1/3	51°51'18.71"	08°40'58.69"	130	5	4	08.2006-07.2008	4% formalin
20	Münster	A, C, I	4011-4	51°55'59.75"	07°39'48.13"	60	7	3	04.2000-07.2000	brine
21	Osterklee	F	3712-4	52°13'17.86"	07°45'38.91"	110	1	4	04.2008-07.2008	4% formalin
22	Schirfheide	D	3913-3	52°00'37.30"	07°51'14.58"	60	1	5	06.2008-10.2008	Renner (**)
23	Stolzenburg	F	5405-3	50°30'55.82"	06°34'00.57"	450	1	10	04.1971-09.1971	4% formalin
24	Talgraben	A	4014-1	51°57'15.53"	08°01'36.96"	50	1	5	05.1992-08.1992	unknown
25	Teverener Heide	A, C, D	5002-1/3	50°57'35.05"	06°04'08.22"	90	5	5	2004	5% acetic acid
26	Vennster Moor	D	4111-1	51°51'51.16"	07°32'14.25"	65	1	4	05.2007-10.2007	4% formalin
27	Vinnerberg	I	3913-4	52°01'33.96"	07°58'01.35"	55	1	5	05.1992-08.1992	unknown
28	Wacholderheide Horsteloe	C, E	3907-1	52°05'45.50"	06°54'43.20"	50	2	4	08.2006-07.2008	4% formalin
29	Wahnert Heide	A, C, D	5108/5109-1	50°52'19.48"	07°10'06.46"	100	4	5	01.1994-10.1994	70% ethanol
30	Westruper Heide	B, E, G	4209-3	51°44'07.03"	07°14'16.47"	45	7	4	08.2006-07.2008	4% formalin
31	Wisseler Dünen	A, C	4203-2	51°46'03.44"	06°17'57.39"	15	3	3	06.1992-09.1992	80% ethanol (**)
32	Wulsenberg	F	4519-3	51°26'44.13"	08°51'59.72"	345	4	5	04.1991-10.1996	4% formalin

meadows (SPARMBERG & SACHER 1997, BARNDT 2007, FINCH et al. 2007) and dunes (HEYDEMANN 1964, SCHULTZ 1992). *T. striatus* is distributed all over Germany (STAUDT 2009).

MARTIN (1973a) described the theridiid spider *Theridion ubligi*. He found specimens during an investigation of the nature reserve Rietzer See (cf. MARTIN 1973b). Since then, this species has only been recorded in very few studies in dry grasslands of eastern Germany (PLATEN et al. 1999, JAKOBITZ 2003, STAUDT 2009). Conversely, *T. ubligi* was recorded in dry grasslands and heathlands in the Netherlands and Belgium (JOCQUÉ 1977, KEER & VANUYTVEN 1993, PRINSEN 1996, HELSDINGEN 1999) so that the distribution gap is closed now. One further record refers to DUMA (2008) who found *T. ubligi* in a dry and sandy place of south-eastern Romania. According to HERZOG (1968), BAUCHHENSS (1995), PERNER (1997), PLATEN et al. (1999) and SACHER (2002), the thomisid *Xysticus ferrugineus* is stenotopic of dry and calcareous grasslands. This species is known from only few locations in central and eastern Germany (STAUDT 2009).

The linyphiid spiders *Erigonoplus globipes* and *Meioneta simplicitarsis* are now considered to be extinct in North Rhine-Westphalia:

E. globipes was last recorded by KREUELS (1998b). Due to destruction of the former locations caused by land-use, this population has disappeared. Since then, this species has been considered to be extinct in North Rhine-Westphalia (KREUELS & BUCHHOLZ 2006). *E. globipes* is distributed mainly in higher altitudes of central and southern Germany (BRAUN 1960, BAEHR & BAEHR 1984, BAUCHHENSS & SCHOLL 1985, JOGER 1997) and seems to be absent in the lowlands (STAUDT 2009). According to all the previous records, this species is stenotopic for dry calcareous grasslands (BAEHR 1988, KÖHLER et al. 1989, PERNER 1997). *Meioneta simplicitarsis* is a rare species that has until now been found in eastern Germany (e.g. SACHER & BREINL 1999), Rhineland-Palatinate (WEBER 1999) and North Rhine-Westphalia (CASEMIR 1982). It seems to prefer dry grasslands (BRAUN 1969, BUCHAR & RŮŽIČKA 2002) but also occurs in wet meadows and pastures (HEIMER & NENTWIG 1991, KREUELS & BUCHHOLZ 2006).

