

15. The Collembola of the Hansted Reserve, Thy, North Jutland.

Taxonomy, Ecology.

(with a description of a new species and subgenus
and a record of a single species of Protura).

By

Henning Petersen.

Content.

1. Introduction.....	p. 313
2. Materials and methods.....	p. 314
3. Description of the investigated area.....	p. 315
4. List of the species found.....	p. 319
5. Taxonomical remarks on some species.....	p. 321
6. Ecological part.....	p. 355
The local distribution of the single species....	p. 358
The fauna of the greater habitat units.....	p. 385
7. Summary and conclusions.....	p. 391
8. References.....	p. 392

1. Introduction.

This investigation of the Apterygota of the Hansted game reserve was brought about by the initiative of Dr. S. L. Tuxen as a part of the series of investigations of the insect-fauna of Thy, arranged by the Entomological Society of Copenhagen (Tuxen 1960). The main purpose of the investigation was to make a general survey of the fauna of the Hansted reserve and its surroundings. In the present investigation, however, an attempt has been made to combine the faunistical purpose with an approach to the ecology of the Collembola in this interesting area, almost untouched by man.

Since Bartholin's provisional catalogue of the Danish Apterygota (Bartholin 1916), where the few records of Collembola from Denmark published before this date are described, Bornebusch (1930), Weis-Fogh (1947/48), Haarløv (1957) and Poole (1964) have

given records of Danish Collembola. The latter four investigators, however, worked in rather restricted areas and for purely ecological purposes, thus knowledge of the Danish Collembola-fauna still remained rather incomplete. In this respect the present paper may fill a gap.

I wish to express my deep gratitude to my teacher Dr. S. L. Tuxen, the Zoological Museum of Copenhagen, who gave me my interest in the Apterygota and inspired and supervised the present investigation. He always followed my work with interest and was ever ready to help when problems arose. I also want to thank Dr. H. Gisin, Geneva, for his valuable instruction as to the determination of the material. He kindly controlled some of the more surprising findings. Dr. A. Macfadyen, Swansea, Mr. A. Szeptycki, Ojcow, Poland, and Mr. P. N. Lawrence, London, are acknowledged for procuring type materials for comparison. I also want to thank Mr. P. N. Lawrence for controlling my first determinations. For linguistic corrections I thank Mrs. M. Goodfellow, the Zoological Museum of Copenhagen.

2. Materials and methods.

The material originated for the greater part from my own collections in late August 1963 (24 samples) and late June 1964 (144 samples). In addition, materials of Berlese-samples collected by S. L. Tuxen (July 1957, 14 samples) and A. Nørrevang (early June 1958, 21 samples) have also been treated. Finally, Collembola from the collections of E. W. Kaiser and Carlo F. Jensen from surfaces and shores of fresh waters in Thy have also been determined (17 samples).

My own collections include Berlese-samples, samples obtained by means of a sweep-net (50 sweeps used as a standard), samples collected from water-surfaces by means of a small net and samples sucked up by a small aspirator.

The Berlese-samples were obtained from samples of soil, litter, moss etc. with a volume of approximately $\frac{1}{2}$ l. They were dug up by a shovel in such a way that the surface area was about 10×10 cms and the depth about 5 cms. The samples of moss cushions or moss blankets

in particular were probably somewhat compressed by the digging, and the estimated volume may in reality represent something more than $\frac{1}{2}$ l moss in natural state.

My samples from the first year of collection (samples 1—37), together with the samples of Tuxen and Nørrevang, were treated in Haarløv's modification of the Tullgren-funnel (Haarløv 1947). The funnels used were provided with 90 watt carbon-filament bulbs.

In the second year of collection, a series of transportable Tullgren-funnels provided with 60 watt bulbs were used. At this time the animals driven out were caught on the surface of a saturated solution of NaCl which proved to retain the Collembola very well, and were swept up into a tube by means of small pieces of filter-paper. As on an average the samples from the second year of collection yielded much higher numbers of individuals than either my own samples from the preceding year or those of Tuxen and Nørrevang, it was assumed that the older Haarløv-Tullgren-funnels were defective, the heat-generation probably being too strong. Therefore, my samples 1—37, as well as those of Tuxen and Nørrevang, have only been used for the purpose of positive qualitative information.

3. Description of the investigated area.

The sample sites.

The investigated area consists of the Hansted game reserve (about 3500 hectares) and the adjoining conifer-plantations (mainly the Tved plantation east of the reserve). A few samples were taken in the mixed conifer- and deciduous plantation of Vilsbøl.

A more satisfactory description of the area than space here permits is found in the introduction to the investigation-series (Tuxen 1960), which also includes a map of the territory. The geology is treated by H. Gry (1960), the vegetation by T. Christensen (1960).

Only a broad survey is given here in relation to the description of the sample sites.

Morphology: The Hansted reserve extends from the North Sea coast in the West about 6 kms inland to the lake Nors sø and the Tved plantation. The basic morphological element of the greater western part of the reserve is a former stone age sea-bed. An old emerged coastline forms a row of chalk cliffs parallel to the present coast-line. The cliffs form the eastern shores of the largest lakes of the reserve (apart from Nors sø), Hykjær and Blegsø. They are most prominent along the shore of Blegsø, being about 16 ms high, fairly steep and in parts devoid of vegetation. A series of samples was taken from this locality. East of the old shore-line the ground rises gradually towards the hill of Isbjerg (altitude about 60 ms).

This basic morphological pattern has been modified by sand-drift. Along the coast the dunes form a continual ridge; on the plain elevated Stone Age sea-bed sand-drift has formed parabola dunes and left extensive low-lying deflation plains between them. The lowest-lying parts of these plains form about 30 small shallow lakes and extended areas of marsh and bogs. On the high-lying eastern part of the reserve the sand has formed an erratic "moon-scenery" of blow-out dunes.

The sample sites and the greater habitat units. To fulfil the primary purpose of this investigation: to make a survey of the Collembola-fauna of the reserve and its surroundings, it was decided to choose sample sites as different as possible in respect of directly observable characters. An attempt has been made to classify the samples into a number of greater habitat units, in most cases defined by conspicuous plant communities. It has here been tried to place the samples together according to mutual resemblance. This classification, however, has been based merely on subjective

estimation and the following result should be regarded with some reservation.

A complete list including descriptions of all sample sites and fauna lists is kept in the Zoological Museum of Copenhagen.

The water-surfaces of lakes and ponds are arranged in accordance with the estimated degree of wind- and wave-protection.

The shores of lakes and ponds. Most of the samples from the shores have been taken from the northern shore of Nors sø. Here the shore is fairly solid and covered by an almost unbroken carpet of vegetation (mainly low grass) close to the water level. About 4 ms from the water level is found an overgrown ridge, 10—30 cms high, of old plant material cast up from the lake. A low ridge of newly cast up organic material is situated near the water level. Some other shores, mainly the western shores of the larger lakes, are more swampy, with plants in tussocks growing out into the water.

The last mentioned type of shore passes without interruption into the unit of habitats called marsh and bogs. It is characterized by vegetation growing in hummocks. In the more humid parts the space between the hummocks may be submerged, in the dryer parts the space consists of bare, peaty soil. The vegetation of the hummocks varies from *Molinia coerulea*, *Carex* spp. and *Myrica gale* in the moister parts to *Erica tetralix* and *Calluna vulgaris* in the dryer parts. Some parts of the marsh which are of medium moistness have a characteristic vegetation of *Narthecium ossifragum* and *Gentiana pneumonanthe*.

Small areas covered by drenched moss, mostly *Sphagnum*, are usually found near the western shores of the lakes.

A dried-up pond or appendix to the lake Tormål, surrounded by high grass-vegetation, *Glyceria* and *Phrag-*

mites, was investigated. The bottom was sticky, humid.

Samples from meadows mostly originate from an area near the shores of Nors sø, inside the inner ridge of accumulated organic material. The vegetation is dominated by grass. This unit ranges from fairly moist soil covered by luxuriant vegetation to soils of a more dry appearance dominated by e. g. *Anthoxanthum odoratum*.

The heather moor is dominated by *Calluna vulgaris* and *Empetrum nigrum*. The moister parts, dominated by *Erica tetralix*, pass into the marsh. Other parts pass gradually into the "grey" or "white" dunes.

The "grey" dunes are composed of mature dunes covered by a more or less continual vegetation. Sandy flats in the "grey" dune areas are characterized by a vegetation of *Polytrichum piliferum* and lichens, mainly *Cladonia*.

The "white" dunes are the young "living" dunes, only sparsely covered by *Psamma arenaria* or a few other plants. In wind-protected basins, however, a luxuriant vegetation of low flowering plants and grasses (mainly *Festuca pratensis*) may be found. The "white" dunes constitute the external ridge of dunes nearest to the sea-shore, but a single dune 4 kms inland, Hybjerg, also has the character of a "white" dune.

The plantations are almost exclusively pine plantations (*Pinus mugo*). The forest floor is for the greater part covered by a moss-blanket, mainly *Pleurozium schreberi*. In other parts *Calluna* and *Empetrum* dominate, or the floor may be devoid of vegetation and covered only by the needle-litter.

In the plantations are found humid hollows, ditches or the like, often covered by *Myrica gale* and *Molinia coerulea* in tussocks.

A large glade in the pine plantation is partly covered by grass, partly by *Calluna* and *Empetrum*.

Outside the plantations, in the heather moor or the

"grey" dunes small groups of low shrub-like pines occur. A few samples have been treated from the floor under one of these "pioneer pines".

4. List of the species found.

- *1. *Podura aquatica* Linné 1758
2. *Hypogastrura litoralis* (Linnaniemi 1907)
3. — *scotica* (Carpenter and Evans 1899)
4. — *denticulata* (Bagnall 1941)
5. *Xenylla maritima* Tullberg 1871
6. *Willemia aspinata* Stach 1949
7. — *intermedia* Mills 1934
8. — *anophthalma* Börner 1901
9. *Friesea mirabilis* (Tullberg 1871)
10. *Odontella armata* Axelson 1903
11. *Pseudachorutes parvulus* Börner 1901
12. *Anurida tullbergi* Schött 1891
13. — *pygmaea* (Börner 1901)
14. — cf. *forslundii* (Gisin 1949)
15. *Neanura muscorum* (Templeton 1835)
16. *Onychiurus furcifer* (Börner 1901)
- 17.—24. *O. armatus* (Tullberg) s. lato
17. — *fimatus* Gisin 1952
18. — *bicampatus* Gisin 1956
19. — *tricampatus* Gisin 1956
20. — *armatus* (Tllb. 1869) Gisin 1952
21. — *subarmatus* Gisin 1957
22. — *subuliginatus* Gisin 1956
23. — *vanderdrifti* Gisin 1952
24. — *pseudovanderdrifti* Gisin 1957
25. *Onychiurus volinensis* Szeptycki 1964
26. *Tullbergia krausbaueri* (Börner 1901)
27. — (*Scaphaphorura arenaria* n. subgen. n. sp.)
28. *Tetracanthella wahlgreni* Linnaniemi 1911
29. *Anurophorus laricis* Nicolet 1842
30. *Folsomia quadrioculata* (Tullberg 1871)
31. — *nana* Gisin 1957
32. — *spinosa* Kseneman 1936
33. — cf. *bisetosa* Gisin 1953
34. — *fimetaria* (Linné 1758)

*) not found in the Hansted reserve, but collected from other localities in Thy.

35. *Folsomia* sp.
36. *Isotomiella minor* (Schäffer 1896)
37. *Folsomides navacerradensis* Selga 1962
- *38. *Proisotoma schoetti* (Dalla Torre 1895)
39. — *minima* (Absolon 1901)
40. *Isotomina thermophila* (Axelson 1900)
41. *Isotoma sensibilis* (Tullberg 1876)
42. — *monochaeta* Kos 1942
43. — *cinerea* Nicolet 1841
44. — *notabilis* Schäffer 1896
45. — *viridis* Bourlet 1839
46. — *maritima* Tullberg 1871
47. — *antennalis* (Bagnall 1940)
48. *Isotomurus ciliatus* Stach 1947
49. — *palustris* (Müller 1776)
50. — *plumosus* Bagnall 1940
51. *Entomobrya albocincta* (Templeton 1835)
52. — *corticalis* (Nicolet 1841)
53. — *nivalis* (Linné 1758)
54. *Orchesella cincta* (Linné 1758)
55. *Lepidocyrtus lignorum* (J. C. Fabricius 1775)
56. — *violaceus* Lubbock 1873
57. — *cyaneus* Tullberg 1871
58. *Pseudosinella alba* (Packard 1873)
59. *Tomocerus flavescens* (Tullberg 1871)
60. *Neelus minimus* Willem 1900
61. *Sminthurides pumilis* (Krausbauer 1898)
62. — *aquaticus* (Bourlet 1843)
63. — *malmgreni* (Tullberg 1876)
64. — *schoetti* (Axelson 1905)
65. — *pseudassimilis* Stach 1956
66. — *parvulus* (Krausbauer 1898)
67. *Arrhopalites* cf. *principalis* Stach 1945
68. *Sminthurinus elegans* (Fitch 1863)
69. — *aureus* (Lubbock 1862) var. *ochropus* Reuter 1891
70. *Bourletiella insignis* (Reuter 1876)
71. — *novemlineata* (Tullberg 1871)
72. — *bilineata* (Bourlet 1842)
73. — *linnaniemi* (Stach 1920)
74. — *viridescens* Stach 1920 s. Gisin 1948
75. — *repanda* (Ågren 1903)

*) not found in the Hansted reserve, but collected from other localities in Thy.

76. *Sminthurus nigromaculatus* Tullberg 1872

Protura:

77. *Eosentomon transitorium* Berlese 1908**5. Taxonomical remarks on some species.**

The determinations of the species found are based on Gisin's "Collembolenfauna Europas" (1960) and Stach's monography of the Polish Collembola (Stach 1947—1963). Since the publication of these excellent works, intense research on Collembolan systematics has continued, and a great number of papers published on this subject.

In this chapter a number of taxonomical remarks are given to some of the species from the list above. With regard to classification into families and genera, I follow Gisin (1960), and as to species, references are only given when not mentioned in this author's work.

Poduridae.

Hypogastrura litoralis (Linnaniemi 1907).

Gisin (1962) found that the variety of *Hypogastrura purpurescens* (Lubbock), which Linnaniemi (1907, 1912) described as var. *litoralis*, constitutes a good species, which is in fact more closely related to *H. tullbergi* (Schäffer) than to *H. purpurescens* because of the arrangement of the clavate tibiotarsal hairs.

Only one specimen was found, the characters of which accord very well with Gisin's description.

Xenylla maritima Tullberg 1871.

Some uncertainty has until recently been involved in the determination of the *Xenylla* species because of the variability of the mucrodens. Quite recently da Gama published studies of the chaetotaxy of *Xenylla* and other Collembolan genera in her dissertation "Colêmbolos de Portugal Continental" (da Gama 1964). The specimens from Thy all agree with the chaetotaxy-characters she described for *X. maritima*.

Willemia aspinata Stach 1949.

The specimens found accord with the description of Hüther (1962) in his revision of the genus *Willemia*.

Willemia intermedia Mills 1934.

One specimen was found to be in accordance with Hüther's redescription of *Willemia intermedia* (Hüther 1962).

Willemia anophthalma Börner 1901.

In accordance with Hüther (1962).

Friesea mirabilis (Tullberg 1871).

None of the specimens examined had a mucro developed and all should be referred to var. *reducta* (Stach 1949), if this taxon should not have subspecies rank. A few test-samples of the material have proved to accord with the chaetotaxy-characters described by da Gama (1964).

Pseudachorutes parvulus Börner 1901.

The chaetotaxy-studies of da Gama (1964) have made the discrimination between *P. subcrassus* Tullberg 1871 and *P. parvulus* quite safe. The previously employed characters, the number of vesicles in the postantennal organ and the shape of the apical sensory papilla, have proved to be variable and partly overlapping.

Thus, some of the specimens from the Hansted-reserve had a faint appearance of being three-lobed, but the number of vesicles in the postantennal organ never exceeded seven. The chaetotaxy-characters of da Gama have definitely referred the specimens to *P. parvulus*.

Anurida cf. forsslundi (Gisin 1949).

Only one juvenile animal was found (length: 0.5 mm). The characters of this specimen e. g. the number of olfactory hairs on ant. IV, and the shape of the furcadiments, agree with those described by Gisin, but it has, at the front-margins of the paired circular parties

of coarser granulation on the tergites of Th. II—Abd. I, an extra fine setula. Whether this single character is significant enough to justify the erection of a new species or subspecies can not be established without studying a greater material of adult animals.

Onychiuridae.

Onychiurus armatus (Tullberg 1869) s. lato.

In a series of papers Gisin split up *Onychiurus armatus*, in the sense previously accepted, into a number of separate species characterized by the number of pseudocelli on the different segments and by certain chaetotaxy-characters. The number of species in the *armatus*-group amounted to 38, as recorded by Gisin (1960). Since that time about 30 more species have been described.

