



A survey of lifespans in Oribatida excluding Astigmata (Acari)

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Abstract

This contribution provides an update on the duration of life cycles and lifespans of oribatid mites based on a literature review. The total lifespan is the sum of the immature developmental time (egg to adult) and the longevity of the adult. Most investigations were carried out in the laboratory, few were performed in the field, under field conditions and/or compared with field data. Many life cycles were investigated under different environmental influences. The life cycles of 144 oribatid species are listed. Compared with the total number of known oribatid species, this number is very low. Data for the total lifespan are given for 52 species, either from observations in the laboratory or estimated in comparison with field studies, but can only be guesses of the real lifespan. The typical lifespan of an oribatid species in temperate or boreal regions lasts between 1 and 2 years, rarely 3 years. The few investigated tropical species from laboratory experiments show generally faster development and shorter lifespans as species from temperate regions; no field studies have been carried out in the tropics yet. Long lifespan periods of 5 to 8 years are particularly characteristic of species in polar regions and in mountainous temperate regions. Some examples of species with different longevity in distinct climate regions, very long lifespans and change of life parameters under stressful laboratory conditions are presented.

Keywords: life-history, life cycle, development, longevity, generation time

Introduction

The oribatid mites (Acari, Oribatida) are a large group of minute free-living organisms, mainly terrestrial in organic soil litter, in moss or on trees, some species are aquatic (Behan-Pelletier & Eamer 2007; Schatz & Behan-Pelletier 2008), and some occur in the marine littoral zone (Pfingstl 2017). At present there are about 11.500 species known (Subías 2004, unpublished update 2021). The Astigmata, which have phylogenetic relationships to Oribatida (Norton 1998), have evolved different morphological and biological characters and largely a different mode of life, and are not considered here.

The ontogenetic development of Oribatida shows the complete sequence of the Chelicerata with six postembryonic instars: an immovable and inactive prelarva, a hexapod mobile larva, three octopod nymphal stages (proto-, deuto-, tritonymph, all morphologically differentiated by further development), and the reproductive adult stage (Walter & Proctor 2013). Variations and exceptions from this scheme are known in some larviparous taxa, mainly in aquatic and marine littoral environment (Norton 1994; Behan-Pelletier & Eamer 2007). All instars from larva to adult are separated by moulting. It should be noted that Oribatida have an unusually high rate of parthenogenesis. Almost 10% of the known species may be thelytokous, most concentrated in a few families (Norton & Palmer 1991; Norton *et al.* 1993). Generally, Oribatida are “K-strategists” with low metabolic rate, low fecundity and reproductive output, and comparatively longer life cycles (Mitchell 1977a; Norton 1994; Norton & Behan-Pelletier 2009). Most species are iteroparous with relatively long-living adults (Norton *et al.* 1993). Few exceptions from this scheme are known from species in extreme or unpredictable habitats (such as hot deserts, fresh water), with short developmental times and high reproduction rates characteristic for opportunistic “R-strategists” in unstable ecosystems (Wallwork 1980; Fernandez & Athias Binche 1986; Wallwork *et al.* 1986).

The total lifespan of an oribatid mite is the sum of the immature developmental time and the possible longevity of the adult. It is therefore essential for the estimation of total lifespan to consider the development from egg to adult. The term “life cycle” is mostly used as development from egg of the first generation to the egg of the second generation (generation time). Norton and Ermilov (2014, unpublished update 2021) list almost 900 oribatid species with morphological descriptions of juvenile instars. C.L. Koch described and named some immature oribatid mites (e.g., Koch 1835; 1839; 1841) although he was not aware that these were juvenile instars. Nicolet (1855) was the first author who studied the development of oribatid species in the laboratory, followed by Michael (1880) who also recognized the “potential for juveniles to inform classification” (a detailed history of studies on immature oribatid mites is given in Norton & Ermilov 2014).

Michael (1884) observed the developmental time of some oribatid species in the laboratory. Since then, the duration of development from egg to adult has been published frequently. Most investigations were carried out in culture under simple laboratory conditions at room temperature (e.g., Michael 1884; Grandjean 1950), some combined with feeding experiments (e.g., Denmark & Woodring 1965; Seniczak *et al.* 2016), or under controlled constant or variable temperature regimes (e.g., Woodring & Cook 1962; Weigmann 1975; Bhattacharya *et al.* 1978), or under seminatural conditions which approximated field conditions (in field enclosures, e.g., Harding 1971, Lebrun 1971), some were also compared with the phenology from the field data (e.g., Block 1965; Lebrun 1970b; Weigmann 1975; Bellido 1979; Luxton 1981b; West 1982). Older data on developmental rates have been summarized by Lebrun (1970a—36 species), Luxton (1981a—51 spp.), Kaneko (1988b—43 spp.) and Grishina (1991—75 spp.). In the recent decades the studies of life cycles declined and concentrated on a few species (see results and Table 1). The causes of the differing lengths of life cycles such as species-specific, ecological or phylogenetic aspects have been discussed by several authors (e.g., Mitchell 1977a; Luxton 1981a; Norton *et al.* 1993; Norton 1994; Siepel 1994; Lebrun *et al.* 1991; Lebrun & van Straalen 1995; Bale *et al.* 1997; Belozarov 2008). Norton (1994) outlined the resulting consequences for survivorship and mortality from the available data from field and laboratory observations.

In contrast to the frequently investigated life cycles, the total lifespan of Oribatida has been observed or calculated much less frequently. Luxton (1981a) provided a list of the longevity in the laboratory for 13 species of adult oribatid mites, based on the results of different authors. This contribution, as a literature review, summarizes the present stage of studies on lifespan of oribatid mites.

TABLE 1. Lifespan data (in days) for oribatid mites observed in laboratory or in field studies. ‘Longevity’ refers only to the duration of adult stage, ‘lifespan’ gives the full duration of life including juvenile development. ‘Egg–adult’ is the time from egg deposition to hatching of the adult (mostly referred to as developmental time or life-cycle) and ‘egg–egg’ is the time from egg deposition of the first generation to egg deposition of the second generation (also frequently referred to as generation time).