Agnyphantes expunctus, *Diplocephalus connatus*, *Halorates reprosus*, *Hypselites jacksoni* and *Linyphia tenuipalpis* are rarely distributed to North Rhine-Westphalia in particular and Germany in general

(KREUELS et al. 2008, STAUDT 2009). *Agnyphantes expunctus* seems to be restricted to humid habitats in low mountain ranges and mountains, e.g. in the Eifel (CASEMIR 1976, 1982), Harz (HEIMER 1980, SACHER 1997, 1998) and the Alps (KREUELS & LÜCKMANN 1998, MUSTER 2001). *Diplocephalus connatus* apparently prefers humid habitats as well (HÄNGGI et al. 1995, KREUELS & BUCHHOLZ 2006) and was hitherto sporadically recorded in western and central Germany (MORITZ 1973, ALBRECHT et al. 1994, ESSER 1997). Furthermore, *Halorates reprosus* was rarely found in the northern part of North Rhine-Westphalia (BUCHHOLZ & KREUELS 2005) and single locations along the Rhine (BRAUN 1960) and the North Sea coast (HELDINGEN 2003, STAUDT 2009). Apart from southern Germany, *Hypselites jacksoni* was sampled in northern (SCHAEFER 1970, 1972), western (CASEMIR 1960, 1976, RASKIN 2000) and eastern (HERZOG 1974, HIEBSCH 1985, OTTO et al. 2001) parts of the country. According to previous records, both, *Halorates reprosus* and *Hypselites jacksoni* apparently prefer humid habitats (cf. HÄNGGI et al. 1995). Finally, *Linyphia tenuipalpis* is mainly distributed to the lowlands (e.g. NW-Germany: MERKENS 2002, SCHMIDT & MELBER 2004; NE-Germany: PLATEN et al. 1999, SCHNITTER et al. 2003, BARNDT 2005; Netherlands: TUTELAERS 2000, 2001) with southernmost records in Thuringia (MALT & PERNER 2002).

When working with the present data one has to consider several taxonomical problems. For example, *Alopecosa accentuata* and *Alopecosa barbipes* are closely related species that were once considered to be synonyms. However, several studies have confirmed the separation of both species (DAHLEM et al. 1987, CORDES & HELVERSEN 1990, CORDES 1995, VINK & MITCHELL 2002). On the other hand, at least the identification of female specimens is very difficult, while males can be clearly distinguished by the hair coat on Tibia I. Furthermore, both species show a different phenology and distribution (CORDES & HELVERSEN 1990, STAUDT 2009). Nevertheless, SCHMITT (2008) stated that several authors might have ignored the differences between both species found during previous studies, which makes the current status of *A. accentuata* and *A. barbipes* questionable. Consequently, we checked specimens from most of the lowland sites (2, 5, 7, 9, 10, 19, 21, 30) and one highland site (16). As a result of this, we state that all lowland records belong to *Alopecosa barbipes* while individuals from the low mountain ranges belong

to *A. accentuata*. Thus, former data on *A. accentuata* that were published by BUCHHOLZ & HARTMANN (2008) and BUCHHOLZ (2008) have to be transferred to *A. barbipes*.

Further taxonomic questions arise concerning *Dicymbium nigrum brevisetosum* which was first described by LOCKET (1962) and WIEHLE (1965) as a form and recognised as a species by LOCKET et al. (1974). Later, THALER (1986) discussed the existence of further forms of *Dicymbium nigrum* s. str. in the southern Alps. Finally, ROBERTS (1987) downgraded *D. n. brevisetosum* back to a form. This taxonomical problem is not completely solved yet, but differences in the hair coat of Tibia I which is considerably shorter in *D. n. brevisetosum* might justify the separation of both as valid species. Both have been recorded from Germany (WIEHLE 1965, HARMS 1987) but it is assumed that numerous records of *Dicymbium nigrum* s. str. might belong in fact to *D. n. brevisetosum* since, for example, drawings of the first one given in the reference guide of NENTWIG et al. (2003) in truth refer to *D. n. brevisetosum* (cf. WIEHLE 1960, 1965). Hence, we checked all available material and exclusively found specimens with short hair coats on Tibia I which according to ROBERTS (1987) indicated the occurrence of only *Dicymbium nigrum brevisetosum* within the study area. Consequently, records for *Dicymbium nigrum* published by BUCHHOLZ & HARTMANN (2008) and BUCHHOLZ (2008) have to be adjusted to *D. n. brevisetosum*.

Finally, we have to keep in mind the fact that several parts of North Rhine-Westphalia are hitherto poorly investigated. Especially for the eastern and southern parts of the federal state (e.g. Sauerland, Weserbergland), as well as for the mountains of the Eifel, faunistic records are almost entirely missing (KREUELS et al. 2008). This is a drawback for this study since large parts of the semi-natural dry grasslands and scrubland facies on calcareous substrates are situated in these regions and thus remained undersampled yet. As opposed to this, the coverage level for dry and sandy heathlands and grasslands has been thoroughly improved within detailed studies during the last years.

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Tab. 2: Species list (nomenclature follows Platnick 2009). Abbreviations: End = status of endangerment in North Rhine-Westphalia (according to KREUELS & BUCHHOLZ 2006); * = not endangered, V = endangerment may be assumed, R = extremely rare, not declining species, 3 = endangered, 2 = highly endangered, 1 = in imminent danger of becoming extinct, 0 = extinct, nr = new record for North Rhine-Westphalia, ? = hitherto not assessed; Dis = Distribution: C = species that exclusively occurred on calcareous substrates.

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