Bödvarsson (1959), as well as others (e. g. Stach 1954), has criticized the basis of separation of the species emphasizing the variability of the characters used. This variability is, according to Bödvarsson, reflected in the frequent occurrence of animals being asymmetrical with respect to Gisin's diagnostical characters, and thus are apparently intermediate between two species in the sense of Gisin.

Recently Gisin (1963) pointed out that asymmetries may be two different kinds: one normal intermediate within a range of bilateral variance, and another abnormal, an exception from a fixed bilateral configuration of characters, one side of the animal being altered. In this last case, the bilateral condition, when also the other side of the animal is altered in the same way as the first side in relation to the normal form, will be even more rarely found than the asymmetrical form. Gisin regards his species of the *O. armatus*-group to belong to the last type. This implies that a specimen could possess the outer diagnostic characters of one species, while genotypically belonging to another.

Some findings do seem to support the assumption that Gisin's subdivisions of Tullberg's *O. armatus*, or at least some of them, constitute "good" separate species. Thus, Hale (1964) described some very interesting observations on the breeding biology of four species of the *O. armatus*-group described by Gisin. It is not intended to refer his findings here. It is only pointed out here that each of the four species in breeding cultures yielded offspring which developed into adults identical to the parent stock. He found differences between the species as to breeding biology and ecological preferences.

The problem of the legitimacy of the species rank attributed to the subdivisions of *Onychiurus armatus* is not yet solved. But it would be incorrect to neglect the existence of these differentiated forms. To affirm the genetical relationships of the specimens it is, however, necessary to have a large material of adult specimens, and to work it up by means of statistical methods.

In my material members of the *Onychiurus armatus*-group are comparatively rare, and many of the specimens are juveniles. I have for this reason not attempted a precise determination of each individual. Thus, the determinations mentioned in the species list refer, in all cases, to several identical specimens from each sample. Determinations based on only one single specimen should at any rate be regarded with some reservation.

Onychiurus volinensis Szeptycki 1964. (Fig. 1—12).

A material of about 180 specimens of an *Onychiurus* species was identified as belonging to this species in spite of disagreement with the description given by Szeptycki. Correspondance with Mr. Szeptycki, Ojcow, Poland, has revealed a mistake in his description: the ventral organ of the male is placed on the sternite of the fourth abdominal segment, and not, as described, in the posterior part of the third. Further, his description is based

on a single young male, and the setae of the ventral organ of fully developed males proved to have another and very characteristic shape (fig. 5). Mr. Szeptycki has kindly allowed me to publish this correction.

A study of the holotype (young male) and a fully developed male from the type locality which was identified by Mr. Szeptycki after the publication of his description, has revealed no important differences between the specimens from Thy and the Polish ones. Therefore, the opportunity has been taken to redescribe the species, based on all the material from Poland and Denmark.

Redescription:

Body shape (fig. 1): Cylindrical or a little flattened in dorso-ventral direction. The abdomen becomes gradually thicker from the front towards the hind end, culminating in the fourth segment. The relative lengths of the segments dorsally from Th. I to Abd. VI are about: 8:33:35:30:30:30:35:15:18. The head is fairly large in proportion to the body.

Colour of animals fixed in alcohol is white.

Length: Adult specimens range from 0.45—0.55 mm., the females being on an average a little longer than the males.

Granulation of cuticle: Very fine and homogenous. Is only distinct when magnified about 300 times.

Setae: The body is sparsely furnished with moderately short hairs. Near the median line, four irregular transversal rows of setae are recognized on the tergites of Th. II—Abd. V. On the first abdominal tergite only one row is found. Between the two posterior pseudocelli on Abd. V a conspicuously thickened seta (fig. 10) is placed.

Pseudocelli: are often very indistinct, but the abundance of material has allowed a safe statement of their numbers, as shown in the formulae (Gisin 1960) given below. The formulae are not completely in agreement with those given by Szeptycki, but at least the fully

developed male from Wolin has proved to have the same distribution of pseudocelli as here described. The number and distribution seems to be fairly constant. Only one specimen was found to differ from the formulae, having four pseudocelli at the antennal base instead of three. No examples of asymmetrical distribution were found.

Dorsal pseudocelli: 32/233/33343
Ventral „ : 2/000/0112
Subcoxae : 222

Of the ventral pseudocelli on the head, one pair is situated a distance of about $\frac{1}{3}$ of the head-length from the anterior end of labium, the other laterally near the hind margin of the head.

Antennae: are a little shorter than the diagonal of the head (ratio about 30:37). The relative lengths of the antennal segments (Ant. I-IV) are about: 10:15:20:28. The diameter of the first antennal segment measures rather more than $1\frac{1}{2}$ times its length. At a short distance from the apex of the antennae is found a subapical pit containing a small globular seta (fig. 2). The fourth antennal segment is further furnished with about 30 pointed sensory setae. Some of them are strongly curved towards the tip of the antenna, others are bent in an angle near the base, the distal part being nearly straight. Situated dorsally is one strong pointed sensory seta, about twice as thick as the setae just described, and bent in an angle basally. The sense organ of third ant. segment (fig. 3) consists of two pear-shaped sensory clubs, with two slender sensory rods between them. The shape of the sensory clubs is variable, the pear-like shape being less conspicuous in some specimens. The sensory clubs and rods are half hidden by four granulated papillae and guarded by five strong pointed setae, alternating with the papillae. Postantennal organ (fig. 4): is situated in an oval depression of the cuticle. It is of the compound type, con-

sisting of 9—11 primary tubercles covered by several secondary ones. These compound tubercles are not always very well separated from each other. The postantennal organ is guarded by two median and two lateral setae.

Claws (fig. 12): have neither inner nor lateral teeth.

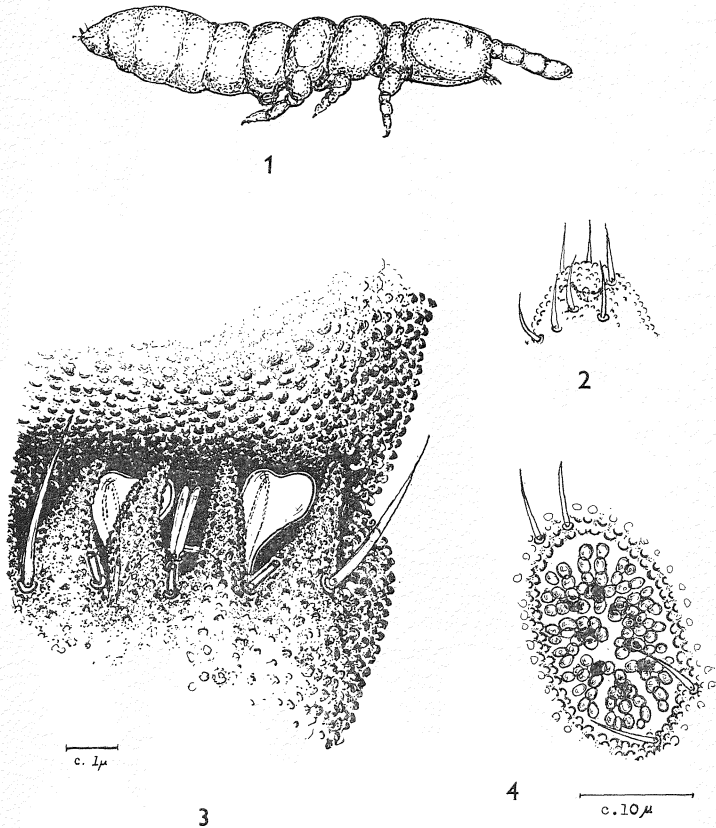


Fig. 1—4: *Onychiurus volinensis* Szeptycki.

Fig. 1: Habitus. — Fig. 2: Subapical pit of 4th antennal segment with sensory rod. — Fig. 3: Sense organ of 3rd antennal segment. (Three setae not fully drawn). — Fig. 4: Postantennal organ.

The empodial appendage tapers gradually into a fine apical needle, exceeding the length of the claw by one eighth. Szeptycki states the length to be only $\frac{3}{4}$ of the length of the claw, but in a phase-contrast microscope the apical needle was distinct both in the type and the other specimen from Wolin.

Ventral tube: has 2 pairs of setae basally, 2-3 pairs in some distance from the tip, and 3-4 pairs subapically. Ventral organ of the male: is situated on the fourth abdominal sternite, about half-way between anterior and posterior border of the segment. The fully developed male (genital areas as shown in fig. 5 and 6) has four pairs of very finely granulated club-shaped hairs, fixed in wide alveoles (fig. 5 and 7), and between them two pairs of fine pointed hairs situated in a faintly upvaulted part of the cuticle limited by shallow grooves. Behind the posterior border of the area, the cuticle forms a ridge, the hind-border of the area resembling a segment limit. In young males (genital areas as fig. 8 and 9) the setae of the ventral organ have the shape described by Szeptycki and shown in fig. 8.

Anal spines: two strongly curved anal spines (fig. 10 and 11) placed on very low papillae, are found on sixth abdominal segment. The length amounts to $\frac{2}{3}$ — $\frac{3}{4}$ of inner edge of third pair of claws.

Fig. 5—9: *Onychiurus volinensis* Szeptycki.

Fig. 5: Adult male: Sternite of abd. IV with ventral organ and both pseudocelli of one side and the median one of the other; hind margin of abd. III with the pseudocellus of one side; and anterior part of 5th abdominal sternite with genital area. — Fig. 6: More highly developed genital area of another male. (Enlargement as fig. 5). — Fig. 7: Seta from ventral organ. (Greatly enlarged). — Fig. 8: Young male: 4th abd. sternite with ventral organ and the two pairs of pseudocelli; and 5th abd. sternite with genital area. (Enlargement as fig. 5). — Fig. 9: Genital area of another male with the same type of ventral organ as in fig. 8. Genital area more highly developed. (Enlargement as fig. 5).

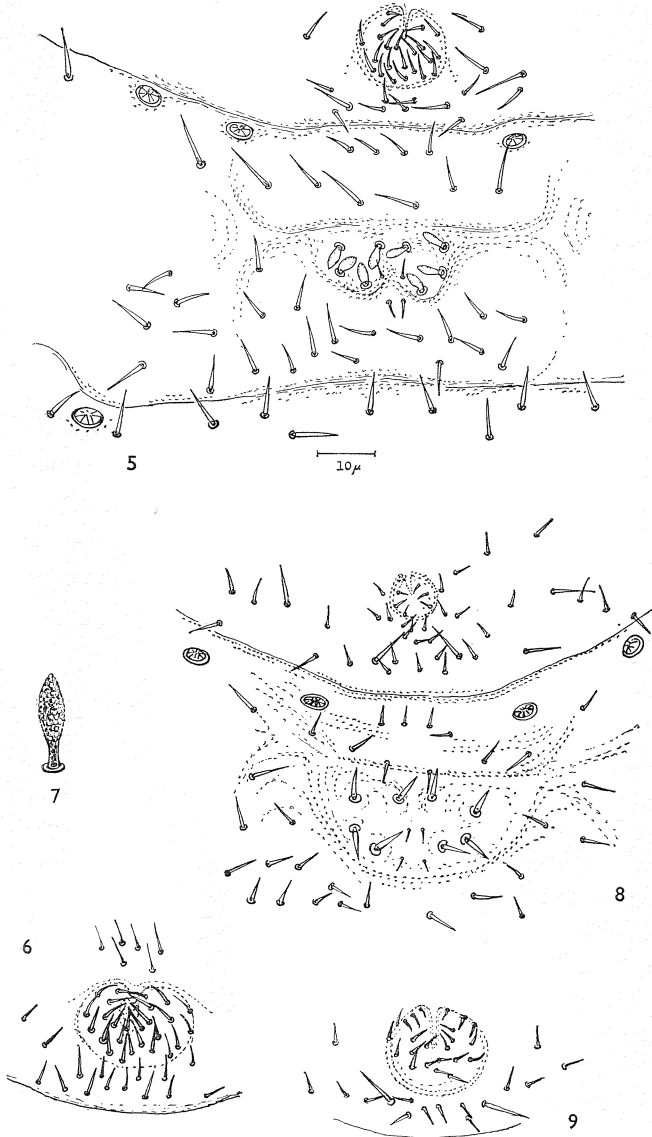


Fig. 5—9: *Onychiurus volinensis* Szeptycki.

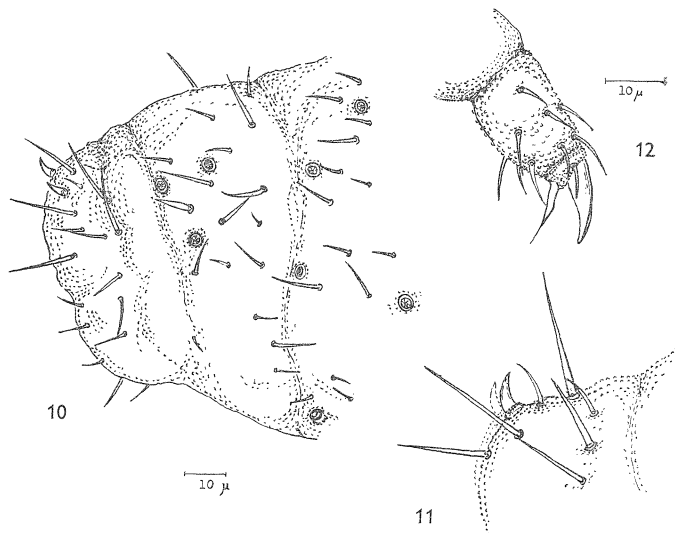


Fig. 10—12: *Onychiurus volinensis* Szeptycki.

Fig. 10: Dorso-lateral aspect of posterior part of 4th, 5th and 6th abdominal segment. — Fig. 11: Dorsal part of 6th abd. segment with anal spines. Lateral view. (Enlargement as fig. 12). — Fig. 12: Tibiotarsus, claw and empodial appendage of first pair of legs.

Tullbergia (Scaphaphorura) n. subgen.

A new species of Tullbergiinae was found in the Hansted reserve. It proved to differ from all other members of the subfamily in following characters: 1) Sense organ of 3rd antennal segment with only one sense-club (the dorsal). — 2) Postantennal organ oval, consisting of about 150 tubercles arranged in 6—8 irregular rows. — 3) Claws shovel- or spoon-shaped. — 4) Apical papilla of 4th antennal segment situated in a deep pouch.

The isolated position of this species caused by the characters mentioned here seems to call for the erection of a monotypical taxon here given subgenus rank. Description and discussion is included in the following treatment of the type-species: *Tullbergia (Scaphaphorura) arenaria*.

The subgenus name from Greek, skafion (=shovel) owing to the shape of the claws, and aphorura (=without tail) formed in accordance with most other genus- and subgenus-names in the subfamily *Tullbergiinae*.

Tullbergia (Scaphaphorura) arenaria n. sp. (Fig. 13—20).
Diagnostic characters: 1) Sense organ of third antennal segment with only one sense-club and two sense rods only partly hidden by an integumentary fold without papillae. 2) Postantennal organ oval, made up of about 150 tubercles arranged in 6(—8) irregular rows. 3) Claws without empodial appendage, shovel- or spoon-shaped. 4) Apical papilla of third antennal segment situated in a deep pouch. 5) Pseudocelli starlike. 6) 6th abdominal segment without semicircular ridges. 7) Anal spines simple.

Holotype: Adult female. Locality: Hansted reserve, Thy, Denmark; sample 169: Sand covered by *Psamma arenaria* and *Festuca rubra*. Near blow-out in "white" sand-dune in the external wind-exposed row of dunes about 50 ms from the sea-shore. About 6 kms SW of Hanstholm light.

Holotype and 20 other specimens are kept in the Zoological Museum of Copenhagen. 4 specimens are kept in the Museum of Natural History of Geneva. For the distribution of the species within the Hansted reserve see next chapter!

Description:

Body shape (fig. 13): very elongated and slender, cylindrical, worm-like. Segments Th. III—Abd. IV of nearly equal thickness, while the following, and also to some extent the preceding segments gradually narrow, the head being "streamlined" and narrower than the thoracic segments. The relative length of the segments (Th. I—Abd. VI) dorsally are 17:42:42:36:30:30:35:22:23.

Colour: of animals fixed in alcohol, white.

Length: of adult specimens, 0.45—0.50 mm.

Granulation of cuticle: is very fine and of almost homogenous distribution. In the environment of the pseudocellus of the antennal base the granulation is a little coarser.

Setae: The body is sparsely furnished with mostly short hairs, which only on the sixth abd. segment reach a considerable length, the longest being nearly as long as the segment. On the first thoracal tergite is found one transversal row, on Th. II—III and Abd. IV three rows are found, on the remaining segments two rows. In front of the pseudocellus on fifth abd. segment is placed a thickened sensory hair (fig. 20).

Pseudocelli (fig. 14, 20): Dorsal pseudocelli are distinctly visible in a sequence expressed in the following formula (Gisin 1960): 11/011/01011. In a few cases the one on Th. II has been missing, or missing on one side only. They are very large in proportion to the body-size, especially the first pair, placed at the antennal bases, being nearly $\frac{1}{3}$ of the diameter of the first antennal segment. The shape is star-like, a little like the pseudocelli of *Tullbergia krausbaueri*, but they usually have nine arms. The arms are provided with a fine granulation, which gradually becomes coarser towards the bases, and passes into the granulation of the surrounding cuticle without forming a distinct limit.