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
Palaeacaridae						
<i>Palaeacarus kamenskii</i>	-	240	91	-	lab / 25°C	Shereef (1972)
Brachychthoniidae						
<i>Eobrachychthonius oudemansi</i>	-	-	730	-	field / subantarctic climate	West (1982)
Hypochthoniidae						
<i>Eohypochthonius magnus</i>	-	-	420-450	730	field	Kaneko (1989), Japan
<i>Hypochthonius rufulus</i>	-	-	-	730	field	Luxton (1981a), Denmark
	-	-	122	-	lab / 25°C	Sengbusch (1958b)
	<2	-	-	-	lab / 5–25°C	Madge (1964), reaction to temperature and relative humidity
Lohmanniidae						
<i>Lepidacarus ornatissimus</i>	-	-	178	-	lab / 30±1°C	Haq & Adolph (1981)
<i>Papillacarus aciculatus</i>	730	-	71	95	lab / 25°C	Shereef (1976b)

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TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
<i>Papillacarus egypticus</i>	730		101	116	lab / 25°C	Shereef (1976b), sub <i>Lohmannia egypticus</i>
Mesoplophoridae						
<i>Archoplophora rostralis</i>	-	-	-	730	field	Kaneko (1989), sub <i>Archoplophora villosa</i> , Japan
Euphthiracaridae						
<i>Acrotritia clavata</i>	-	-	61–72	-	lab / 28±2°C	Syamjith & Ramani (2020)
<i>Euphthiracarus</i> sp.	-	-	64	-	lab / 25°C	Rohde (1955)
<i>Pseudotritia</i> sp.	-	-	64	-		Rohde (1955)
Phthiracaridae						
<i>Steganacarus</i> cf. <i>striculus</i>		-	730	-	field / 0–15°C	Hagvar (1998)
<i>Steganacarus magnus</i>	-	730– 1095	400	-	lab / 18°C	Webb (1977)
	550–688	950	400	500	lab / 11.6–18°C	Webb (1989)
Trhypochthoniidae						
<i>Allonothrus giganticus</i>	-	-	30–51	-	lab / 29±1°C	Ramani & Haq (1993), different food
<i>Archegozetes longisetosus</i>	-	-	30–65	60–228	lab / 23°C	Bergmann (2006)
	-	126–280	32–88	-	lab / 28°C	Seniczak (1998), Brückner <i>et al.</i> (2018), reared on different diets
	-	-	32–65	-	lab / 22–31°C	Haq & Adolph (1981), Heethoff <i>et al.</i> (2007), Honciuc (1996)
	10–88	-	27–58	-	lab / 30°C	Seniczak <i>et al.</i> (1998, 2005, 2006, 2009), Seniczak & Seniczak (2002), tested effects of toxic metals
<i>Mainothrus badius</i>	-	-	59–114	-	lab / 19–22.5°C	Ermilov (2008)
<i>Trhypochthoniellus brevisetus</i>	-	> 1825	1825	-	field	Kuriki (1995), Northeast Japan mountainous area
<i>Trhypochthoniellus longisetus</i>	-	-	66–148	-	lab / 19–22.5°C	Ermilov (2008)
<i>Trhypochthoniellus crassus</i>	-	58–208	-	-	lab / 15–25°C	Kuriki (2010), sub <i>Trhypochthoniellus crassus</i>
<i>Trhypochthonius tectorum</i>	-	-	49–116	-	lab / 17–20°C	Ermilov <i>et al.</i> (2004)
	-	-	49–116	-	lab / 17–20°C	Ermilov (2008)
	-	-	50–77	-	lab / 20.6–27°C	Taberly (1987) <i>ex</i> Grishina (1991)
Nothridae						
<i>Nothrus anaunensis</i>	-	-	172–296	-	lab / 20–23°C	Ermilov (2008)
<i>Nothrus biciliatus</i>	-	-	73–278	-	lab / 28°C	Saichue <i>et al.</i> (1972), reared on different diets
<i>Nothrus borussicus</i>	-	-	154–246	-	lab / 20–23°C	Ermilov (2008)
<i>Nothrus lasebikani</i>	4–6	-	-	-	lab / 28±2°C	Badejo & Akinwole (2007), reared on different diets
<i>Nothrus palustris</i>	-	-	< 150	-	lab / 18–20°C	Grishina (1997)
	-	-	148–174	-	field	Shaldybina (1984), Russia, Volga

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TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
	-	140–351	-	-	lab / 20°C	Lebrun (1970a)
	250	-	262	-	lab / 18–20°C	Lebrun (1970a)
	-	-	147–148	-	lab / 18–20°C	Shaldybina (1981) ex Grishina (1991)
<i>Nothrus silvestris</i>	145	221	75	85	lab / room temp.	Heba (2009)
	-	-	153	-	lab / 25°C	Sengbusch (1958b)
	-	-	143–227	-	lab / 20–23°C	Ermilov (2008)
Crotoniidae						
<i>Camisia biurus</i>	-	-	101–119	-	lab / 19–20°C	Ermilov (2007)
	-	-	101–193	-	lab / 17–19.5°C	Ermilov (2008)
<i>Camisia segnis</i>	200–336	-	131–246	-	lab / room temp.	Grandjean (1950)
	-	-	90–169	-	lab / 17–19.5°C	Ermilov (2008)
<i>Camisia spinifer</i>	-	-	126	-	lab / 25°C	Sengbusch (1958b)
	-	-	133–231	-	lab / 20–23°C	Ermilov (2008)
<i>Heminothrus longisetosus</i>	-	-	122–176	-	lab / 22.5°C	Ermilov (2008)
<i>Heminothrus thori</i>	-	-	159–174	-	lab / 22.5°C	Ermilov (2008)
<i>Platynothrus peltifer</i>	-	-	240–300	330–365	field / 5°C mean annual	Block (1965)
	-	-	114–303	-	lab / 20–27°C	Taberly (1988)
	-	-	117–150	-	lab / 15–20°C	Grandjean (1950), Hartenstein (1962d)
	156–212	310–355	143–154	-	lab / room temp.	Grandjean (1950)
	-	332	-	-	lab / room temp.	Haarløv (1960)
	1–7	-	-	-	lab / 5–25°C	Madge (1964), reaction to temperature and relative humidity
	406	576	170	-	lab / 25°C	Jalil (1972)
	-	-	330–365	-	lab / 3–15°C	Weigmann (1975)
	-	-	154–216	-	lab / 20.5–22.5°C	Ermilov (2008)
<i>Platynothrus skottsbergii</i>	-	-	365	-	field /subantarctic climate	West (1982)
Nanhermanniidae						
<i>Nanhermannia</i> cf. <i>coronata</i>	-	-	112–149	-	lab / 20–22.5°C	Ermilov & Łochyńska (2008)
<i>Nanhermannia nana</i>	-	-	83–144	88–170	lab / 25°C	Sengbusch (1958a)
	<2	-	-	-	lab / 5–25°C	Madge (1964), reaction to temperature and relative humidity
Hermanniiidae						
<i>Hermannia gibba</i>	-	-	205–280	1.5–730	lab / 15–20°C	Bäumler (1970)
<i>Hermannia scabra</i>	-	-	185	-	lab / 20°C	Jalil (1965)
<i>Hermannia subglabra</i>	-	540–600	120–365	-	lab / 3–15°C	Weigmann (1975)
Neoliodidae						
<i>Teleioliodes</i> sp.	102	-	-	-	lab / 28±2°C	Badejo & Akinwole (2007), reared on different diets
Damaeidae						