Antennae: are considerably shorter than the diagonal of the head (ratio about 45:65). The relative lengths of the segments (Ant. I—IV) are about 9:9:11:14. The diameter of first antennal segment is rather more than $1\frac{1}{2}$ times its length. The fourth antennal segment (fig. 15) is furnished with a thick blunt sensory seta dorsally, and two thinner ones on each side dorso-laterally, which are sharply deflected towards the apex of the antenna in one third of their length from the base. In front of

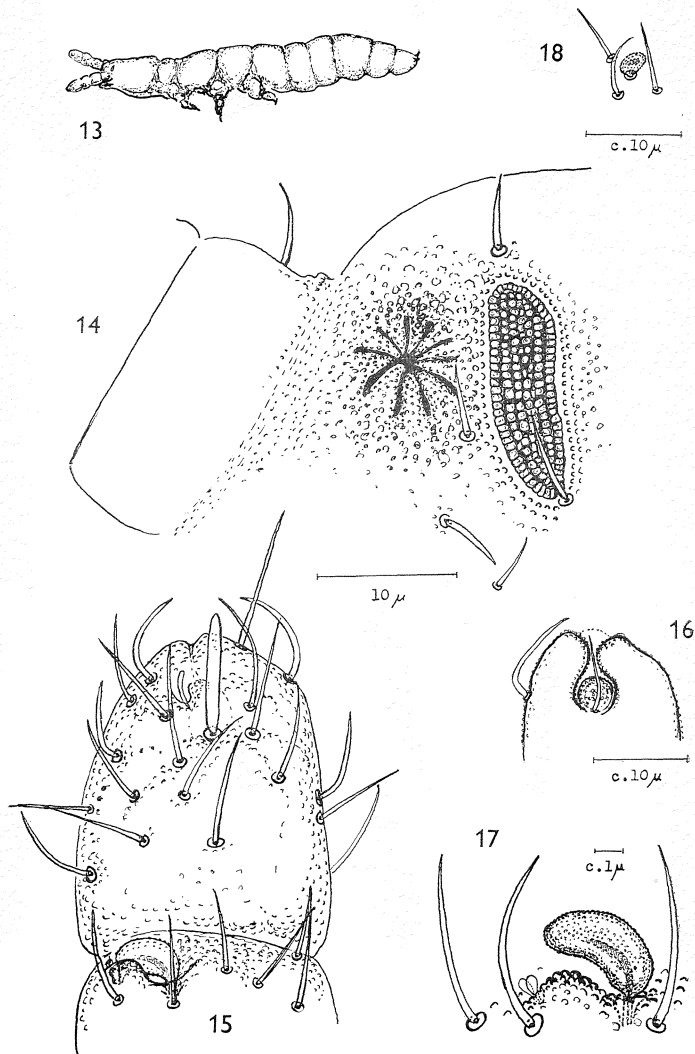


Fig. 13—18: *Tullbergia (Scaphaphorura) arenaria* n. subgen., n. sp.

Fig. 13: Habitus. — Fig. 14: Dorso-lateral aspect of right antennal base, pseudocellus and postantennal organ. — Fig. 15: 4th antennal segment and distal part of 3rd. Dorsal aspect. On 4th segment the subapical pit with sensory rod are seen as well as one thick and 4 thinner sensory setae. (Enlargement as fig. 14). — Fig. 16: Horizontal optical section through the apical part of ant. IV showing apical papilla in its deep pit. Papilla seen from dorsal side. — Fig. 17: Sense organ of 3rd ant. segment. — Fig. 18: Ventro-lateral sense-club of 3rd ant. segment.

the thick sensory seta is found a subapical pit with a fairly long rod-like sensory seta. At the tip of the antenna is found the narrow entrance to a deep pouch (fig. 16), housing a globular finely granulated papilla and an s-shaped pointed hair, inserted near the base of the papilla and projecting through the entrance of the pouch. Whether this papilla can protrude or not is not known. The condition of all the specimens examined was as here described.

The sense organ of third antennal segment (fig. 17): consists of only one thick cylindrical sensory club, the dorsal one, deflected downwards, and two small ovoid sensory rods. An insignificant integumentary fold not divided into papillae is seen between the sensory club and -rods. Three guarding setae are inserted near the sense organ. Ventro-laterally on the third ant. segment is a globular or ovoid sensory seta, protected by three common setae (fig. 18).

Postantennal organ (fig. 14): is situated in a depression of lancet-like circumference. Its greatest length is

about $\frac{3}{4}$ of the diameter of the first antennal segment. It is made up by about 150 globular tubercles packed together, forming 6(—8) irregular longitudinal rows.

Legs: are short. The claws have a unique shape (fig. 19). The basal part is shaped like a handle wrapped by a finely granulated cuff-like structure, bearing a tooth behind, directed towards the base of the claw. The distal half of the claw is bent in an angle to the basal part, the apex of the claw being turned inward. This distal part of the claw is broadened bas-

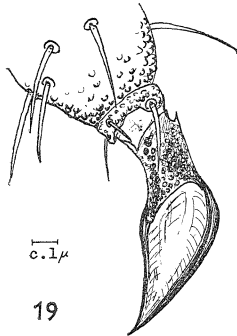


Fig. 19: *Tullbergia (Scaphaphorura) arenaria*.

Distal part of tibio-tarsus and claw of 3rd pair of legs.

ally and hollowed out from the inner side, being spoon- or shovel like. Distally the claw tapers gradually towards the apex.

Empodial appendage: is absent or represented by a very indistinct integumentary fold ventrally on the pretarsus.

Ventral tube: is furnished with two pairs of short setae basally, and four pairs subapically.

Genital area: of female is lip-shaped and furnished with two setulae on the front lip. The male genital area is approximately semicircular. Three pairs of setulae encircle the genital opening, two pairs are placed in front of these and one pair laterally on the genital area. Sixth abdominal segment (fig. 20): is simple, without semicircular ridges or areas of coarser granulation. Anal spines: two are present, placed on high papillae. They are moderately curved, of about the same size as the claws.

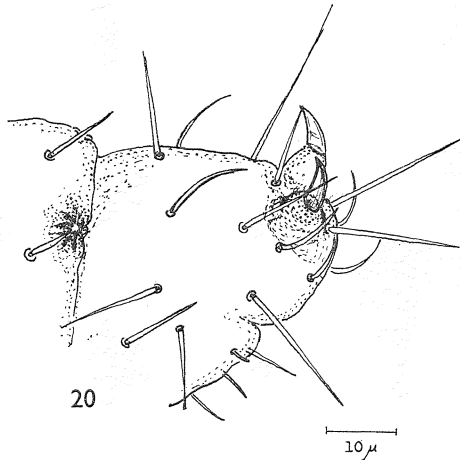


Fig. 20: *Tullbergia (Scaphaphorura) arenaria*.

Posterior margin of 5th abd. segment with pseudocellus and sensory hair; and 6th segment with anal spines.

Affinities: The elongated body-shape, the form and distribution of pseudocelli, the absence of empodial appendage and the shape of the sense organ of third antennal segment (the only sensory club present being the dorsal one, distinctly curved downwards), clearly classes this species with the *Tullbergiinae*. It is without doubt related to the genus *Mesaphorura*, Börner 1901, in the sense of Stach (1954), having simple anal spines and an integumentary fold not divided into papillae protecting the sense organ of third antennal segment. Also the presence of a thickened seta just in front of the pseudocellus of abd. V, and the absence of empodial appendage, indicate relationship with *Mesaphorura*. The star-like pseudocelli have a strong resemblance to those of *Mesaphorura krausbaueri* Börner. The general appearance is very much like that of juvenile *Tullbergia krausbaueri*, and it is not unlikely that members of this new species have previously been recorded as young *Tullbergia krausbaueri*. The present description is based on specimens with highly developed genital areas and thus in all probability adults not likely to undergo radical alterations through further moults. The absence of the ventral sensory club in the sense organ of third antennal segment and the unique shape of the postantennal organ and the claws, however, isolate this species not only from *Tullbergia krausbaueri* but also from all other known members of the subfamily, and the establishment of a new taxon seems to be called for. The rank is debatable. Probably it should only constitute a subgenus in the sense of Gisin (1960) having the same rank as *Tullbergia* s. str. (incl. *Mesaphorura* s. Stach), *Metaphorura* etc.

To me, the species seems to represent a specialized branch of the *Tullbergiinae*, probably originating from a species related to *Tullbergia (Mesaphorura) krausbaueri*.

The peculiar shape of claws and possibly also the strong development of the postantennal organ are sup-

posedly adaptations to an existence in such extreme habitats as interstices between particles of drift-sand sparsely covered by vegetation and exposed to wind-erosion and drying out. The shovel-shaped claws may be well fitted for clinging to rootlets or the like, and the post-antennal organ may enable the animals to react very precisely on humidity gradients.

Isotomidae.

Folsomia quadrioculata (Tullberg 1871) and **F. nana** Gisin 1957. (Diagrams 1, 2, fig. 21).

The legitimacy of the separation of the three species *Folsomia quadrioculata*, *F. nana* and *F. manolachei* (Bagnall 1939), has never been established with a fairly degree of certainty. Haarløv, for instance, found in his material from Dyrehaven near Copenhagen, that the relative length of the macrochaetae at the posterior end of the abdomen, which is the most important diagnostic character separating the three species, varied from individual to individual. For this reason he did not regard *Folsomia manolachei* as being a separate species, but considered it a variety of *Folsomia quadrioculata* (Haarløv 1957). Rusek (1963) found *Folsomia quadrioculata* and *F. nana* living together in a locality in Moravia. *F. nana* was represented by individuals ranging in size from 0.3 to 1.0 mm. Only the largest, ranging from 0.9—1.0 mm, had genital areas developed. The specimens determined to *F. quadrioculata* ranged in size from 0.9 to 1.4 mm and all had a well developed genital area. He concludes from these observations that the specimens determined as *F. nana* constitute the young stages of *F. quadrioculata*, the discontinuity between the two forms being caused by a moult.

In the material from the Hansted reserve specimens determined as *F. quadrioculata* and as *F. nana* are abundantly found, and this large material has allowed me to

elucidate the problem by means of simple frequency distributions. In diagram 1 is shown the frequency distribution of the proportion between the longest macrochaetae on the end of the abdomen and the mucro, ventrally measured. The column diagram has two distinct tops, one representing the frequency of a macrochaeta/mucro-ratio of 2.2—2.4, the other a ratio of about 3.8—4.0. The diagram is explained in a simple manner to be composed of two overlapping normal distributions, showing that the material contains two groups of animals, different to each other with respect to macrochaeta/mucro-ratio. This character, however, varies from one individual to another to overlap with the other group. The group varying around the ratio 2.3 has been referred to *Folsomia nana* although descending to a ratio between 1.8

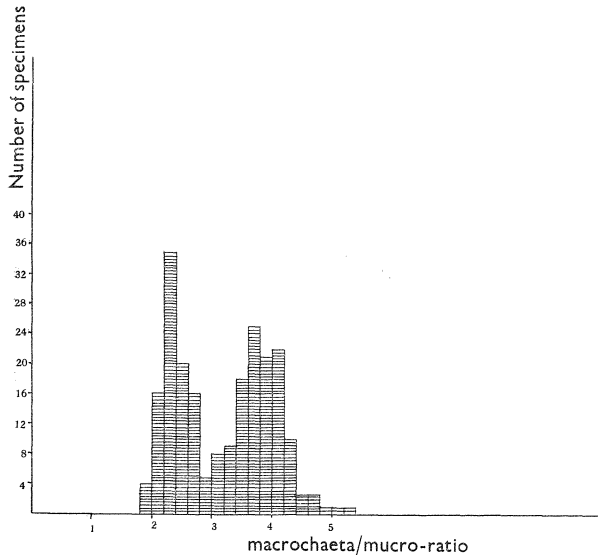


Diagram 1: *Folsomia quadriculata* (Tullb.) and *F. nana* Gisin.
Frequency distribution of the abdominal macrochaeta/mucro-ratio.

Size of classes: 0.2.

and 2.0, this being characteristic for *F. manolachei*. The group varying around the ratio 3.9 has been referred to *Folsomia quadrioculata*.

Diagram 2 shows that the two groups cannot be referred to two age-groups as indicated by Rusek. The diagram shows frequency distribution of the body-length of a number of specimens determined by means of the macrochaeta/mucro-ratio and classified into 12 groups characterized by the stage of development of their genital areas. Some of the developmental stages are shown on fig. 21. Many examples of asymmetrical chaetotaxy were found. These have been classified according to the most highly developed side.

The juvenile stages A, B and C comprise both sexes. In the place of the genital opening some of the genital areas of stage B and the majority of those of stage C were provided with a groove which was distinctly extended in longitudinal or transverse direction, thus indicating the sex of the animals, but in others the indication of the prospective genital opening was very faint and the sex could not be determined. The remaining stages all refer to females. A similar series of male genital areas has also been found but a corresponding treatment has not been carried out in the present paper.

Agrell has studied the postembryonic development of the genital tract of *Folsomia quadrioculata* (Agrell 1948). My stage A, having no well defined genital area, is comparable with his instar 1., although I have found no confirmation of the difference between males and females he indicates. Stage B is fairly concordant with Agrell's second instar, having two pairs of setae situated anteriorly on a well defined genital area. Stage C, which further has one pair of setae situated posteriorly is concordant with his instar 3, and stage D, with his instar 4 having two pairs of setae placed posteriorly. Agrell's fifth instar is comparable with my stage L/l, having in

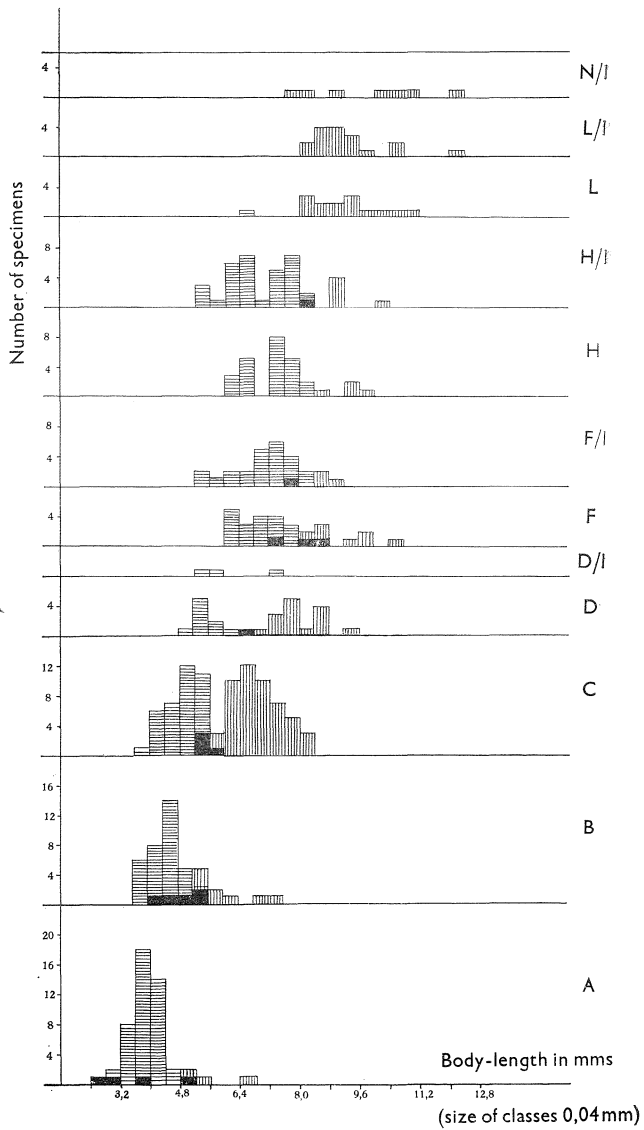


Diagram 2: *Folsomia quadrioculata* (Tullb.) and *F. nana* Gisin.