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TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
<i>Damaeus (Adamaeus) onustus</i>	-	-	> 132	-	lab / 20.5°C	Lebrun (1974), development only to tritonymph
	634	-	140	-	lab / 20–25°C	Pauly (1956)
	1–40	-	-	-	lab / 5–25°C	Madge (1964), sub <i>Belba geniculosa</i> , reaction to temperature and relative humidity
<i>Belba corynopus</i>	-	-	63–327	-	lab / 15–20°C	Luxton (1981a)
<i>Belba meridionalis</i>	-	> 365	54	-	lab / 25°C	Shereef (1972)
<i>Damaeus angustipes</i>	56	-	87	-	lab / 20°C	Hartenstein (1962a), sub <i>Belba kingi</i>
<i>Damaeus auritus</i>	-	-	64–85	-	lab / 20–25°C	Pauly (1956), Sengbusch (1958b)
<i>Damaeus clavipes</i>	-	-	240–300	330–365	field / 5°C mean annual	Block (1965), field observations in Westmorland England
	-	-	-	240–365	field	Luxton (1981a), field observations in Denmark
	-	-	77–182	-	lab / 15–20.5°C	Lebrun (1974), Luxton (1981a)
<i>Damaeus gracilipes</i>	-	-	76	-	lab / 20–25°C	Pauly (1956)
	-	-	130	-	lab / 25°C	Sengbusch (1958b)
<i>Epidamaeus diversipilis</i>	-	-	120	-	lab / 20°C	Schenker (1987)
<i>Epidamaeus grandjeani</i>	-	-	55–136	-	lab / 14–26°C	Lyashchev (1984) ex Grishina (1991)
<i>Epidamaeus kamaensii</i>	-	-	105	-	lab / 18–20°C	Chistyakov & Orlova (1979) ex Grishina (1991)
	-	230	-	-	-	Shereef (1972)
<i>Epidamaeus verrucatus</i>	-	-	25–44	-	lab / 17–25°C	Enami (1992)
<i>Epidamaeus (Akrodamaeus) sp.</i>	180–240	240–300	63–67	-	lab / 20–25°C	Estrada-Venegas & Norton (2001)
<i>Metabelba montana</i>	-	-	65	-	lab / 20°C	Hartenstein (1962b)
<i>Spatiodamaeus boreus</i>	-	-	120	-	lab / 16–20°C	Sitnikova (1959), sub <i>Damaeus (Spatiodamaeus) boreus</i> ex Grishina (1991)
<i>Spatiodamaeus subverticillipes</i>	-	300	62–75	-	lab / 25°C	Shereef (1972)
Cepheidae						
<i>Conoppia palmicincta</i>	-	-	375	-	lab / 25°C	Michael (1884), Woodring & Cook (1962)
Peloppiidae						
<i>Ceratoppia bipilis</i>	-	-	43–65	-	lab / 17–20°C	Ermilov & Łochyńska (2008)
	-	-	79	-	lab / 25°C	Michael (1884), Woodring & Cook 1962
	-	-	49–87	-	lab / 18°C	Taberly (1957)
<i>Ceratoppia quadridentata</i>	-	-	57–89	-	lab / 17–20°C	Ermilov & Łochyńska (2008)
Liacaridae						
<i>Adoristes ovatus</i>	-	-	1–730	-	field / 6°C mean annual	Gourbière <i>et al.</i> (1985)

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TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
	-	-	730	-	field / 0–15°C	Hagvar (1998)
	-	-	105–137	-	lab / 18–22°C	Travnicek (1989)
<i>Liacarus coracinus</i>	-	-	97–141	-	lab / 18–22°C	Travnicek (1989)
<i>Liacarus nitens</i>	-	-	119–140	-	lab / 18–22°C	Travnicek (1989)
<i>Liacarus subterraneus</i>	-	-	113–146	-	lab / 18–22°C	Travnicek (1989)
<i>Dorycranosus acutus</i>	-	-	121–135	-	lab / 18–22°C	Travnicek (1989), sub <i>Dorycranosus infissus</i>
<i>Dorycranosus moraviacus</i>	-	-	104–139	-	lab / 18–22°C	Travnicek (1989)
<i>Xenillus clypeator</i>	-	-	117–143	-	lab / 18–22°C	Travnicek (1989)
<i>Xenillus tegeocranus</i>	-	-	116–146	-	lab / 18–22°C	Travnicek (1989)
Eremobelbidae						
<i>Eremobelba geographica</i>	-	270	65	-	lab / 25°C	Shereef (1972)
<i>Eremobelba nervosa</i>	-	-	68–75	-	lab / 20°C	Hartenstein (1962b)
Thyrisomidae						
<i>Oribella paolii</i>	-	-	-	365	field	Luxton (1981a), field observations in Denmark
Oppiidae						
<i>Lanceoppia nodosa</i>	-	-	14–54	14–54	lab / 16–32°C	Bhattacharya <i>et al.</i> (1978), sub <i>Oppia nodosa</i>
<i>Multioppia bayoumii</i>	-	-	18–31	-	lab / 25°C	Shereef & Zaher (1980), reared on different diets
<i>Multioppia wilsoni</i>	> 365	-	18–21	25	lab / 25±1°C	Shereef (1976a)
		-	16–23	-	lab / 25°C	Shereef (1976a)
<i>Niloppia sticta</i>	> 365	-	11–16	19	lab / 25±1°C	Shereef (1976a), sub <i>Oppia sticta</i>
<i>Oppia denticulata</i>	-	300–425	21–33	-	lab / 18–25°C	Nannelli (1975), sub <i>Oppia</i> <i>concolor</i> ex Luxton (1981a), Seniczak <i>et al.</i> (2017)
<i>Oppia nitens</i>	-	-	40	-	lab / room temp.	Michael (1884)
	-	-	45–46	105	lab / 20°C	Sengbusch & Sengbusch (1970)
<i>Oppiella nova</i>	-	-	23–60	ca. 180	lab / 15–25°C	Kaneko (1988a)
	30	60	23	30	lab / 25°C	Woodring & Cook (1962), sub <i>Oppia neerlandica</i>
	-	-	24–36	-	lab / 18.5–25°C	Chistyakov (1970) ex Grishina (1991)
Granuloppiidae						
<i>Granuloppia</i> sp.	-	240	34	-	lab / 25°C	Shereef (1972)
Carabodidae						
<i>Carabodes labyrinthicus</i>	-	-	730	-	field (arboricolous)	Wunderle 1991
	> 365	-	-	-	lab / room temp.	Block (1965)
<i>Carabodes polyporetis</i>	-	-	70–84	-	lab / room temp.	Reeves (1991)
Tectocephidae						
<i>Tectocephus sarekensis</i>	-	-	102	-	lab / 25°C	Murphy & Jalil (1964)
<i>Tectocephus velatus</i>	-	-	102	-	lab / 25°C	Murphy & Jalil (1964)
	-	-	57–72	-	lab / 16–20°C	Grishina (1991)