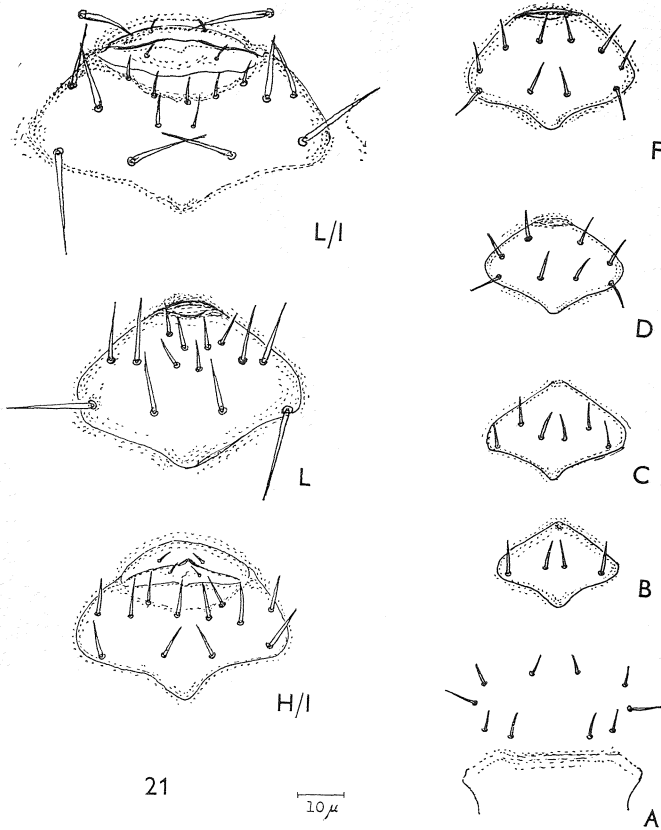


Fig. 21: A, B, C, D, F and H/l: *Folsomia nana* Gisin. — L and L/l: *F. quadrioculata* (Tullb.).

The figures indicate the correspondent different developmental stages of the genital area. See the text and diagram 2.

Figure-text to diagram 2:

Frequency distributions of the body-length of specimens arranged into 12 groups according to genital area development. A—C: juveniles not determined to sex. D—N: females. D, F, H and L: Genital areas without developed lips. D/l, F/l, H/l, L/l and N/l: Genital areas with developed lips.

Horizontal hatching: *F. nana*.

Vertical hatching: *F. quadrioculata*.

Black: Both species.

addition to the two posterior pairs of stage D and D/l, three pairs of setulae which are about half as long as and placed between the former. My stage N/l is probably comparable with Agrell's sixth instar, having more than three pairs of setulae placed along the front lip.

The types of genital areas F and F/l have three pairs of setae near the posterior margin of the genital area, i. e. one median pair in addition to the two lateral pairs found in the types D and E. In the case of specimens determined as *F. quadrioculata*, these median setae were about half as long as the lateral ones. In the case of specimens determined as *F. nana*, the median setae were about the same length as the lateral ones. The same difference between the two species is found in the types H and H/l. Here two median pairs of setae are present, or one pair and one unpaired median seta.

All genital areas referred to the types L and L/l have had the posterior median setulae about half as long as the lateral ones. The specimens with these types of genital areas were all (apart from one dubious specimen) determined as *F. quadrioculata* by means of the macrochaeta/mucro ratio. Thus this new character seems to be a good specific one. A similar difference separating the males has not been found.

An interesting feature is the development of swollen lips surrounding the genital opening, each lip provided with a pair of setulae. The presence of lips does not seem to be connected with the development of the chaetotaxy of the genital area in a simple manner as it appears from the paper of Agrell. Swollen lips were found in genital areas of a few *F. nana* (D/l) with a chaetotaxy as stage D. About half of the genital areas of *F. nana* with a chaetotaxy as stage F proved to have lips developed (F/l). Finally, genital areas of *F. nana* provided with lips (H/l) were more abundant than those without lips when the chaetotaxy was as stage H.

As to *F. quadrioculata* no specimens with a chaetotaxy of the genital area as stage D had lips developed. Only a few *F. quadrioculata* had a chaetotaxy as stage F and H. Genital areas with and without developed lips were found in equal numbers. Genital areas with a chaetotaxy as L were more often provided with lips (L/l) than not and finally all genital areas showing the highest development of chaetotaxy had lips developed.

The stages with developed lips are supposed to be stages of fertilization and oviposition. Mayer (1957) found in *Orchesella villosa* and *O. cincta* that reproductive phases alternate with nonreproductive ones separated by a moult. Possibly the same may be the case in *F. nana* and *F. quadrioculata* and expressed in an alteration between stages with and without developed lips, but it cannot be deduced with certainty from the present material. Even if it is true, it does not seem to be a regular alteration. In a few specimens the developmental stage of the genital area of the new cuticle lying within the old one of animals ready for moulting has been observed. In three cases the new cuticle was found to have developed lips but had the same chaetotaxy as the old cuticle. In two cases the old cuticle had the same chaetotaxy as the new one, but no lips, while the new cuticle had lips developed. In one case the transition from stage C to stage D (without lips) was noted.

It is true that the number of specimens analyzed is too small yet to support the following statement statistically within all groups of genital area development. Nevertheless, the diagram seems to indicate with a reasonable degree of certainty that the species differ distinctly from each other in respect of body-length through all developmental stages, *F. quadrioculata* being the longest. Further, it may be seen that *F. nana* increases in size through four moults, having reached the maximum size in stage F or F/l. The genital area seems in this

species to reach its highest development in the stages H and H/l. The stages H and H/l do not seem to show any differences in body size from stages F and F/l. These stages may be reached in the same instar as F and F/l, or the two stages may be reached after one or more moults not involving growth.

Regarding *F. quadrioculata* the stage N/l represents the highest development of the genital area. As in *F. nana* the mean size seems to increase through four moults. Although the largest specimens had genital areas as stage L/l and N/l no significant mean size differences between the stages F to N/l have been found in the present material and as in the case of *F. nana* a solution of the problem whether the stages F to N/l represent a sequence of instars separated by moults or a variation within one or a few instars must be left for future investigations involving studies of laboratory cultures.

To summarize the present findings: *Folsomia quadrioculata* and *Folsomia nana* seem to constitute two well separated species. The diagnostic character: the abdominal macrochaeta/mucro-ratio, has been found to be distributed in two distinct groups, although the variation causes overlapping. The length of *F. quadrioculata* seems to be greater than that of *F. nana* throughout all instars. The development of the female genital area is parallel in the two species throughout the first 4 instars. Growth can be distinctly observed in both species through 5 instars. After the fourth instar the females of the two species can be distinguished by means of the genital area: *F. quadrioculata* has the posterior median setae about half as long as the lateral ones; in *F. nana* the same setae are about the same length as the lateral ones.

The other characters previously used for the separation of the species viz., the length of the setae in the posterior transversal row of abd. III, their points transversing, reaching or not reaching the hind-border of the

segment (Gisin 1960), are found to be useless. The segments are often telescoped a little into each other, or the inter-segmentary integument has been stretched, the segment border being indefinable.

The colour varies considerably. Adult specimens of both species vary in colour from nearly black to light spotted grey, the differently coloured specimens often being unevenly distributed in the different habitats. Mostly, however, *F. quadrioculata* is found to be light grey, *F. nana* more or less blackish.

In the material from Thy only two species are found. *Folsomia quadrioculata* can without any doubt be referred to the species described by Tullberg. The other has been determined as *F. nana* Gisin. The separation of this species from *F. manolachei* Bagnall could not be illustrated by means of this material. The two forms may be synonyms. Until this problem has been solved, however, my specimens should be referred to *F. nana*.

Folsomia cf. bisetosa Gisin 1943 (fig. 22, 23).

More than 300 collemboles from the same locality in the Hansted reserve were determined as *F. bisetosa*. A comparison with the type material from Jan Mayen Island which Dr. Macfadyen, Swansea, kindly lent me, revealed, however, a few differences between the two populations. More than 70 specimens from the material from Jan Mayen were examined. All but one had 3 setae situated near the postantennal organ, one below and two behind (fig. 23), whereas the specimens from the Hansted reserve mostly had one seta below and three behind (fig. 22). As to the latter, however, the variation was found to be great, and the same chaetotaxy as in the Jan Mayen animals was found in several cases. Another character different in the two populations is the ratio between the diameter of the first antennal segment and the length of the postantennal organ. The mean

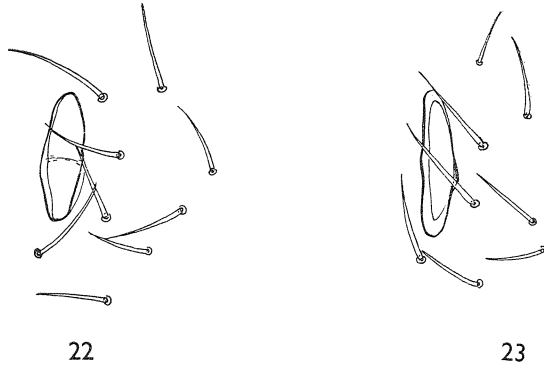


Fig. 22—23:— Fig. 22: *Folsomia* cf. *bisetosa* Gisin. Postantennal organ of specimen from the Hansted reserve.— Fig. 23: *Folsomia bisetosa* Gisin. Postantennal organ of specimen from Jan Mayen.

value of the ratio in the Jan Mayen population was 1.2 (max. 1.7, min. 1.0) and in the Hansted population 1.5 (max. 1.8, min. 1.3). No other differences between the two populations have been found.

The differences found might call for a description of a new species. Both materials, however, consist exclusively of females indicating parthenogenetical reproduction. Further, both materials originated from very restricted localities, so the differences noted might characterize different clones and not be significant at the specific level. Until materials from other localities have been examined it seems reasonable, at least, to refer the specimens from Jutland to *Folsomia bisetosa*.

***Folsomia* sp. (*fimetaria*-group).**

Only five juvenile specimens have been found. The number of manubrial setae is not fully developed, so the identity of the specimens could not be determined. They differ from *F. fimetaria* by lacking the inner tooth of claws and by having a broad inner lamella on the empodial appendage. They should probably be referred to *F. litsteri* Bagnall 1939.

Folsomides navacerradensis Selga 1962 (fig. 24—27).

This species has been separated from the closely related *F. pusillus* (Schäffer 1900) by the following characters: 1) The median eyes, G and F, are of nearly the same size as the remaining ones, 2) the shape of the furca, 3) clavate tibiotarsal hairs are absent and 4) the chaetotaxy of the dorsal side of the dentes has each two setae basally, i. e., one in the middle and one distally contrary to that of *F. pusillus*, in which each dens has one seta basally, two in the middle and one distally.

32 specimens (mostly juveniles) agree with the description by Selga, apart from the last-mentioned character which has proved to be highly variable, only one out of 23 specimens examined having the same configuration as described by Selga. The different variations found are mentioned below. The formula used should be read: (basal + median + distal). Asymmetries are indicated in this way: $\frac{1}{2}$.

1 adult	symmetrical	(2 + 1 + 1)	as Selga.
9 juveniles	"	(1 + 1 + 1)	
1 "	"	(1 + 2 + 1)	as <i>pusillus</i> .
5 ad. + juv.	asymm.	($\frac{1}{2}$ + 1 + 1)	
5 juv.	"	(1 + 1 + $\frac{1}{2}$)	
1 ad.	"	(2 + 1 + $\frac{1}{2}$)	
1 juv.	"	($\frac{1}{2}$ + 1 + $\frac{1}{2}$)	

These facts seem to represent a "true variation" in the sense of Gisin (1963), and thus this character is invalid for separation of the two species *Folsomides navacerra-*

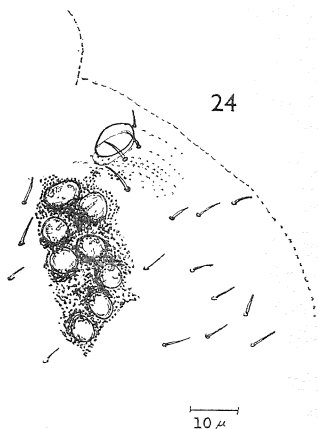


Fig. 24: *Folsomides navacerradensis* Selga. Postantennal organ and eyes of the right side of the head.

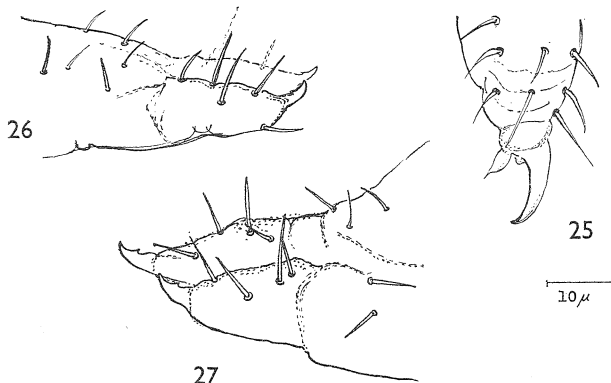


Fig. 25—27: *Folsomides navacerradensis* Selga.

Fig. 25: Distal part of tibia with claw and empodial appendage. — Fig. 26: Distal part of manubrium, denticles and mucrones. Chaetotaxy as in *Folsomides pusillus* (Schäffer). (Enlargement as fig. 25). — Fig. 27: The same as in fig. 26 in another specimen. Chaetotaxy as described by Selga. (Enlargement as fig. 25).

densis and *F. pusillus*. The other diagnostic characters constant in my material, however, seem to justify a determination as *Folsomides navacerradensis*.

***Isotoma (Pseudisotoma) monochaeta* Kos 1942 (fig. 28).**

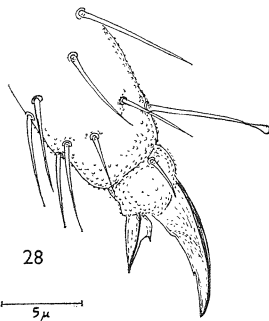


Fig. 28: *Isotoma (Pseudisotoma) monochaeta* Kos: Distal part of tibia, claw and empodial appendage of first, right leg. Seen from the inner side.

20 specimens were determined to this species. All were in agreement with the description given by Stach (1947), but the inner tooth of the claws was distinctly seen, and the apex of the clavate tibiotarsal hair is spatulate rather than club-shaped. The colour of the specimens was very light bluish or yellowish, the pigment being nearly absent. On the first and second tibiotarsus in one specimen the two neighbouring setae to the clavate hair were very faintly club-shaped. This

may support the suggestion that *I. monochaeta* constitutes a subspecies or variety of *I. sensibilis* as has been discussed (Stach 1947). However, the differences from the specimens of *I. sensibilis* found in the Hansted reserve are obvious, adult specimens of *I. monochaeta* being stouter and longer, less pigmented and having only one distinctly and constantly present clavate hair, which is considerably longer and thicker than the three clavate hairs of *I. sensibilis*. It is thus concluded that *I. monochaeta* constitutes a separate species.

Isotoma viridis Bourlet 1839.

All the adult specimens from the Hansted reserve had a more or less dark blue or violet colour and are thus referable to the var. *coerulea*, Börner 1901. The juvenile specimens were mostly light reddish violet.

Contrary to these specimens, most of the specimens determined from the material of Kaiser and Jensen from other localities in Thy, can be referred to var. *riparia* Nicolet 1841.

Isotoma maritima Tullberg 1871.

Altner recently redescribed this species (Altner 1963). He found that specimens from Norway, Southern Sweden, England, Ireland and the German North Sea coast belong to the same subspecies, characterized by the presence of two furcated setae on the outer side of tibiotarsus II.

In my material only three specimens were found, two having female genital area developed. One of the adult specimens had one indistinctly branched seta in the proximal part of the tibiotarsus. On the others no branched setae were observed.

Isotomurus ciliatus Stach 1947 (fig. 29—31, 35).

This species agrees very well with the description of Stach. Figure 29 shows the characteristic dorsal side of the dens covered by low elliptical elevations instead of

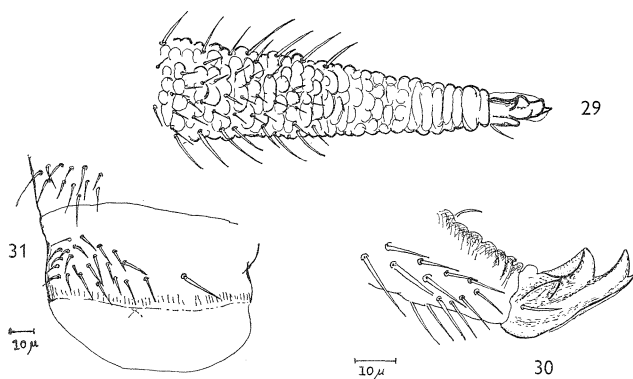


Fig. 29—31: *Isotomurus ciliatus* Stach.

Fig. 29: Distal part of left dens and mucro, dorsal aspect. — Fig. 30: Mucro from the outer side. — Fig. 31: Lateral flap of ventral tube. The front is to the left.

transversal crenulation. In this figure is also seen the mucro from the dorsal side with its inner horizontal lamella. The mucro is seen from the outer side in figure 30. The chaetotaxy of the lateral flap of the ventral tube has been pointed out by Yosii (1963) as a new character. In this species the anterior part of the lateral flap is abundantly furnished with short setae. Laterally, one stronger seta is found (fig. 31). The marginal thickening of the manubrium is shown in three variations in fig. 35, the significance of which is described later.

Isotomurus palustris (Müller 1776) (fig. 33, 34) and ***I. plumosus*** Bagnall 1940 (fig. 32, 36).