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TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
	-	-	> 730	-	field	Solhøy (1975), Norway
Hydrozetidae						
<i>Hydrozetes lemnae</i>	-	-	56–57	-	lab / 20.6°C	Ermilov (2006)
Ameronothridae						
<i>Ameronothrus lapponicus</i>	-	-	1460–2190	-	field	Tilrem (1994), South Norway, Hardangervidda
<i>Ameronothrus lineatus</i>	730–1095	> 1825	1095–2920	ca. 1825	lab / polar climate	Søvik & Leinaas (2003a, b), Svalbard
	730–1095	2190–2920	1095–2920	ca. 1825	field / polar climate	Søvik <i>et al.</i> (2003), Svalbard
	-	< 365	150–270	-	field	Bücking <i>et al.</i> (1998), German North Sea coast
<i>Ameronothrus maculatus</i>	-	ca. 730	ca. 365	-	field	Bücking <i>et al.</i> (1998), German North Sea coast
<i>Ameronothrus marinus</i>	-	ca. 730	ca. 365	-	field	Bücking <i>et al.</i> (1998), German North Sea coast
<i>Ameronothrus schneideri</i>	-	-	330	-	lab / 3–15°C	Weigmann (1975), German North Sea coast
Podacaridae						
<i>Alaskozetes antarcticus</i>	> 730	2190–2555	-	> 1825	field / polar climate	Convey (1994), Block & Convey (1995)
Cymbaeremacidae						
<i>Cymbaeremaeus cymba</i>	-	-	365	-	field (arboricolous)	Wunderle (1991)
Micreremidae						
<i>Micreremus brevipes</i>	-	-	365	-	field (arboricolous)	Wunderle (1991)
Scutoverticidae						
<i>Scutovertex perforatus</i>	-	-	66–85	-	lab / 23°C	Ermilov <i>et al.</i> (2008)
<i>Scutovertex sculptus</i>	-	-	72–135	-	lab / 18–23°C	Ermilov <i>et al.</i> (2008), sub <i>Scutovertex rugosus</i>
Phenopelopidae						
<i>Eupelops torulosus</i>	-	-	180	-	lab / 18–21°C	Sitnikova (1969) ex Grishina (1991)
Achipteriidae						
<i>Achipteria coleptrata</i>	-	-	-	730	field	Luxton (1981a), field observations in Denmark
<i>Achipteria holomonensis</i>	-	-	261	-	lab / 25°C	Stamou (1989)
<i>Parachipteria punctata</i>	-	-	96–111	-	lab / 22°C	Chistyakov (1984) ex Grishina (1991)
<i>Plakoribates multicuspidus</i>	313	-	81–93	103	lab / 25°C	Shereef (1977)
Oribatellidae						
<i>Oribatella berlesei</i>	-	-	107	-	lab / 16°C	Chistyakov (1981) ex Grishina (1991)
Limnozetestidae						
<i>Limnozetes ciliatus</i>	-	78–142	-	-	lab / 15–25°C	Kuriki (2008)
Ceratozetidae						

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TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
<i>Ceratozetes cisalpinus</i>	> 330–390	-	32	47–52	lab / 25°C	Woodring & Cook (1962)
<i>Ceratozetes gracilis</i>	-	-	41	-	lab / room temp.	Haarløv (1960)
	-	-	119–149	-	lab / 20°C	Hartenstein (1962c)
	-	-	-	> 730	field	Luxton (1981a), field observations in Denmark
	-	ca. 4.730	540	-	lab / 15°C	Mitchell (1977b)
	-	-	54–113	-	lab / room temp.	Shaldybina (1964) ex Grishina (1991)
<i>Ceratozetes kananaskis</i>	ca. 4.730	-	465	-	lab / 15°C	Mitchell (1977b)
<i>Ceratozetes mediocris</i>	-	-	51–69	-	lab / room temp.	Shaldybina (1967) ex Grishina (1991)
<i>Ceratozetes minimus</i>	-	-	39–60	-	lab / room temp.	Shaldybina (1964) ex Grishina (1991)
<i>Ceratozetes virginicus</i>	-	-	53	-	lab / 25°C	Rockett & Woodring (1966), sub <i>Ceratozetes jeweli</i>
<i>Edwardzetes elongatus</i>	-	-	> 730	-	field / subantarctic climate	West (1982)
<i>Euzetes globulus</i>	-	-	59–77	-	lab / 18–20°C	Shaldybina (1973) ex Grishina (1991)
<i>Fuscozetes fuscipes</i>	-	-	60–112	-	lab / room temp.	Shaldybina (1978) ex Grishina (1991)
	1–26				lab / 5–25°C	Madge (1964), reaction to temperature and relative humidity
<i>Oromurcia sudetica</i>	432–783	1095– 2190	730–1460	1095– 2190	lab / 8–20°C	Schatz (1985) reared under high alpine conditions
<i>Sphaerozetes orbicularis</i>	-	-	127–133	-	lab / room temp.	Shaldybina (1968) ex Grishina (1991)
<i>Trichoribates berlesei</i>	-	-	49–75	-	lab / 20–22°C	Shaldybina (1960), sub <i>T. trimaculatus</i> ex Grishina (1991)
<i>Zetomimus furcatus</i>	-	-	30–61	-	lab / 18–20°C	Shaldybina (1969) ex Grishina (1991)
Chamobatidae						
<i>Chamobates cuspidatus</i>	-	-	-	365	field	Luxton (1981a), field observations in Denmark
<i>Chamobates spinosus</i>	-	-	44–48	-	lab	Shaldybina (1966) ex Grishina (1991)
<i>Chamobates subglobulus</i>	-	-	71–124	-	lab / 18–20°C	Shaldybina (1971) ex Grishina (1991)
Maudheimiidae						
<i>Maudheimia wilsoni</i>	-	4–1825	-	1095	field / antarctic climate	Marshall & Convey (1999)
Humerobatidae						
<i>Humerobates rostromellatus</i>	124	221	97	-	lab / 25°C	Jalil (1969)
	4–57				lab / 5–25°C	Madge (1964), reaction to temperature and relative humidity
Punctoribatidae						

...Continued on the next page

TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
<i>Minunthozetes semirufus</i>	-	-	38	-	lab / 25°C	Sengbusch (1958b)
	-	-	57–76	-	lab	Shaldybina (1965) ex Grishina (1991)
<i>Paralamellobates bengalensis</i>	-	-	27	-	lab / 29±1°C	Haq & Ramani (1984)
<i>Punctoribates hexagonus</i>	-	-	31–38	-	lab	Shaldybina (1967) ex Grishina (1991)
<i>Punctoribates punctum</i>	-	-	70–81	-	lab	Shaldybina (1965) ex Grishina (1991)
Mochlozetidae						
<i>Drymobatoides malabaricus</i>	-	-	17–19	ca. 60	lab / 30±1°C	Adolph & Haq (1984), sub <i>Pelokylla malabarica</i>
	-	-	26	-	field / 25±1°C	Adolph & Haq (1984), sub <i>Pelokylla malabarica</i>
<i>Uracrobates indicus</i>	-	-	33	50	lab / 31±1°C	Ramani & Haq (1988)
Oribatulidae						
<i>Jornadia larreae</i>	-	365	28–42	-	field	Wallwork <i>et al.</i> (1986), New Mexico, influence of rainfall
Scheloribatidae						
<i>Hemileius initialis</i>		-	730	-	field	Luxton (1981a), field observations in Denmark
<i>Muliercula inexpectata</i>	48–52	-	-	-	lab / 28±2°C	Badejo & Akinwole (2007), reared on different diets
<i>Scheloribates decarinatus</i>	-	-	29–38	40–53	lab / 26–32°C	Ramani & Haq (1987)
<i>Scheloribates laevigatus</i>	-	-	42–115	-	lab / 25°C	Cleat (1952)
	-	109–158	21–28	32–38	lab / 25–30°C	Elmoghazy <i>et al.</i> (2012)
	-	-	28	-	lab / 27.8–32.7°C	Narsapur (1983)
	120	180	64	84	lab / 25°C	Woodring & Cook (1962)
	-	-	179	-	lab / 5°C	Woodring & Cook (1962)
	-	-	70	-	lab / 20–24°C	Subbotina (1967) ex Grishina (1991)
	-	-	66–185	-	lab / 15–25°C	Subbotina (1948, 1970) ex Grishina (1991)
<i>Scheloribates latipes</i>	-	-	84–85	-	lab / 18–23°C	Subbotina (1967), Soldatova (1948) ex Grishina (1991)
<i>Scheloribates mochlosimilaris</i>	26–46	-	-	-	lab / 28±2°C	Badejo & Akinwole (2007), reared on different diets
<i>Scheloribates (Hemileius) nicki</i>	-	-	31–33	31–33	lab / room temp.	Denmark & Woodring (1965), sub <i>Hemileius nicki</i>
<i>Scheloribates nudus</i>	-	-	14–24	25–35	lab / 23°C	Woodring (1965)
<i>Scheloribates parabilis</i>	-	-	14–24	25–35	lab / 23°C	Woodring (1965)
Haplozetidae						
<i>Protoribates lophotrichus</i>	-	-	150	-	lab / 25°C	Hartenstein (1962e), sub <i>Protoribates lophotrichus</i>
<i>Protoribates seminudus</i>			18–23	-	lab / 28±1°C	Ramani (1999), sub <i>Xylobates seminudus</i>

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TABLE 1. (Continued)

Taxon	Longevity	Lifespan	Egg-adult	Egg-egg	Rearing	References and notes
<i>Protoribates souchnaiensis</i>	> 365	-	86–108	123	lab / 25°C	Shereef (1977), sub <i>Xylobates souchnaiensis</i>
<i>Rostrozetes ovulum</i>	90–210	120–240	35–45	-	lab / 23°C	Woodring (1965), sub <i>Rostrozetes flavus</i> ex Luxton (1981a)
Parakalummidae						
<i>Neoribates gracilis</i>	730	>730	31–53	-	lab / 18–30°C	Travé & Duran (1971)-
Galumnidae						
<i>Acrogalumna longipluma</i>	-	-	25	-	lab / 30±1°C	Haq & Adolph (1981), sub <i>Galumna longipluma</i>
	-	-	61–66	-	lab / 25°C	Sengbusch (1954, 1958b), sub <i>Galumna longipluma</i>
<i>Galumna flabellifera</i>			48–67	-	lab / 25°C	Reddy et al. (1978)
<i>Galumna flabellifera orientalis</i>	-	-	25	-	lab / 30±1°C	Haq & Adolph (1981)
<i>Galumna ithacensis</i>	-	-	87	-	lab / 25°C	Sengbusch (1954), sub <i>Galumna elimata</i> <i>ithacensis</i>
<i>Galumna louisianae</i>	60–180	120–240	46–50	74–78	lab / 23°C	Woodring (1965), sub <i>Galumna confusa</i> ex Luxton (1981a)
<i>Galumna parva</i>	60–120	90–150	33–41	-	lab / 23°C	Woodring (1965) ex Luxton (1981a)
<i>Galumna unica</i>		-	34	-	lab / 28°C	Haq & Shereef (1992), sub <i>Galumna unica</i>
<i>Galumna triquetra</i>	-	-	30–39	42–59	lab / 27±1°C	Shereef & Haq (1992)
<i>Galumna</i> sp.	365	-	65–94	-	lab / 25°C	Stunkard (1944), intermediate host of <i>Moniezia</i> <i>expansa</i>
<i>Pergalumna ekaterinae</i>		-	48	-	lab / 26.4°C	Paez <i>et al.</i> (2019)
<i>Pergalumna emarginata</i>	-	> 210	42	-	lab / 25°C	Rockett & Woodring (1966), sub <i>Pergalumna omniphagous</i>
<i>Pergalumna nervosa</i>	-	-	43–63	-	lab / 20–25°C	Sengbusch (1954, 1958b), sub <i>Galumna nervosus</i>
	37–121	-	33–51	-	lab / 30°C	Seniczak (2007), tested effect of copper
	-	-	47	-	lab / 25°C	Sengbusch (1954), Woodring & Cook (1962)
	-	-	110–158	-	lab / 16–18°C	Chistyakov & Orlova (1982) ex Grishina (1991)
<i>Pergalumna</i> sp.	-	-	27–50	-	lab / 20–30°C	Tanimoto (1980)
<i>Pergalumna</i> sp.	46–287	-	-	-	lab / 28±2°C	Badejo & Akinwole (2007), reared on different diets
<i>Orthogalumna terebrantis</i>	-	54–94	-	-	lab / 25°C	Cordo & DeLoach (1975)
Galumnellidae						
<i>Galumnella</i> sp.	12	-	-	-	lab / 28±2°C	Badejo & Akinwole (2007), sub <i>Galumnella sonpona</i> (nomen nudum), reared on different diets