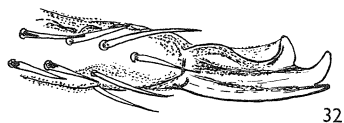
The integrity of the *Isotomurus palustris*-group has been much discussed (Stach 1947). Stach (1947) restricted *I. palustris* to include only specimens with ciliated macrochaetae, smooth common dorsal setae, claws without inner tooth and empodial appendages with a corner tooth. He separated specimens having ciliated common body setae and empodial appendage without inner tooth, from *I. palustris* and referred them to a new subspecies, *sub-*

ciliatus, of *I. palustroides* Folsom 1937. Stach himself mentions Bagnall's *I. plumosus* as a possible synonym for his new subspecies. Recently Dunger (1963) has also stated this assumption.

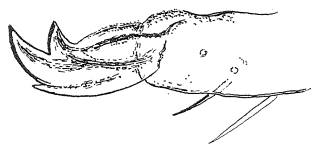
Seven paratype specimens of *I. plumosus* from the collections of the British Museum (Natural History) were kindly procured by Mr. P. N. Lawrence. Unfortunately the slides were badly preserved, but all characters examined, i. e. colour pattern, ciliation of common body setae, mucro, claws and empodial appendages, proved to be in accordance with the specimens from the Hansted reserve. My specimens determined to *I. plumosus* also agree fairly well with Stach's description of *I. palustroides subciliatus*, but ciliated setae are usually more abundant in my adult specimens than Stach's description indicates, nearly all setae on the tergites of third and fourth abdominal segments being ciliated. Ciliated setae were also found on the posterior part of the head. The ciliation was distinctly seen by an enlargement of 8×40 . In the juveniles ciliated setae were few in number or missing.

Most of the specimens determined as *I. palustris* agree with Stach's description, having a corner tooth on the empodial appendage and all setae without ciliae. The colour varied from uniformly yellowish (f. *prasina* (Reuter 1891)) to dark violet or brownish grey (f. *fucicola* (Reuter 1891)). A few specimens of *I. palustris*, however, agreeing with the other characters mentioned by Stach and the shape of mucro treated below, had distinctly ciliated common body setae as found in *I. plumosus*. This character thus seems to be variable. This was also stated by Murphy (1958). He indicates that a hint of ciliation can always be found by using great enlargement. By an enlargement of 8×100 , however, only a few more specimens than those previously mentioned revealed very slight ciliation.

In spite of the variability of the ciliation of the body setae it seems to me that the two species are well separated. One character more is believed to support this



32



33

Fig. 32—33: — Fig. 32: *Isotomurus plumosus* (Bagnall). Mucro from inner side. — Fig. 33: *Isotomurus palustris* (Müller): Mucro from inner side.

assumption: The shape of the mucro of *I. plumosus* (fig. 32) was found to be constantly different from that of *I. palustris* (fig. 33). The mucro of *I. plumosus* is distinctly more slender than that of *I. palustris*, the proportion between the length and the height being greater. Further, a lamella runs from the inner proximal tooth towards the base of the mucro, which is always absent in *I. palustris*. Gisin (1949b) con-

siders this last-mentioned character invalid for characterizing species because of great variability. In my numerous material as well as in the seven paratypes of *I. plumosus*, however, no variation of this character was found.

Yosii (1963) has called the attention to some new characters: the shape of the marginal thickening distally

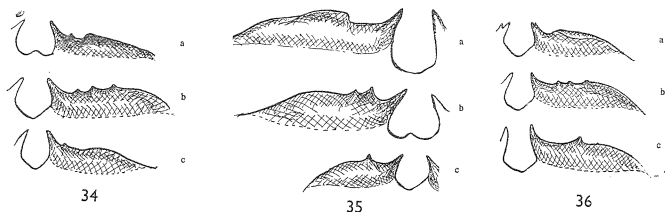


Fig. 34—36: — Fig. 34: *Isotomurus palustris* (Müller). One side of marginal thickening of manubrium, ventral aspect. Three variations (a-c) are shown. — Fig. 35: *I. ciliatus* Stach. The same as in fig. 34. — Fig. 36: *I. plumosus* (Bagnall). The same as in fig. 34.

on the manubrium, the shape of the labrum and the chaetotaxy of the lateral flap of the ventral tube. He described some species based on these characters.

The material from the Hansted reserve, however, has revealed that the manubrial marginal thickening is highly variable within each of the three species determined. Some examples of the variations found are shown in fig. 34—36, one, two or three accessory teeth being present. Asymmetrical specimens are very often found.

The shape of the labrum is similar in all specimens of both species, agreeing with Yosii's figure 20A. Both species have three setae on each lateral flap of the ventral tube.

Entomobryidae:

Lepidocyrtus lignorum (J. C. Fabricius 1775) Gisin 1964.

The specimens primarily determined as *L. lanuginosus* (Gmelin 1788) proved to agree with Gisin's redescription of Fabricius' species (Gisin 1964 a, b).

Lepidocyrtus violaceus Lubbock 1873, s. Gisin 1964 and
L. cyaneus Tullberg 1871, s. Gisin 1964.

The specimens belonging to these two species were primarily all determined as *L. cyaneus*. The revision of the genus proved that the two species could be distinguished (Gisin 1964 a, b).

Sminthuridae.

Sminthurides aquaticus (Bourlet 1843).

All the specimens are pale yellowish without pigment on the greater part of the body. The antennae have a reddish violet colour becoming stronger towards the apex. The oral-region and a spot ventro-laterally on abd. IV has a violet colour, a triangular spot between the eyes is black.

Arrhopalites cf. principalis Stach 1945 (fig. 37—41).

Six specimens have with some doubt been referred

to this species. The main discrepancies between the specimens and Stach's description are as follows: 1) The dentes have shown great variability (fig. 37—39). On the outer side they either have one spine-like seta placed in a distance of $\frac{1}{3}$ of the length of the dens from its apical end as in Stach's description (fig. 39), or they have two or more of the setae basal to the spine more or less spine-like (fig. 37, 38), resembling the condition of *A. gisini* Nosek 1960, or *A. postumicoides* Cassagnau and Delamare 1953. 2) The empodial appendages of the third pair of claws have a distinct inner tooth (fig. 40). 3) The subanal appendages are broom-like, but not bifurcated

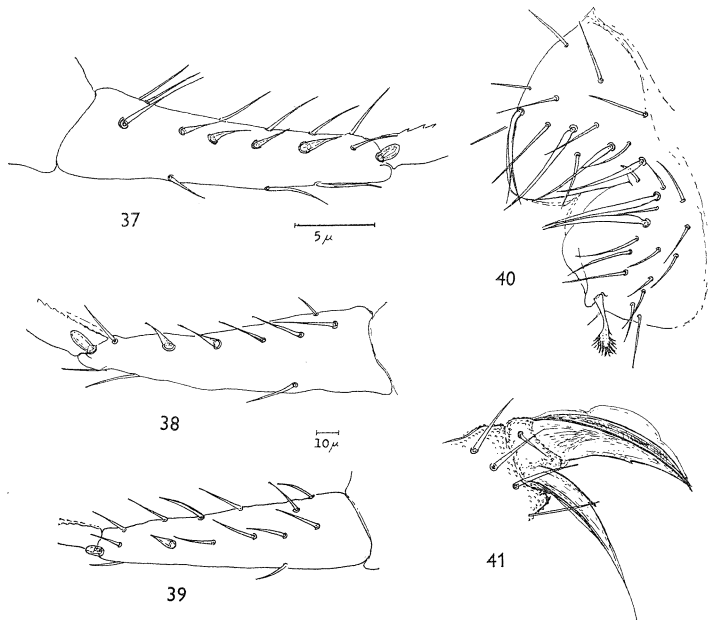


Fig. 37—41: *Arrhopalites* cf. *principalis* Stach.

Fig. 37—39: 3 different variations of dentes. Seen from outer side. — Fig. 40: Claw and empodial appendage of 3rd pair of legs. — Fig. 41: 6th abdominal segment with subanal appendage. (Enlargement as fig. 38).

(fig. 41). 4) The bristles surrounding the anus (fig. 41) are somewhat broadened near their bases.

With respect to the maximal number of spines present on the outer side of the dens and the broadened bristles surrounding the anus, the specimens agree better with the description of *A. gisini* than that of *A. principalis*, but the broom-like subanal appendage is very different from that described by Nosek. The colour of the specimens found is reddish brown, as described for *A. principalis*, thus different from the white colour of *A. gisini*. The variability of the number of spines on the dens coincides with the variability of other characters used as diagnostic specific marks within the genus pointed out by Lawrence (1961). The demarcations of the species in this genus are thus very uncertain as yet, and a revision of the genus may involve a great deal of systematical alteration.

Until more material of the present species has been examined the identity cannot be established with absolute certainty.

6. Ecological Part.

As previously mentioned the primary purpose of this investigation was to obtain an impression of the Apterygotan fauna of the Hansted reserve in keeping with the treatment of other insect groups in this series of investigations of the reserve. For this reason sample sites as different as possible have been chosen with respect to general external appearance, the character of the soil, degree of humidity, vegetation and exposure to sun and wind etc. On the other hand, an attempt to obtain representative mean values of the participation of the species from homogenous habitats was abandoned.

For the purpose of drawing ecological conclusions this deficiency may seem very disadvantageous. However, until now it has not been found what really is a

homogenous habitat for a Collembolan. A comparison of works concerning Collembolan ecology reveals a very confusing picture of the distribution of Collembola in various habitats. Often species, characteristic for a certain habitat in one locality, are found abundantly in quite different habitats in other localities. For instance, Schaller (1951) found *Brachystomella parvula* to be remarkably frequent in nearly bare sand, though Gisin (1943) found it to be a character-species in his "*Brachystomella parvula*-synusie" in loamy meadow soils and bogs.

Linnaniemi (1907), together with many subsequent authors of Collembolan ecology, considered the greater part of Collembolan species ubiquitous or eurytopic, and ascribed this condition to the great tolerance of these species to the external factors of the habitats. This view has, however, been recently questioned, partly because of the increasing knowledge of Collembolan systematics and partly because of a new opinion on the distribution pattern of the Collembola. Regarding the latter the papers of Poole (1961, 1963, 1964) should be emphasized.

Poole investigated some small areas of forest soil in Wales and Jutland demarcated by a few coniferous trees. The species found were distributed in a mosaic-like pattern between each other, though culmination of their density was reached by more than one species in the same place supposed to be especially favourable in one way or another. The distribution of some species could in a few cases be correlated with a single physical factor, i. e. the moisture content and the depth of the organic layer, but in other cases it could not. Poole suggests that more than one single physical factor determines the distribution of the species and that a biotic factor, possibly the distribution of the mycorrhizal rootlets, is also responsible for the distribution of the Collembola. The observation that more than one species reaches its maximal density within the same patch of soil while

elsewhere their distribution is not correlated, does, he believes, contradict a theory that the aggregations are an effect of real sociability.

Observations such as these by Poole show it rather aimless to try to establish well-defined Collembolan communities characterizing greater habitat units as e. g. heather moor, pine plantation, "grey" dunes etc. These greater units, often defined by conspicuous plant-communities, are not considered homogenous regarding the factors or compositions of factors determining the distribution of the Collembola. Conditions favourable for different species or assemblies of species are thought to be distributed in a "mosaic-like" manner between each other, in a way not always detectable by means of known methods. Some microbiotopes like these may be restricted to just one plant-community or another greater unit, but others may have a wide distribution through several greater units. This may explain the apparent ubiquitous nature of many Collembolan species, which are perhaps more or less stenotopic in respect to certain compositions of external factors. The latter are, however, realized in several different biotopes in the sense generally perceived.

Thus, it does not seem to be very important that representative values of the species composition of greater units of plant-communities are missing. On the other hand, investigations of the species distribution within very restricted sections of plant-communities might without any doubt yield interesting and statistically well supported information. The most valuable ecological information the present investigation comprising the whole area of the Hansted reserve and the surrounding plantations can yield is assumed to give some idea of the ecological valence of the single species. In this respect, the way of choosing the sample sites seems to be the most suitable.

The local distribution of the single species.

Poduridae.

1. **Podura aquatica** Linné 1758.

Danish records: Bartholin, 1916; Haarløv, 1957.

Not found in the Hansted reserve, but collected by Kaiser and Jensen: $^{22}/_8$ 1954. Canal east of Tømmerby fjord.

2. **Hypogastrura litoralis** (Linnaniemi 1907).

New to Denmark.

Known from Finland, Northern Russia and Greenland.

One specimen found in washed-up plant material, near the water-level (41 *).

3. **Hypogastrura (Ceratophysella) scotica** (Carpenter and Evans 1899).

New to Denmark.

Recorded from Sweden, Finland, Great Britain and Northern Germany.

Found in eight samples, mostly in rather few specimens. More than ten specimens were found in two samples, one from a moist Sphagnum-cover (134), the other from drenched soil between tussocks of *Molinia coerulea* (92). The other samples originated from similar types of drenched sites, apart from one which was taken from the external layers of an ant-hill in the "grey" dunes.

This distribution agrees very well with Gisin's statement (Gisin 1960): "Principally in bogs and swamps".

4. **Hypogastrura (Ceratophysella) denticulata** (Bagnall 1941).

Danish records: ?*Hypogastrura armata*: Bartholin 1916; Bornebusch 1930; Weis-Fogh 1947/48; ?*Ceratophysella armata*: Haarløv 1957.

Since Gisin's revision of the *Hypogastrura armata*-group (Gisin 1949) it has been found that at least two

*) Figures in brackets refer to the sample numbers.

very common species were included in the previous interpretation of *H. armata* (Nicolet 1841): *H. armata* (Nic.) and *H. denticulata* (Bagnall). Only the latter was found in the reserve.

H. denticulata has been recorded from many widely different habitats: Compost heaps (G. Gisin 1952), rotten wood, cow dung, cabbage roots, stream moss (Lawrence 1962), subalpine- and alpine pastures (Cassagnau 1961), wrack (Strenzke 1963).

In the area treated here the greatest abundancy and frequency seems to occur in ridges of cast-up organic material along the lakes when not too exposed for being washed by the surf. On the whole this species is restricted to the humid belts around the lakes, and has not been found in the plantations, the heather moor or the dunes. In drenched types of soil outside the lake shores such as marsh, bogs and moss cushions, the species is rarely found. *Hypogastrura scotica* seems here to substitute *H. denticulata*. A high content of decaying organic material in connection with a fairly high degree of humidity are probably factors of great importance for the distribution of the species.

5. ***Xenylla maritima*** Tullberg 1871.

Danish records: Weis-Fogh 1947/48.

The species is recorded from several North-European localities.

In the investigated area it was almost exclusively found in the "grey" dunes. The greatest abundancies were found in samples from lichen (*Cladonia*) covered areas.

Most records about the ecology of this species agree very well with my findings. It has mostly been recorded from environments with a very low content of free water (Agrell 1934, Schaller 1951). Gisin (1943) calls it "xerophile".

6. **Willemia aspinata** Stach 1949.

New to Denmark.

Known from Poland (Stach 1949), Germany, Finland (Hüther 1962), Scania (Bödvarsson 1961).

Biotopes recorded are needle-litter, moss, old tree stumps, under loose bark (Stach 1949), leaf- and needle-litter, grass-grown soils (Bödvarsson 1961).

Together with *W. anophthalma* this species was found with a high degree of constancy in the Pleurozium blanket, needle-litter and raw humus in the pine plantations. The greatest densities, however, were present in the surface layers of an ant hill of *Formica rufa* (148) and in dark mull under a willow shrub on the top of the chalk-cliff (130). In the last mentioned sample *W. anophthalma* was not found. In the ant hill sample *W. aspinata* were considerably more abundant than *W. anophthalma*. In most other cases *W. anophthalma* occurred slightly more often.

7. **Willemia intermedia** Mills 1934.

New to Denmark.

Recorded from Germany and Finland.

1 specimen found in sandy soil between roots of a tussock of dead grass from the large glade in the plantation (67).

8. **Willemia anophthalma** Börner 1901.

New to Denmark.

Recorded from many localities in Northern Europe, incl. Scania.

The habitats recorded in the literature do not differ considerably from those of *W. aspinata*. Additionally the present investigation has only revealed faint hints of a difference in ecological preference of the two species. See above.

Gisin (1943) assumed that the species belongs to the "acidiphilen und xerophilen Euedaphon".

9. *Friesea mirabilis* (Tullberg 1871) var. **reducta** Stach 1949.

Danish records: Weis-Fogh 1947/48; Haarløv 1957.

This species mostly occurs in relatively small numbers in several samples from widely different habitats. The inner zones of the lake-shores and the chalk-cliff appear to show the highest degree of constancy and the dryer parts of the shores also the greatest densities (112, 114, 71). The species is, however, found sporadically in most other habitats: marsh and bogs, heather moor, "grey" dunes, beech wood, litter in pine plantation, under bark.

The apparently ubiquitous character of this species concords with opinions of several authors (Stach 1949, Bödvarsson 1961, Haarløv 1957). Gisin (1943) calls it "euryhygr" and found it most numerous in acid surroundings.

10. *Odontella (Xenyllodes) armata* Axelson 1903.

New to Denmark.

The species is widely distributed in Europe, but is, according to Stach, rather rare.