Results

Table 1 lists the results of 210 investigations in 135 publications with data on life cycles (generation time and/or developmental time, 128 publications) and on lifespans (50 publications) of 153 oribatid species belonging to 45 families. Up to the present, the life cycles of 144 oribatid mite species from 42 families have been studied, most species from the families Damaeidae (15 spp.), Ceratozetidae, Galumnidae (13 spp. each), Liacaridae (8 spp.), Crotoniidae, Oppiidae, Scheloribatidae (7 spp. each), Trhypochthoniidae (6 spp.). The lifespan of 52 species (25 families) has been observed or estimated, mainly from the families Galumnidae (7 spp.), Damaeidae (5 spp.), Oppiidae (4 spp.), and Ceratozetidae, Nothridae, Scheloribatidae, Trhypochthoniidae (3 spp. each). The duration of the particular immature stages was not taken into account here.

The majority of life cycle studies on oribatid mites were carried out before 1990 (107 spp.) (Fig. 1). After this period the number of studies declined. During the last three decades 38 further species were studied, and 23 additional investigations concerned already studied species. Similarly, most lifespan observations were published before 1990 (33 spp.), with 19 additional species in the later years. Since 1990, further studies on 11 species with already known lifespans were carried out, mainly on *Archezogetes longisetosus* (see below). Most investigations (178) were done in the laboratory, some performed in the field and/or compared with the field data (31 investigations). Earlier studies considered the morphology and taxonomic assignment of immature stages to certain species and were performed at room temperature in the laboratory. From around the middle of the previous century, most investigations concentrated on the influence of temperature on the duration of development, the food quality and other parameters influencing life cycle, longevity or mortality.

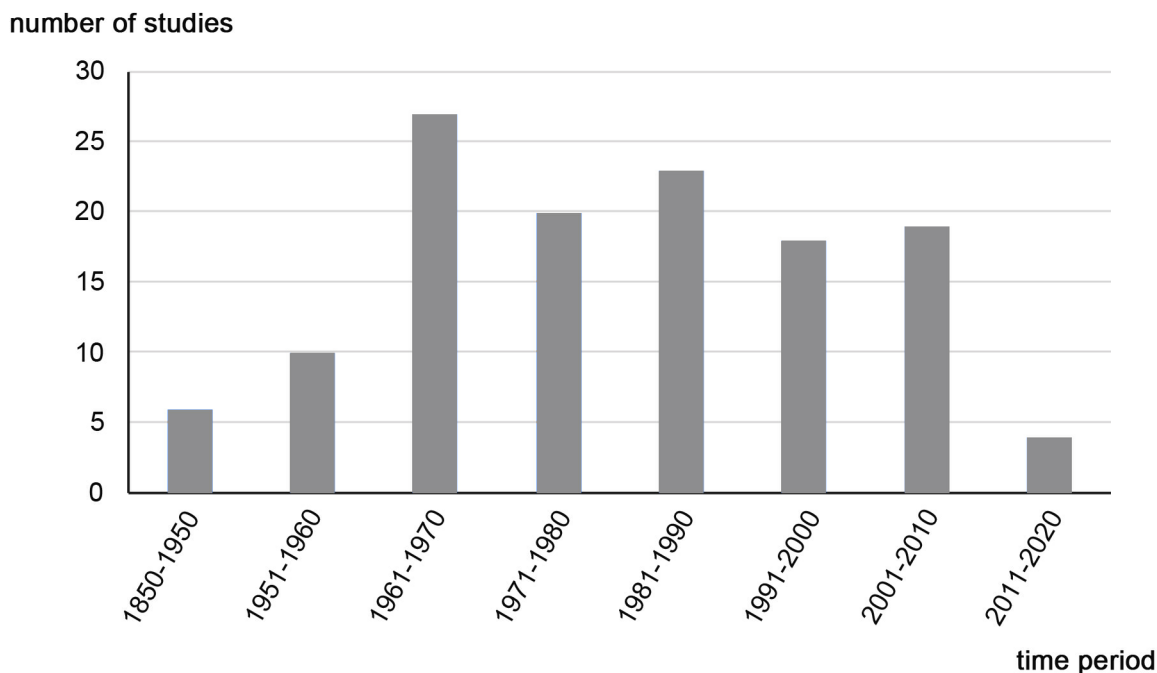


FIGURE 1. The number of studies on life history and lifespans in oribatid mites performed during 1850–2020, indicating a strong decline in the last decade.

Compared to the total known number of oribatid mite species, the studies on immatures and life cycles or the total lifespan are very sparse. Of all currently known oribatid species, juvenile instars of less than 8% of the species are described (Norton & Ermilov 2014), the duration of the developmental cycle of 1.25% species and the estimation or observation of the lifespan of 0.45% species are presently known:

- known oribatid species ~11.500 (173 families)
- number of species with descriptions of juvenile instars 898 (120 families)
- number of species with studies of life cycle duration 144 (42 families)
- number of species with studies / estimation of life span 52 (25 families)

The typical lifespan of an oribatid mite lasts one or two years in temperate to boreal regions (Norton and Behan-Pelletier 2009), rarely three years. In laboratory cultures the observed lifespan is generally shorter and decreases at higher temperatures. Very short longevities of adults were found in a nutritional experiment with some tropical species (Badejo & Akinwale 2007) and in different relative humidities at different constant temperatures (Madge 1964). In *Archezogozetes longisetosus*, also a tropical species, the short lifespan is influenced by stressful laboratory conditions or exposure to toxic substances (Seniczak 1998, 2006; Seniczak *et al.* 1999, 2005, 2006). Other tropical species show considerably faster development, and generally shorter lifespans, some species show lifespans of up to two years in the laboratory (Shereef 1976b). No field studies on the lifespan of oribatid mites have been carried out in the tropics. Long lifespan periods are particularly characteristic of species in polar regions (*Alaskozetes antarcticus*—Convey 1994; *Ameronothrus lineatus*—Søvik & Leinaas 2003a; *Maudheimia wilsoni*—Marshall & Convey 1999), but also in mountainous temperate regions (Canada: *Ceratozetes gracilis*, *C. kananaskis*—both estimates—Mitchell 1977b; Japan: *Trhypochthoniellus brevisetus*—Kuriki 1995; European Alps: *Oromurcia sudetica*—Schatz 1985). The duration of the life cycle of a certain species can change in different geographic regions, as can be observed in *Nothrus palustris* (Grishina 1997) or in *Ameronothrus lineatus* (see below).

Discussion

The longevity of an oribatid mite depends on several environmental abiotic and biotic factors, such as temperature, light, humidity, soil acidity, duration of growing season, disturbances, availability and quality of food, or presence of toxic substances as heavy metals (e.g., Madge 1964; Siepel 1994; Maraun & Scheu 2000; Ermilov & Łochyńska 2008). It was recognized earlier on that temperature is likely to be one of the main parameters for the longevity of an oribatid species. At higher temperatures the developmental time tends to decrease (summarized in Lebrun 1970a; Luxton 1981a). Seniczak (2006) demonstrated in laboratory experiments on *Archezogozetes longisetosus* that a high population density decreases the fertility of females, prolongs the developmental period of juveniles and increases the juvenile mortality, but has no influence on the lifespan of adults. In adults of *Achipteria holomonensis* high densities in culture also diminish the fecundity of females, while—in opposite to the previously mentioned species—the juvenile mortality and their developmental duration does not seem to be influenced (Stamou *et al.* 1981). As some authors suggest, the longevity might be shorter in more derived groups, while the dependence of the longevity on the animal size is controversial (e.g., Lebrun 1970a; Luxton 1981a; Haq & Adolph 1981; Grishina 1991; Convey 1996). Siepel (1994) assumed that the genetic predisposition has a stronger influence on the generation time than other factors. However, heritable genetic variation of life-history traits is currently indistinguishable from phenotypic responsiveness to environmental conditions (Norton 1994). Molecular studies could provide a possible answer here.

Most of the data on lifespan of oribatid species are based on laboratory studies and can only be indicative of the potential natural lifespan. Adult oribatid mites survive frequently for a considerable period in culture. A comparison with field data was carried out rarely, mostly for species living under extreme conditions (e.g., Asikidis & Stamou 1992; Schatz 1985; Wallwork *et al.* 1986; Convey 1994; Søvik & Leinaas 2003a, b). Developmental times in culture and in the field can vary considerably. Luxton (1981a, b) studied the life cycle of several oribatid species in a temperate forest in Denmark where the majority of the species display an annual or two years cycle, in opposite to observations of some of the same species in the laboratory with much shorter developmental periods (e.g., Woodring & Cook 1962, Luxton 1981a). These differences could be explained by long resting stages before moulting and/or the cold season of the year (Norton 1994), the latter factor can be diminished in semi-natural conditions in culture, e.g. in microcosms (e.g., Weigmann 1975; Schatz 1985; Convey 1994; Søvik & Leinaas 2003a, b). The number of generations a species can have in a year or in another specified period of time will not be discussed here because it is beyond the focus of this survey, but this parameter was used several times for the estimation of developmental time from the field data (e.g., Weigmann 1975; Webb 1977; Thomas 1979; Haq & Adolph 1981; Luxton 1981a; Haq & Ramani 1984; Asikidis & Stamou 1992).

Few studies are available regarding the natural survival rate of each instar, although mortality is concentrated in immatures. During the pre-ecdysial resting stage and moulting oribatid mites are particularly vulnerable, as they are exposed to predators and can experience difficulties emerging from the exuvium (Lebrun & van Straalen 1995). The mortality seems to decrease from egg to tritonymph (Schatz 1983; Kuriki 1995), but the survival probability of an egg reaching the adult instar can vary widely (e.g., Schatz 1985; Fernandez & Athias Binche 1986; Mitchell 1977b; Convey 1994). Generally, older immature stages have longer developmental time (Luxton 1981a; Kaneko 1988b). In temperate and colder climate zones the life cycle is frequently extended, whereby different juvenile instars and adults can hibernate in dormancy (quiescence or diapause) thus reducing mortality (Belozero 2008). An important survival tool during prolonged exposure to low temperatures without freezing is supercooling by synthesis of cryoprotectant substances. This phenomenon is known from numerous oribatid mites in cold climates, but also in temperate zones, especially in some alpine species (Sømme 1982; 1989; Cannon & Block 1988). On the other hand, oribatid mites in hot deserts or in the Mediterranean climate with dry summer have evolved another kind of opportunistic adaptation, developing unique behaviour and exceptional life cycles by synchronizing the reproduction with the precipitation cycle (Wallwork *et al.* 1986; Stamou 1995). The hardened cuticle of oribatid mites (Norton 1994), the ptychoid defense mechanism (Schmelzle *et al.* 2015) and other defensive strategies, are adaptations of adults against predators, which may allow higher survival rates and thus longer lives.

Some striking examples

Alaskozetes antarcticus (Michael, 1903) (Fam. Podacaridae)

This species is widely distributed on sub-Antarctic islands and throughout the Antarctic Peninsula as a dominant member of many terrestrial communities in the maritime Antarctic (Block & Convey 1995), and also found in some places in New Zealand (Luxton 1990). A detailed study of the life cycle of this species in the field and under seminatural conditions (field enclosures, 2–12°C) has been carried out by Convey (1994). The life cycle of this species is not seasonal and all life stages overwinter in the field. Individual mites usually spend one year between moults, so the life cycle (from egg to egg) will last around 5 years. Adults survive at least two summers, females commence oviposition in their second summer, which can prolong the total lifespan to up to 7 years. This extended life cycle is exceptional and a special adaptation to survive the harsh environmental conditions of the Antarctic, linked with cold tolerance strategies such as increased resistance to desiccation by supercooling (Block & Convey 1995).