14 specimens were found in one single sample (40): bare drenched soil between *Erica tetralix*-hummocks in a depression between "grey" dunes. Gisin (1943) found this species restricted to alkaline soils. Linnaniemi (1907) found it a littoral animal. In Central Europe it is restricted to mountain forests.

11. *Pseudachorutes parvulus* Börner 1901.

New to Denmark.

Known from e. g. Germany, England and Sweden.

Gisin (1943) describes it as a fairly rare species restricted to acid soils of coniferous woods.

In the investigated area it was found with a fairly high degree of constancy in the *Pleurozium* blanket, needle litter and raw humus of the pine plantation and also in a few samples from heather moor and "grey"

dunes. A considerable density was only found in one sample of *Pleurozium* incl. the raw humus layer (80).

12. **Anurida tullbergi** Schött 1891.

New to Denmark.

Registered from nearly all European countries.

The species is usually described as littoral, occurring near shores of salt- and fresh water (Stach 1949).

This accords with my findings: The species seems usually to be found in a rather narrow zone, drenched, but not actually exposed to the action of the waves.

13. **Anurida pygmaea** (Börner 1901).

Danish records: *Micranurida pygmaea*: Weis-Fogh 1947/48; Haarløv 1957.

Widely distributed in Europe.

Gisin (1943) found this species in so many different habitats that he hesitated to comment upon its ecological specificity. He only found a few specimens from each locality, which accords with the records of many other authors.

In the Hansted reserve, however, the species was abundant in quite a few samples from the forest floor of the plantation. The number of animals pr. sample exceeded 100 in a sample of *Hylocomium splendens* under a "pioneer" pine shrub in the "grey" dunes. The species is very constant in the plantation. It is, however, sparse in most other habitats, and not present at all in the Sphagnum cushions, the marsh and bogs, the chalk cliff and the "white" dunes. In all habitats outside the plantation and its "pioneers" the number of specimens per sample was low.

14. **Anurida forsslundi** (Gisin 1949).

New to Denmark.

Known from Swedish Lapland, the Alps and other mountains of Central Europe, in acid forest soils. (Gisin 1960).

One specimen was found in a "white" dune between roots of *Salix repens arenaria* (96).

15. *Neanura muscorum* (Templeton 1835).

Danish records: *Achorutes muscorum*: Bartholin 1916; Bornebusch 1930.

A common species which has been recorded from nearly all habitats (Gisin 1943, Stach 1951).

In the Hansted reserve it was found to occur in all habitats, but in low numbers.

Onychiuridae.**16. *Onychiurus furcifer* (Börner 1901).**

New to Denmark.

Known from e. g. Sweden, Finland, England, Germany.

According to Stach (1954) this species occurs under loose bark and in leaf- and needle litter.

In the present investigation it was only found in the samples from the chalk cliff. It was found in the greatest number in moss- and grass vegetation from the upper part of the cliff (125), but also in samples from bare chalk gravel (127) and from mull on top of the cliff (130), but not in the humid basal parts of the cliff or in the dry overhanging moss blanket (128).

17.—24. *Onychiurus armatus* (Tullberg 1869) *sensu lato*.

Danish records: Bartholin 1916; Bornebusch 1930; Weis-Fogh 1947/48; Haarløv 1957.

In accordance with other authors, Gisin (1943) called this form an eurytopic soil animal. Since that time, however, he has split this form up into a number of separate species (see preceding chapter), which he considers to be stenotopic.

O. armatus *s. lato* has been found in most greater habitat units in the investigated area. It was, however, not found in the *Sphagnum* cushions, marsh and bogs, heather moor and the "grey" dunes. It has been found fairly frequently in the grass-covered soil of the meadows and found to be very constant in the samples from the chalk cliff and the "white" dunes. It was very spar-

sely distributed in the floor of the plantation and in the lake-shore zones.

In most cases, where a considerable proportion of the specimens in a sample have been determined exactly to species, most of the specimens have proved to be identical. The dominating *Onychiurus*-species within each sample changed from one habitat to another. These observations may support the concept of Gisin, the subdivisions of *Onychiurus armatus* s. lato being "good" separate species with a narrow ecological valence, but may also be explained as morphologically distinct ecotypes or pheno-typical modifications.

The distribution of the *Onychiurus*-species in strict meaning are recorded below.

17. *Onychiurus fimatus* Gisin 1952.

New to Denmark.

Known from Germany and Central Europe in compost.

About 10 specimens were found in fairly moist, grass-covered soil near lake-shore (71).

18. *Onychiurus bicampatus* Gisin 1956.

Danish records: Description based on specimens from Vorsø, Denmark.

Most of the 15 specimens from a sample from rather dry grass- and moss-covered soil (119) proved to belong to this species.

19. *Onychiurus tricampatus* Gisin 1956.

Danish records: Material from Zealand and Vorsø makes up part of the type material. — Haarløv 1957.

The habitats recorded are mostly meadows or other open plant communities which have a rather dry appearance: Knurrevang, Eremitagesletten (Haarløv 1957), but it has also been recorded from beech wood thickets (Vorsø).

Most of the 26 specimens from a sample of meadow soil covered by grass (*Poa pratensis*) (118) were determined to this species and *O. subuliginatus*.

20. **Onychiurus armatus** (Tullberg) s. stricto Gisin 1952.
Danish records: Gisin, 1956, Vorsø.

On Vorsø the species was found in beech forest and meadows. Gisin (1960) writes: "Generally in fairly dry soils".

Most of 50 specimens of *O. armatus* s. lato from a sample from the "white" dunes (171) were determined as *O. armatus* s. stricto. In two other samples from the "white" dunes the members of the *O. armatus* group were also found to be *O. armatus* s. stricto. One specimen of *O. armatus* s. stricto was found in a tussock of dead entangled grass on fairly moist soil near a lake shore (6).

21. **Onychiurus subarmatus** Gisin 1957.

New to Denmark.

Known from Southern Germany.

Two specimens were found in a sample from washed up plant material (165).

22. **Onychiurus subuliginatus** Gisin 1956.

New to Denmark.

A few specimens found in samples from the chalk cliff (125), the "white" dunes (171, 96) and the meadows (118, 119).

23. **Onychiurus vanderdrifti** Gisin 1952.

New to Denmark.

One sample from the chalk cliff and one from the "white" dunes contained a few specimens.

24. **Onychiurus pseudovanderdrifti** Gisin 1957.

New to Denmark.

Known from Southern Germany and Austria.

This species was found to be characteristic of the chalk cliff, occurring here in fairly high densities.

25. **Onychiurus volinensis** Szeptycki 1964.

New to Denmark.

Only known from the Island of Wolin in the Baltic.

There, it was found in sand-dunes without trees near the coast.

In the Hansted reserve it was restricted to the "white" dunes. About 160 specimens were found together in a sample from a mat of *Honckenya peploides* growing in a somewhat sheltered position in the external row of dunes (171). It was also found in low numbers in samples from more wind-exposed sites in the external row of sand-dunes, i. e. wind-eroded mats of *Festuca rubra* and *Psamma arenaria* (168, 169), and in samples from Hybjerg which is an isolated "white" sand-dune about 4 kms from the sea shore.

26. **Tullbergia krausbaueri** (Börner 1901).

Danish records: Weis-Fogh 1947/48; Haarløv 1957; Poole 1964.
Recorded from all Europe.

Gisin (1943) found it an abundant species in nearly all soils. Weis-Fogh (1947/48) found it dominant and constant in the dry end of his sampling line, but also regularly occurring in all other localities. Haarløv (1957) found it in ant hills, flooded pasture, thicket and pond-shore.

In the area investigated here the species was found in all greater habitat units, but was very sparse in drenched habitats such as the lake-shores and the marsh and bogs. It was also seldom found in the "grey" dunes. The species was fairly constant in the plantations, the meadows, the heather moor and the "white" dunes. The highest densities were found in the last mentioned habitat. Thus sample 171 contained, in addition to the 160 specimens of the preceding species, and 50 specimens of *Onychiurus armatus* (Tullb.) s. str., about 800 specimens of *Tullbergia krausbaueri*. In sample 172, which was taken from a piece of the vegetation mat from the top of dunes which had fallen onto the beach, and thus extremely exposed to wind-action, *T. krausbaueri* was found to be

the only species and even occurred in fairly large numbers.

27. **Tullbergia (Scaphaphorura) arenaria** mihi (see p. 330).

This species was found in three samples, one of them from a sandy flat, covered by lichen and *Polytrichum* (131), another from a blow-out in a mature dune (163) and a third from a blow-out in the external row of "white" dunes (168). As *Onychiurus volinensis*, this species seems to be restricted to wind-exposed sandy habitats.

Isotomidae.

28. **Tetracanthella wahlgreni** Linnaniemi 1911.

New to Denmark.

According to Gisin (1960) this species has only been found in Great Britain and in Finnish and Swedish Lapland, records from other localities being due to a confusion with the closely related *T. arctica* Cassagnau, 1959. Bödvarsson (1961), however, records *T. wahlgreni* from Scania. Whether these specimens should actually be called *arctica* is not known. Stach (1947) calls it a boreo-alpine species, but has confused it with *T. arctica*.

In the Hansted reserve it was found in 4 samples from humid bottoms of basins in the mature inland-dunes with sparse vegetation, often characterized by *Drosera* (Tx. 6, Tx. 8, 1, 39).

29. **Anurophorus laricis** Nicolet 1842.

Danish records: Bartholin 1916.

Gisin (1943) described it as "Xerophile Form der Rinden". Bartholin found it under the bark of trees. Agrell (1934, 1941) records the species as dominant in the needle litter of pine-woods in Lapland and in a drift-sand area of Scania.

Although the latter area closely resembles the pine-plantations in Thy, *A. laricis* has only been found once under *Parmelia*-lichens on the bark of pine trees.

30/31. **Folsomia quadrioculata** (Tullberg 1871) and **F. nana** Gisin 1957.

Danish records of *F. quadrioculata*: Bartholin 1916; Bornebusch 1930; Weis-Fogh 1947/48; Haarløv 1957; Poole 1964.

The two species have without any doubt often been confused in previous records. According to these records *F. quadrioculata* is a very common species occurring in nearly all habitats. Weis-Fogh found it dominant in all but the lowest lying localities along his sampling line. Haarløv found it in all the habitats he investigated.

Gisin (1957) states that *F. nana* replaces *F. quadrioculata* progressively in altitudes exceeding about 1700 m in the Alps, being rare in the lowlands. Rusek (1963) found *F. nana* and *F. quadrioculata* together in the Moravian mountains. Szeptycki (1964) found *F. nana* on the Island of Wolin.

In the Hansted reserve both species were frequently found, and often in a very great number per sample. Both species occurred in many different habitats, and were often found together in the same sample. A difference in the distribution of the two species, however, seems to be evident, although somewhat mysterious. *F. nana* has proved to have the widest distribution, and has been found in the greatest quantities. On the floor of the pine plantation, i. e. in the needle-litter and in the Pleurozium-blanket, *F. nana* was found with a high degree of constancy and in considerable numbers. *F. quadrioculata* was not found here. The samples from the moss-cover under the "pioneer" pine (49) had a very dense population of *F. nana* (about 500 specimens). The sample from the moss-cover outside the "pioneer" pine shrub, less than $\frac{1}{2}$ m from sample 49, had a population of about 150 *F. nana* and about 10 *F. quadrioculata* (51). The raw humus under the moss-cover of both sites contained considerably fewer specimens than the moss above, but also here

F. quadrioculata was restricted to the sample from outside the shrub.

In the samples from the chalk cliff *F. nana* was constant and found in great numbers, while *F. quadrioculata* was almost absent.

None of the species was found in the most drenched substrates of the bogs. In the dryer parts only *F. nana* occurred.

Both species were missing in the outer zone of the shores. In the inner zone both species were found, but *F. quadrioculata* seems to be greatest in number. It seems, however, that the two species substitute each other from one sample to the other, one species being abundant, when the other is poorly represented or absent. The same may be seen in the samples from the meadows.

In the heather moor and the "grey" dunes *F. nana* was more abundant than *F. quadrioculata*. In the "white" dunes only *F. quadrioculata* was found in a considerable number and only in a sample from the bottom of a wind-protected basin in the external row of dunes, which had a relatively luxuriant vegetation of low flower-plants (176).

The distribution of the two species is somewhat confusing. *F. quadrioculata* seems to prefer more humid habitats than *F. nana*, but it seems curious that only *F. nana* was found in the bogs, and that *F. quadrioculata* was found in fairly great numbers in a sample from the "white" dunes and in, for instance, a sample from a steep slope of a "grey" dune partly covered by *Empetrum* (161).

It is to be hoped that further studies of the two species might solve this problem.

32. *Folsomia spinosa* Kseneman 1936.

New to Denmark.

Known from Central Europe.

The species was found in one sample only, containing 9 specimens. The sample (117) originates from stony gravel with meadow-vegetation.

33. *Folsomia* cf. *bisetosa* Gisin 1953.

New to Denmark.

F. bisetosa was until now only recorded from the Island of Jan Mayen (Gisin 1953) and from Spitsbergen (Gisin 1961).¹⁾

At Jan Mayen the species was constant in some of the sample units from slopes near a bird cliff, but only one sample unit had a dense population of this species (mean: 95 specimens per 50 ccm). (Macfadyen 1954).

In the Hansted reserve more than 300 specimens nearly related to *F. bisetosa* (see preceding chapter!) were found in a sample from nearly bare, moist, peaty soil between hummocks of an area characterized by *Narthecium ossifragum* (140). Only one specimen was found in a sample taken from the top of a hummock between roots of *Calluna* a few cms from the sample just mentioned (142) The same was the case in a sample from a *Sphagnum* pillow from the same locality (141). It was found in no other samples from the Hansted reserve, and it seems very probable that it is a species with very specific demands as to its surroundings.

34. *Folsomia fimetaria* (Linné 1758).

Danish records: Bartholin 1916; Weis-Fogh 1947/48; Haarløv 1957.

Only one specimen has been determined with certainty. It was found in a hummock of *Sphagnum*, *Carex* and *Equisetum* surrounded by water (98).

35. *Folsomia* sp.

See the preceding chapter!

Five juveniles were found between moss-cushions and litter in the birch-moor.

36. *Isotomiella minor* (Schäffer 1896).

Danish records: *Isotoma minor*: Weis-Fogh 1947/48; *Isotomiella minor*: Haarløv 1957; Poole 1964.

Widely distributed in and outside Europe.

¹⁾ Also from Ellesmere Island (Oliver in "Arctica" vol. 16, 1963, p. 177.)

Gisin (1943) found that *I. minor* and *I. paraminor* Gisin 1942, act as substitutes for each other, *I. paraminor* being restricted to the humid forest-soils, and *I. minor* living in most other habitats.

The species was sparsely distributed in most habitats of the reserve, but when found it mostly occurred in great numbers. It was found to be rather constant in the median zone of the shores, i. e. the zone between outer and inner ridge of washed up organic material, and in the "white" dunes. In the last habitat, however, it was only represented by few specimens per sample. It was almost absent in the plantation, and completely absent in the "grey" dunes.

37. *Folsomides navacerradensis* Selga 1962.

New to Denmark.

Only known from Spain (Navacerrada, Guadarrama).

Found in two samples from the "white" sand-dune of Hybjerg (95, 96). One of them contained about 30 specimens, mostly juveniles.

38. *Proisotoma (Ballistrura) schoetti* (Dalla Torre 1895).

New to Denmark.

Stach (1947) describes this species as a true halophilous animal, widely distributed along the European coasts. However, Gisin (1960) also records it from fresh water and stable manure.

It was not represented in the material from the Hansted reserve, but one individual was found in the Kaiser and Jensen material: 8/11 1953, Vestervig å north of Krik (a river of estuarine character) (Kaiser 1958).

39. *Proisotoma minima* (Absolon 1901).

Danish records: Weis-Fogh 1947/48.

Stach (1947) describes it as a fairly rare species from North- and Central Europe. It has been recorded from caves, stumps, forest-floor, meadow soil and stable manure. Weis-Fogh found it to be dominant in "the mea-

dow" and in a few specimens in the lowest locality of his sampling line.

In the Hansted reserve a few specimens were found in two samples from the "white" dunes and one sample from humid hollows in the plantation characterized by *Myrica* gale-vegetation (89).

40. *Isotomina thermophila* (Axelson 1900).

New to Denmark.

This species is widely distributed in Europe, e. g. South Finland, Germany and Sweden.

Linnaniemi (1912) describes it as a typical inhabitant in humus soil near human settlements and in hot-houses. Gisin (1943) found the name very characteristic of the ecological preference of the species. Schaller (1951) described it as dominant on and characteristic for the open sand-covered areas of the "Mainzer Sand", and thought this distribution was connected with the great heat resistance of the species.

In the Hansted reserve the species was confined to the "white" dunes, where it was found twice in small numbers. The "white" dunes are probably comparable with Schallers "Mainzer Sand", and his explanation of the occurrence in the "Mainzer Sand" may well be valid also in this case.

41. *Isotoma (Pseudisotoma) sensibilis* (Tullberg 1876).

New to Denmark.

Distributed from the Arctic islands and Greenland to the Alps.

Gisin (1943) states it to be a character-species for bark, moss on bark and rocks. Agrell (1941) found it a dominant species of the "regio alpina sterilis".

In the Hansted reserve it was found to be sparse and in very different habitats: vegetation-covered basin in "white" dunes, lichen-vegetation along a road in the plantation and a heap of mouldering bark and wood.

42. *Isotoma (Pseudisotoma) monochaeta* Kos 1942.

New to Denmark.

This species has until now only been recorded from the Carpathians, the Julic Alps, the Pyrenees and other mountains of South-Western France and Spain (Gisin 1960, Cassagnau 1961). Stach (1947) calls it a high-alpine animal.

Regarding the habitats of this species, Stach describes it as a typical moss inhabitant.

The discovery of this species in Northern Jutland is surprising. Probably it has a very sporadic distribution north of the Central European mountains.

In the Hansted reserve 20 specimens were found in a sample from the surface layers of an ant hill of *Formica rufa*.

43. *Isotoma (Vertagopus) cinerea* (Nicolet 1841).

Danish records: Bartholin 1916.

I. cinerea is a typical corticicole animal (Gisin 1960, Stach 1947, Bartholin 1916).

In the investigated area it was found once, under loose bark of a pine-stump.

44. *Isotoma notabilis* Schäffer 1896.

Danish records: Weis-Fogh 1947/48; Haarløv 1957; Poole 1964.

Stach (1947) describes this species as a typical inhabitant of moss- and forest-litter; greatest densities found in needle-litter, in low moss covering forest-floor and on old tree-stumps. Others have called it ubiquitous (Linnaniemi 1912).

In the area investigated here it was found to be constant in the needle-litter and Pleurozium blanket of the plantation. Outside the plantation it was more sparsely distributed in relatively dry meadow soils, shores of lakes and ponds, the chalk cliff, the heather moor and the luxuriant basin in the "white" dunes (176). It was not found in the "grey" dunes and in the marsh and bogs.

45. *Isotoma viridis* Bourlet 1839.

Danish records: Bartholin 1916; Bornebusch 1930; Weis-Fogh 1947/48; Haarløv 1957.

This common species has been recorded from different, mostly humid biotopes. Gisin (1960) calls it hygrophile. The var. *riparia* Nicolet 1841, seems especially to be bound to very moist biotopes, e. g. shores of fresh and saline waters (Palissa 1960, Altner 1963).

I. viridis var. *riparia* was not found in the reserve, but was determined from samples collected by Jensen and Kaiser in other parts of Thy, all from shores of rivers, canals and lakes.

Nearly all the specimens found in the reserve and the plantations could be referred to var. *coerulea* Bourlet 1839. This variety was represented in all greater habitat units, but very poorly in the sand-dunes. It occurred with great constancy only at the shores of lakes and ponds and on the chalk cliff. On one occasion it was collected from the surface of water (169).

46. *Isotoma maritima* Tullberg 1871.

Danish records: Bartholin 1916.

Recorded from all coasts of Northern Europe.

Three specimens collected from the underside of boards on the beach.

47. *Isotoma antennalis* (Bagnall 1940).

New to Denmark.

Until now only recorded from moss cushions and from the surface of puddles in English bogs.

In the Hansted reserve it was found in similar humid habitats: bogs and marsh, bottom of dried-up pond and drenched moss cushions.

48. *Isotomurus ciliatus* Stach 1947.

New to Denmark.

This species has until now only been recorded from Poland, Ukraine and Hungary. Stach (1947) suggests it is "an element of the north-eastern fauna of Europe".

Stach writes that the species seems to be restricted to water surfaces of reservoirs of stagnant water overgrown with plants.

In the Hansted reserve *I. ciliatus* was exclusively found on water surfaces, but these did not seem to be as wind-protected as indicated in Stach's description. However, in all three localities stems of Phragmites, Equisetum or Heleocharis protruded through the water surface, apparently forming refuges for the Collembola. The animals were often densely crowded on the lower part of the stems.

I. ciliatus was also found in several samples from the material of Kaiser and Jensen from rivers, canals and lakes in Thy. The specimens were probably caught from water-surfaces.

49. *Isotomurus palustris* (Müller 1776).

Danish records: Bartholin 1916; Weis-Fogh 1947/48; Haarløv 1957.

Gisin (1943) records *I. palustris* from moist habitats such as meadows, bogs and humid forest-soils. He (1960) describes it as typically hygrophilous.

In the Hansted reserve this species was almost exclusively found in a rather narrow zone along the shores of the lakes and ponds. It was found in very few specimens in the surf-exposed external zone, where *I. plumosus* occurred frequently. From the outer ridge of washed-up organic material, in a zone not extending as far as to the inner ridge of organic accumulations, the species occurred constantly and in great numbers. Most of the specimens were uniformly blue or violet and were without common body setae furnished with ciliae (f. *fucicola* Reuter), but in samples 41 and 110 from the outer accumulation-ridge a few pale specimens with ciliated body setae occurred (see the previous chapter!). In sample 109, 6 specimens of *I. palustris* were found on the water surface together with *I. ciliatus*. All these specimens had

the mucro and empodial appendage typical of the species, but the common body setae were distinctly ciliated as in *I. plumosus* and *ciliatus*. The colour was brownish-green.

An interpretation of the forms with ciliated body setae is not possible from this small material. They may be ecological modifications or ecotypes of *I. palustris*, or perhaps hybrids of *I. plumosus* or *I. ciliatus* and *I. palustris*. At least, the complexity of the different forms of *Isotomurus* within the area is not fully explained by the presence of 3 different species.

50. **Isotomurus plumosus** Bagnall 1940.

New to Denmark.

Has been recorded from Great Britain, Germany and Ukraine, occurring on banks of brooks and rivers, and in forests.

In the Hansted reserve it was frequently found on surfaces of ponds and lakes as well as in the outer surf-exposed zone of the shores. Outside these habitats it was found once in the beech wood, fairly close to the shore of Bagsø, where a dense population occurred (179). It was fairly abundant in the drenched moss cushions and the bottom of the dried-up pond.

Entomobryidae.

51. **Entomobrya albocincta** (Templeton 1835).

Danish records: Bartholin 1916.

Recorded from e. g. Finland, Southern Sweden, Northern Germany and Great Britain. Stach (1963) suggests that it is confined chiefly to regions with an atlantic climate.

Regarding ecological preference, Stach notes that it mostly occurs under loose bark, but often seeks shelter under stones.

In the Hansted reserve it was found singly in a few samples from different habitats, viz. the bogs, a glade in the plantation and most interesting of all, a wind-

eroded plant-mat with free hanging roots from the windward part of the external row of dunes, a very extreme habitat.

52. **Entomobrya corticalis** (Nicolet 1841).

Danish records: Bartholin 1916.

Widely distributed in Europe.

The species is mostly corticicole, but has been found elsewhere, e. g. in dead leaves.

In the Hansted reserve it was found once between hummocks of a humid flat between dunes (40).

53. **Entomobrya nivalis** (Linné 1758).

Danish records: Bartholin 1916; Haarløv 1957.

A very common species recorded from many different biotopes: on herbs, shrubs and trees, in moss, in litter etc.

In the investigated area it was found sparsely in Berlese-samples from all greater habitat units apart from the "white" dunes and the exterior zones of the shores. In addition it was caught with a sweep-net from a pine tree in the plantation, a "pioneer" pine and in the grass-vegetation of a "dry" meadow.

54. **Orchesella cincta** (Linné 1758).

Danish records: Bartholin 1916; Haarløv 1957.

According to Stach (1960) it is a common species which generally occurs near human settlements under pieces of wood, stones and litter. Gisin (1960) also records it from bark.

In the present area it was found once in needle-litter and once under bark of a pine stump.

55. **Lepidocyrtus lignorum** (J. C. Fabricius 1775), s. Gisin 1964.

Danish records: ?*Lepidocyrtus lanuginosus*: Bartholin 1916; Bornebusch 1930; Weis-Fogh 1947/48; Haarløv 1957; Poole 1964.

Gisin (1964) has found this species in many different habitats in Switzerland, and in addition, has determined it from materials from England, the Faroes, Finland and Austria.

In the Hansted reserve this species occurred with the highest degree of constancy in the needle-litter and moss-blankets of the plantations. It was especially constant in the samples collected by Nørrevang in early June 1958 (almost exclusively juveniles). Very seldom, however, were more than a few animals (1—5) per sample counted. A few specimens were occasionally found in samples from heather moor, "grey" and "white" dunes. It was not found in the more humid habitats and on the chalk cliff.

56./57. **Lepidocyrtus violaceus** Lubbock 1873 and **L. cyaneus** Tullberg 1871, s. Gisin 1964.

Danish records: *Lepidocyrtus cyaneus*: Bartholin 1916; Weis-Fogh 1947/48; Haarløv 1957.

Gisin (1943) separated the two species merely by means of differences in the colour pattern and found them sharply differentiated ecologically. He found *L. cyaneus* to be a character species for loamy meadows and regularly found in arable fields and dung, but not in dry soils and in woods. On the other hand he described *L. violaceus* as characteristic for bark and epiphytial moss in all types of woods.

The determinations published here and based on the new diagnostical characters described by Gisin (1964a, b) proved that a similar simple distribution could not be found in the Hansted reserve. The reason may be that a difference in ecological preference between geographically separated populations is involved, or it may be that the previously used diagnosis based on colour characters is not very safe and not likely to be always concordant with the recently discovered characters (Gisin: personal communication).

In the Hansted reserve both species were present in the soil of the more humid parts of the meadows and in the inner zones₃ of the lake shores. In two samples both species were found together (Tx 9, Tx 11). In these

habitats, however, *L. cyaneus* was more constant and dominant than *L. violaceus*. In the samples from the chalk cliff only *L. violaceus* was found. *L. violaceus* was also found, but very sporadically, in the "grey" and "white" dunes and in the marsh and bogs. Here *L. cyaneus* was not found. Both species were missing in the plantations.

Very little can be said about the ecological difference between the two species. *L. violaceus*, however, seems to be the less humidity requiring.

58. ***Pseudosinella alba*** (Packard 1873).

Danish records: Haarløv 1957; Poole 1964.

Gisin (1943) describes this species as "Characterart des Wiesenbodens der unteren Stufe". Agrell (1934) calls it a typical humus-species.

In the Hansted reserve a few specimens were found in three samples from the chalk cliff and one from the "dry" meadow.

59. ***Tomocerus (Pogonognathellus) flavescens*** (Tullberg 1871).

Danish records: *Pogonognathus plumbeus*: Bartholin 1916; *Pogonognathellus plumbeus*: Bornebusch 1930; *Tomocerus flavescens*: Haarløv 1957.

Gisin (1943) describes *T. flavescens* as being restricted to forest-litter. Agrell (1934) found it in moss and litter of humid localities.

In the Hansted reserve it did not seem to be as confined to moist localities as most descriptions indicate. It was found in many habitats, most frequently in the plantation. One specimen was caught creeping around on a bare sand-flat about 50 ms from the plantation.

Sminthuridae.

60. ***Neelus (Megalothorax) minimus*** Willem 1900.

Danish records: Haarløv 1957.

Gisin (1943) records that this species is rarely absent in any type of soil, but is most constant in humid soils.

In the investigated area it was found in a great part of the samples from the floor of the plantation and the chalk cliff, but only sporadically in other habitats. The chalk cliff seems the most favourable habitat for this species.

61. ***Sminthurides (Sphaeridia) pumilis*** (Krausbauer 1898).

New to Denmark.

A cosmopolite species.

Gisin (1943) found it mainly in humid grass-covered soils, but records it also from dryer environments. Agrell (1934) found it in the drift-sand area of Scania in relatively dry habitats.

In the Hansted reserve it proved to be less dependent on humidity than the other *Sminthurides* species. It was found in abundance in a sample from the outermost zone of the shores together with *S. malmgreni* and *S. schoetti*, but was also found in great numbers in the inner accumulation ridge, and in the dryer part of the meadows, where the two other *Sminthurides* do not occur. In the humid parts of the meadows all three species occur. *S. pumilis* is completely absent in the marsh and bogs, while *S. schoetti* occurs here constantly and in fairly large numbers. *S. pumilis* and *S. schoetti* both occur, although rather sparsely, in the plantations where *S. malmgreni* is not found. It thus seems that *S. malmgreni* is the species requiring most humidity, and that *S. pumilis* is the most tolerant species to dry conditions.

62. ***Sminthurides aquaticus*** (Bourlet 1843).

Danish records: Bartholin 1916.

This species lives the greater part of its life on the surface of fresh waters and aquatic plants.

In the Hansted reserve it was caught on nearly all water surfaces examined, and is apparently fairly independent of the degree of wind- and wave-protection. In all cases, however, the animals did not seem to move very far from plant stems protruding above the water.

63. **Sminthurides malmgreni** (Tullberg 1871).

Danish records: Haarløv 1957.

S. malmgreni together with *S. aquaticus* is known as an animal living on water-surfaces, but it has also often been recorded from moist Sphagnum in bogs and moss-cushions on the shores of stagnant or running waters.

In the reserve it was never caught on water-surfaces, but, as mentioned in connection with the treatment of *S. pumilis* above, is almost completely restricted to very moist habitats.

64. **Sminthurides schoetti** (Axelson 1905).

New to Denmark.

Known from North and Central Europe.

Stach (1956) records, that *S. schoetti* primarily lives in Sphagnum-moss, but also occurs on the surface of small pools on peat-moors. Gisin (1943) calls it: "Charakterart der Fettwiesen und Moore".

As shown in the treatment in the description of *S. pumilis*, the findings from the Hansted reserve accord very well with these records. *S. schoetti* was, however, never found on water-surfaces.

65. **Sminthurides pseudassimilis** Stach 1956.

New to Denmark.

It is probable that Finnish and North American specimens determined to *S. assimilis* actually belong to this species (Stach 1956). If this is true, the species is distributed in North and Central Europe and North America.

Only one specimen was found in a sample from a Sphagnum-cushion (70), a typical habitat for the species according to Stach.

66. **Sminthurides parvulus** (Krausbauer 1898).

New to Denmark.

Recorded from e. g. Sweden, Germany, and Great Britain.

One specimen found in a cushion of dry Sphagnum (100).

67. Arrhopalites cf. principalis Stach 1945.

New to Denmark.

Has apparently a sparse distribution in the marsh and the meadows of the area. One sample has been taken from a *Molinia* tussock, another from peaty soil covered with *Cladonia* and a third from a fairly dry *Pleurozium* blanket between the grass vegetation of the meadow. Stach (1956) records *A. principalis* from moss drenched with water.

68. Sminthurinus elegans (Fitch 1863).

New to Denmark.

Widely distributed in Europe.

Gisin (1960) indicates that the habitats preferred by this species are dryer than those preferred by *S. aureus*.

In the Hansted reserve it was found once, together with e. g. *Folsomia spinosa*, in a fairly dry locality of stony gravel between meadow vegetation (117).

69. Sminthurinus aureus (Lubbock 1862).

Danish records: Weis-Fogh: 1947/48; Haarløv 1957.

Only the var. *ochropus* Reuter 1891, was found. *S. aureus* was primarily recorded from moss, old tree-stumps and on low meadow- and garden plants (Stach 1956).

In the Hansted reserve the var. *ochropus* was found primarily in the old accumulation ridge of the shores of the lakes (Nors sø 113, Bleg sø 114).

70. Bourletiella (Heterosminthurus) insignis (Reuter 1876).

Danish records: Bartholin 1916.

Stach (1956) supposed the long inner setae characterizing this and the following species to be an adaptation for moving on water-surfaces, and records it from the surface of small water-reservoirs and on plants growing on shores of lakes and other moist habitats.

This was also true in the Hansted reserve. The species was mostly found together with *B. novemlineata* in vegetation on humid soil near the shores of lakes and

ponds and on water-surfaces, mostly in places where these were well protected against wind and waves.

71. **Bourletiella (Heterosminthurus) novemlineata** (Tullberg 1871).

Danish records: Bartholin 1916.

This species is as *B. insignis*. The two species often occur together. No ecological differences have been found.

72. **Bourletiella (Heterosminthurus) bilineata** (Bourlet 1842).

Danish records: *Deuterosminthurus bilineatus*: Bartholin 1916.

According to Stach (1956) *B. bilineata* occurs in low vegetation of both dry and moist meadows, but most frequently in the latter.

This species was the most widely distributed of the epigaeic Collembola found in the investigated area. It was caught in a sweep-net from vegetation of the shores of the lakes, from grass vegetation in a glade in the plantation, from branches of pine trees, from *Calluna* in heather moor and "grey" dunes and from *Psamma arenaria* on the slope of a "grey" dune.

73. **Bourletiella (Heterosminthurus) linnaniemii** (Stach 1920).

New to Denmark.

Known from Poland and Western Russia.

Stach (1956) records this species from grassy places, meadows and arable fields.

One specimen was found in a Berlese sample from soil between *Empetrum* and *Pleurozium* on a "grey" dune.