Ameronothrus spp. (Fam. Ameronothridae)

The known species of this genus are bisexual, univoltine and larviparous, and occur mainly on marine coasts, in estuaries, but also in freshwater, saltmarshes and even in terrestrial habitats (Pfungstl 2017). *Ameronothrus lineatus* (Thorell, 1871) lives on coasts of the Canadian and Alaskan Arctic, Greenland, Svalbard, Scandinavia, also in temperate zones on the coasts of Germany, Netherlands, and the British Isles. Studies on development, life cycle and survival in the Arctic (Svalbard) were carried out by Søvik and Leinaas (2003a; b), Søvik *et al.* (2003), Søvik (2004) in laboratory microcosms under different temperature regimes and in the field. The development is interrupted by quiescence during the long polar winter. Females start larvipositing during the second adult summer, which gives a generation time from larva-to-larva of ca. 5 years. Consistent with the field data, the longevity of the adults is high, the longest-lived females survived almost five summers, while the majority of adults lived for 2–3 years. The total lifespan of *A. lineatus* in the Arctic can thus amount to 5–8 years.

The adult longevity was reduced at higher temperatures in laboratory experiments (Søvik & Leinaas 2003b). This coincides with observations on *A. lineatus* in the temperate zone (Weser estuary, Germany, Bücking *et al.* 1998), where populations had a one-year life cycle. The seasonal development from larva to adult lasted 5–9 months, and most adults lived less than a year, dying in autumn after hatching of larvae.

Observations on other *Ameronothrus* species in the temperate zone show similar developmental times but longer periods of lifespan. *Ameronothrus marinus* (Banks, 1896) and *A. maculatus* (Michael, 1882), also in the Weser estuary, Germany (Bücking *et al.*, 1998), had a developmental time in the field of about one year

and a total longevity of 2 years. *Ameronothrus schneideri* (Oudemans, 1905) from the North Sea coast of Germany had a developmental cycle in the laboratory of about 11 months, the longevity of adults is unknown (Weigmann 1975). On the other hand, the lifespan of *Ameronothrus lapponicus* Dalenius, 1963 in the harsh conditions of Hardangervidda (Finse, South Norway) with extreme changes in temperature and long periods of severe drought is assumed to be 4–6 years (Tilrem 1994 in Bücking *et al.* 1998).

***Archeogozetes longisetosus* Aoki, 1965 (Fam. Trhypochthoniidae)**

This parthenogenetic species occurs in many tropical countries in the Oriental, Australian and Neotropical regions. Due to its relatively large size, short generation time, high fecundity and ease of culture *Archeogozetes longisetosus* is among the most studied soil microarthropods under laboratory conditions, and certainly the best investigated oribatid mite species (Smrž & Norton 2004; Heethoff *et al.* 2013). Numerous studies on its life history have been conducted, mainly regarding food preference and duration of development, some with different results (e.g., Haq & Adolph 1981; Honciuc 1996; Seniczak 1998; Estrada-Venegas *et al.* 1999; Seniczak & Seniczak 2002; Bergmann 2006; Heethoff *et al.* 2007; Seniczak *et al.* 2016; Brückner *et al.* 2018). The reason for this divergence could be attributed to the different origins of the animals, from India (Haq & Adolph 1981), Mexico (Estrada-Venegas *et al.* 1999), and Puerto Rico (all other studies, based on a single gravid female, Bergmann 2006). Some studies show the influence of heavy metals (lead, cadmium, copper, zinc) on this species, prolonging the time of development, increasing mortality or reducing female fecundity (Seniczak *et al.* 1999, 2005, 2006, 2009, Seniczak & Seniczak 2002). Heethoff *et al.* (2007), Seniczak *et al.* (2016) and Brückner *et al.* (2018) give following values from various laboratory cultures and food offers, based on own experiments and literature: the development time from egg to adult 28–88 days and the longevity of adults 48–64 days. The total lifespan of *A. longisetosus* in culture is therefore 76–152 days, depending on temperature, possibly on the quality of food, presence or absence of heavy metals, density and origin of the specimens.

***Oromurcia sudetica* Willmann, 1939 (Fam. Ceratozetidae)**

This species occurs in montane habitats in the Alps and Southeastern European mountains, also in the Caucasus. Subías (unpublished update 2007) treated this name as synonym of *O. bicuspidata* Thor, 1930 without any commentary. If this suggestion is valid, the species has a boreo-alpine distribution. The life cycle and the survival rate of this species in the Austrian Alps has been studied by Schatz (1983; 1985) in laboratory and field studies. Individuals were kept under semi-natural conditions under temperature and light conditions corresponding to the multi-year average annual regime in the investigation area, a meadow above the timberline at ~2000 m a.s.l. The mortality decreases with increasing age from egg to tritonymph. The life expectancy increases slightly from egg to larva, decreasing during the subsequent instars. The survival rate of adults is higher in winter than in summer. Overwintering specimens are inactive, and supercooling was proven (Schatz & Sømme 1981; Sømme 1989). The life cycle is prolonged; breeding and hatching activity occurs only during the short vegetation period. The development from egg to adult takes a minimum of 2 years but can last up to 4 years. The observed longevity of the adults is one to two years. Thus, the total lifespan of *Oromurcia sudetica* in the investigated area can last between 3 and 6 years.

Considering the estimation of mortality rate with an equal gender ratio, each female has to lay 20 eggs in order to maintain the population density of *Oromurcia sudetica* constant in nature. This can be achieved through the long lifespan of the females and iteroparity (Schatz 1983).

Conclusions

Despite their high diversity, comparatively little is known about the longevity of most oribatid species. Several laboratory studies examined the developmental time under different conditions, but the lifespan of most oribatid mite species is unknown. The available results (less than a half percent of all known species) are mostly derived from laboratory observations. The few extrapolations on the real lifespan in the field originate from abundance studies and estimate the potential lifespan. The observed lifespans range from a few months to 8 years. The extreme longevities are known from polar regions, associated with rapid development in the growing seasons

and long resting periods during the cold seasons, and are an excellent adaptation to the climatic conditions, demonstrating the climate as the most influential factor. Tropical species show generally faster development and shorter lifespans to species from temperate regions. Other factors, such as food quality or toxic substances, can also affect the lifespan of oribatid mites.

In view of the important role of oribatid mites as soil decomposers, knowledge about their life history traits and influencing parameters is essential, especially in the context of global climate change and increasing environmental pollution. With few exceptions, the studies on lifespans of oribatid mites were performed in the last decades of the previous century, most in the course of large-scaled ecological programs. At present, such long-term projects are difficult to obtain and finance, although the advanced technological tools would enable a study of evolutionary causes of lifespan at deeper levels by using new molecular biological methods.

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