74. **Bourletiella (s. str.) viridescens** Stach 1920, s. Gisin 1948.

New to Denmark.

Distributed from Sweden to Asia Minor, but possibly absent in Western Europe (Gisin 1960).

The habitats of this species are, according to Gisin (1960), vegetation of poor, dry pastures.

It was found in three different localities in a few specimens: in grass-vegetation (mainly *Holcus lanatus*) near the water level of a lake (106), in dry meadow-vegetation (mainly *Anthoxanthum odoratum*) (107) and in grass-vegetation (*Deschampsia flexuosa*, *Anthoxanthum odoratum*, *Carex arenarea*) in a basin in "grey" dunes (55).

75. *Bourletiella (Deuterosminthurus) repanda* (Ågren 1903).

Danish records: *Deuterosminthurus bicinctus* var. *repanda*: Bartholin 1916.

According to Stach (1956) this species occurs on various plants on dry or more humid, sunny meadows. Gisin (1943) found it the most abundant species of the macrophyta.

In the investigated area it was found in great numbers in high, luxuriant vegetation of *Deschampsia caepitosa* and flowering *Lathyrus pratensis* in a small glade of the pine plantation (76, 77). The *Lathyrus*-vegetation yielded more animals per unit sweeps than the *Deschampsia*-vegetation. The species was also found on the leaves of a young alder in the same glade, and a few specimens were even found on pines surrounding the glade. A high density of *B. repanda* was also found in a high vegetation of *Dactylis glomerata*, *Poa pratensis* and *Avena pratensis* near the shores of Nors sø; in fewer numbers it was found in the less luxuriant vegetation of the dryer parts of the meadow near the locality just mentioned.

76. *Sminthurus nigromaculatus* Tullberg 1872.

New to Denmark.

This species has been recorded from North, Central and Eastern Europe. According to Gisin (1960) it is a common species in meadows.

In the Hansted reserve it was mostly found in habitats of rather dry appearance. It was caught by sweep-net in dry grass- and *Calluna*-vegetation and was found

in Berlese-samples from the "grey" dunes, from a basin in the "white" dunes with a fairly luxuriant vegetation (176), and from the border of a road in the plantation.

Protura.

77. *Eosentomon transitorium* Berlese 1908.

Danish records: *Eosentomon armatum*: Tuxen 1931; 1949; *Eosentomon transitorium*: Haarløv 1957.

The three specimens found were determined by Dr. S. L. Tuxen. One was collected from the chalk cliff, two from the dryer part of the meadow near Nors sø.

The fauna of the greater habitat units.

As mentioned previously, an attempt to establish biocoenoses or synusiae of Collembola characterizing homogenous sections of the nature does not seem profitable as it is not possible to delimit environments which are homogenous in respect of factors responsible for the distribution. Therefore, only a few general considerations on the fauna of the greater habitat units are made here.

The higher vegetation has a characteristic Collembola-fauna. *Entomobrya nivalis* was the only Arthropleona found, the other species were all Symphypleona.

Bourletiella insignis and *novemlineata* were strictly attached to vegetation on moist soil and were often also found on water-surfaces. *Entomobrya nivalis* and *Sminthurus nigromaculatus* seem to be found mainly in vegetation of the dryer types of soil. *Bourletiella bilineata* was found in vegetation of both moist and dry soil. The degree of relative humidity on the surfaces of the more or less xeromorphic plants of the "dry" soil may sink considerably during hot, sunny days, contrary to the relative humidity of the soil itself (cf. Thamdrup 1939). The fact that *E. nivalis*, *S. nigromaculatus* and *B. bilineata* were the only epigeaic Collembola found frequently in

the Berlese-samples may be interesting in this connection. Possibly, the ability of these forms to seek shelter in the soil enables them to exist in draught-exposed habitats.

The water-surfaces. Also this biotope has a quite characteristic Collembola-fauna. *Isotomurus ciliatus* and *Sminthurides aquaticus* were not found in other habitats. *Isotomurus plumosus* is probably more dependent on the shore and has often been found in the outer wave-exposed zone of the shores. *Bourletiella insignis* and *novemlineata* seem to occur only near high vegetation or at least on well wind-protected water-surfaces. *Isotomurus palustris* and *Isotoma viridis* are possibly not typical in this habitat.

The shores of lakes and ponds. The water-content, with its significance for a constant degree of relative humidity, pore-space and oxygen-admission, the exposure for wave-action and inundation, and the content of decaying organic material, are considered to be important factors for the distribution of the Collembola in this habitat. *Hypogastrura denticulata* occurs almost throughout the whole breadth of the shore and is not often found outside this habitat. *Isotomurus plumosus* and *Anurida tullbergi* are also character-animals for the shores, but are restricted to each their narrow zone, *I. plumosus* in- and outside the ridge of newly washed-up organic material, *A. tullbergi* in this ridge and just inside. *Folsomia quadrioculata*, *Isotomiella minor*, *Isotoma viridis* and *Isotomurus palustris* are often found in other habitats, but are most constant and abundant on the shores. They are all restricted to fairly well-defined zones within the belt between the outer and inner accumulation ridge.

The marsh and bogs, including the drenched moss-cushions. The drenched moss cushions (mostly Sphagnum) have not proved to have a characteristic

Collembola-fauna, but show resemblance to the marsh and bogs. *Hypogastrura scotica* and *Isotoma antennalis* have only been found in very few samples outside these habitats, but also here the distribution is rather sporadic. On the whole the unit of habitats brought together here seems to be very heterogenous with respect to the Collembola-fauna. Only *Sminthurides schoetti* occurs fairly constantly.

The heterogeneity of the habitat called marsh and bogs is clearly demonstrated by a comparison of two samples (140, 141), taken within a distance of about 30 cms from each other, one from a Sphagnum cushion on the top of a hummock, the other from the soil between the hummocks. In the firstmentioned sample about 65 specimens of *Isotomiella minor* were found and only 1 specimen *Folsomia* cf. *bisetosa*, in the last-mentioned about 300 specimens of *F.* cf. *bisetosa* were counted and no *I. minor*. It should be emphasized that *I. minor* is not elsewhere restricted to moss cushions.

The meadows. The Collembola-fauna of the habitats classified under the name of meadows is, on an average, richer in respect of species per sample than are the marsh and bogs. Many species reach high degrees of constancy and frequency in this habitat, but no single one has proved to be characteristic. *Onychiurus fimatus*, *O. tricampatus*, *O. bicampatus* and *F. spinosa* are possibly character-species for very restricted sections of the meadows.

The conifer plantations. *Willemia aspinata* and *W. anophthalma* are found constantly in the plantations and very rarely outside. *Pseudachorutes parvulus*, *Anurida pygmaea* and *Isotoma notabilis* have their maximal constancy and are found in the greatest numbers in the moss and needle-litter of the plantations, but are not restricted to this habitat. The dominant species seems to be *Folsomia nana* which, however, also reaches high

abundancies in parts of the heather moor and the "grey" dunes. *Lepidocyrtus lignorum* and *Neelus minimus* are also fairly constant in the plantations.

The road running through the plantation is characterized by the presence of *Xenylla maritima* and *Isotoma sensibilis* which are species often found in dry environments.

The fauna of the plantation floors appears to have a relatively homogenous distribution (many species having a high degree of constancy), and it is rather rich in species as well as individuals.

The "pioneer" pine. The Collembola-fauna seems to have many points of resemblance to the fauna of the "mother" pine plantations, but the number of species is less, and most of them are very poorly represented. In contradiction, the two species *Folsomia nana* and *Anurida pygmaea* are found in greater numbers than elsewhere.

If the few samples give a true indication of the real conditions three explanations are possible: 1) life conditions of the floor under the "pioneer" pine satisfy only a few of the species living in the plantation-floor, in this case *F. nana* and *A. pygmaea*. 2) *F. nana* and *A. pygmaea* have the greatest ability to migrate from the plantation to the "pioneer" pine. 3) The population of the "pioneer" pine originates from the surrounding habitat, in this case from the "grey" dunes. In all three cases the missing competition is considered to result in mass-multiplication of a few species. *F. nana* and *A. pygmaea* both live in the "grey" dune-area, so it seems most probable that the last explanation is the correct one. The reason why e. g. the *Willemia* species are absent under the "pioneer" pine may be that they are not found in the surrounding "grey" dune-area. Whether the life-conditions of these species are satisfied or not in the floor under the "pioneer" pine cannot be stated.

The heather moor and the large glade in the plantation. The large glade in the plantation is treated here in connection with the heather moor being an extended open area of dry appearance, covered partly by *Calluna* and partly by grass. The composition of the Collembola-fauna of the glade is not found to differ a great deal from that of the heather moor. The fauna of the heather moor shows great similarities to the fauna of the plantation-floor, but is in comparison, rather deficient in species, and these are more unevenly distributed. Only *Folsomia nana* and *Tullbergia krausbaueri* are found fairly constantly, and in some samples even in great numbers. Two samples (161, 61) from "grey" dunes have been taken from soil under an *Empetrum*- and a *Calluna*-shrub respectively and show great conformity with the fauna of the heather moor.

The "grey" dunes and sandy flats. The fauna of these habitats is very heterogenously distributed and also very deficient in species as well as individuals. The limitation to the heather moor is indefinable also in respect of the fauna composition. *Xenylla maritima* is characteristic for some sections of the "grey" dune-area, mostly the lichencovered areas.

The "white" dunes. The Collembolan fauna of the "white" dunes is, at least in patches, much richer in respect of species and individuals than the "grey" dunes. Moreover, the fauna seems to contain a pretty high proportion of character-species seldom or never found outside the "white" dunes. Compared with the other greater habitat units within the area, *Onychiurus armatus* s. str., *O. volinensis*, *Folsomides navacerradensis* and *Isotomina thermophila* seem to be characteristic for the "white" dunes. *Tullbergia krausbaueri* occurs in very great numbers in some samples, even from what appear to be the most extreme habitats, with regard to wind- and sun-exposure.

Characteristic for this habitat seems to be the dominance of true euedaphic species with reduced eyes and pigmentation. One sample (171) contained nearly 1000 specimens of *Tullbergia krausbaueri*, *Onychiurus volinensis*, *O. armatus* s. str. (and *Isotomiella minor*) all being white and blind. Additionally, four samples (175, 168, 169, 172) consisted almost entirely of euedaphic species. The absence of hemiedaphic species is assumed to be a result of the extreme climatic conditions of the surface of the sand, which is deficient in having a protecting plant-cover.

Two samples (95, 96) from the "inland" dune of Hybjerg also contained, in addition to the pale and blind forms, the pigmented species *Folsomides navacerradensis* and *Isotomina thermophila*, but also in these species the pigment is rather feebly developed.

Schaller (1951) assumed that the Collembola of the drift-sand areas of the "Mainzer Sand" are especially heat-resistant forms. He mentions *Isotomina thermophila* as a typical example of this. It is probable that at least also *Folsomides navacerradensis* is a thermophilous or heat-resistant species.

One sample (176) from a basin in the external ridge of "white" dunes with a fairly luxuriant vegetation differs considerably from the other samples from the "white" dunes. Here pigmented species such as *Folsomia quadriculata*, *Isotoma notabilis*, *Isotoma sensibilis* and *Isotoma viridis* are more prominent than the euedaphic species.

The chalk cliff. This locality shows a fauna rich in species as well as in individuals. The species composition seems fairly homogenous from one sample to the other. Characteristic species for this habitat seem to be *Onychiurus fuscifer* and *O. pseudovanderdrifti*. *Folsomia nana* is very constant and is the dominating species in nearly all samples. *Neelus minimus* is constantly found.

and reaches its highest densities in this habitat. Also *Friesea mirabilis* and *Isotoma viridis* are fairly constant here, but in relatively small numbers. The constant occurrence of *Folsomia nana* and *Neelus minimus* is a point of resemblance to the plantation-floor. In a sample (130) from the top of the cliff in the shadow of a *Salix aurita* thicket the resemblances to the plantation floor is increased by the presence of *Willemia aspinata* and *Isotoma notabilis*.

7. Summary and Conclusions.

In a taxonomical chapter a new aberrant species of *Tullbergiinae* is described and referred to a new subgenus. An *Onychiurus* species has been redescribed and taxonomical remarks are given to a number of other species. The legitimacy of the distinction between at least two different species within the *Folsomia quadriculata*-group has been supported by an analysis of the variation of the main diagnostic character and by a comparison of different development stages of the genital area of females.

74 species of Collembola and one of Protura are recorded from the Hansted reserve and surrounding plantations, two more are recorded from Thy outside the vicinity of the reserve. 38 of the species found have not formerly been recorded from Denmark. Most of these are known from localities close to Denmark, but the findings concerning *Folsomides navacerradensis* Selga, *Isotoma monochaeta* (Kos) and *Folsomia bisetosa* Gisin are quite surprising.

The distribution of the individual species within the investigated area is described. Most of the species found in considerable numbers occur in more than one of the greater habitat units described, only a few being characteristic of a definable section of the nature.

The "white" dunes seem to be the greater habitat unit, having the most characteristic Collembolan fauna, with a strong dominance of euedaphic forms. The floors of the plantations and the chalk cliff seem to have the most homogenously distributed fauna. The shores of the lakes and ponds have a fairly distinct zonation of the Collembolan fauna. The marsh and bogs, the heather moor and the "grey" dunes have a rather poor and unevenly distributed Collembola-fauna. The water-surfaces of lakes and ponds have a fairly well delimited fauna. Some species seem more dependent on the shores than others.

The epigaeic fauna is very characteristic. The Collembola occurring on the vegetation of the most draught-exposed environments seem to be those which are able to migrate from the plants into the soil.

8. References.

- Agrell, I. (1934): Studien über die Verteilung der Collembola auf Trieb sandboden. — Ent. Tidskr. 55, p. 181—249.
- (1941): Zur Ökologie der Collembolen. Untersuchungen im Schwedischen Lappland. — Opusc. Ent. Suppl. III.
- (1948): Studies on postembryonic development of Collemboles. — Arkiv Zool. 41, p. 11—35.
- Altner, H. (1963): Beiträge zur Systematik und Ökologie der Collembolen Norwegischer Küsten. — Sarsia 10, p. 35—55.
- Bagnall, R. S. (1939): Notes on British Collembola. — Ent. Monthly Mag. 75, p. 58.
- (1940): Notes on British Collembola. — Ent. Monthly Mag. 76, p. 101.
- Bartholin, A. T. (1916): Foreløbig Fortegnelse over danske Apterygoter. — Vid. Medd. Nat. For. 67, p. 155—209.
- Bornebusch, C. H. (1930): The fauna of forest soil. Copenhagen. 224 pp.
- Bödvarsson, H. (1959): Studien über die Variation einiger systematischen Charaktere bei *Onychiurus armatus* (Tullb. 1869). — Opusc. Ent. 24, p. 225—45.
- (1961): Beitrag zur Kenntniss der südschwedischen bodenlebenden Collembolen. — Opusc. Ent. 26, p. 178—198.
- Cassagnau, P. (1961): Écologie du sol dans les Pyrénées Centrales. Les biocénoses des Collemboles. — Paris, 235 pp.
- Christensen, Tyge (1960): Vegetationstyper i Thy. — Ent. Medd. 30, p. 25—32.
- Dunger, W. (1963): Einige Collembolenfunde aus der weiteren Oberlausitz. — Abh. Ber. Nat. Mus. Görlitz 38, (5), p. 1—15.
- da Gama, M. M. (1964): Colêmbolos de Portugal Continental. — Coimbra, 252 pp.
- Gisin, G. (1952): Oekologische Studien über die Collembolen des Blattkompostes. — Rev. suisse Zool. 59, p. 543—78.
- Gisin, H. (1943): Oekologie und Lebensgemeinschaften der Collembolen im schweizerischen Exkursionsgebiet Basels. — Rev. suisse Zool. 50, p. 131—224.
- (1949a): *Micranurida forsslundi* n. sp. — Ent. Tidskr. 70, p. 243.
- (1949b): Notes sur les Collemboles avec description de quatorze espèces et d'un genre nouveaux. — Mitt. Schweiz. Ent. Ges. 22, p. 325—410.

- Gisin, H. (1953): Collembola from Jan Mayen Island. — *Ann. Mag. Nat. Hist.*, 12. ser., vol. 6, p. 228—34.
- (1956): Nouvelles contributions au démembrément des espèces d'*Onychiurus*. — *Mitt. Schweiz. Ent. Ges.* 29, p. 329—52.
- (1957): Sur la faune européenne des Collemboles I. — *Rev. suisse Zool.* 64, p. 475—96.
- (1960): Collembolenfauna Europas. — Genève.
- (1962): Sur la faune européenne des Collemboles. IV. — *Rev. suisse Zool.* 69, p. 1—23.
- (1963): Pour une réforme de la Taxonomie, appliquée aux Collemboles. — *Arch. Sci.* 16, p. 211—16.
- (1964a): Collemboles d'Europe. VI. — *Rev. suisse Zool.* 71, p. 383—400.
- (1964b): Collemboles d'Europe. VII. — *Rev. suisse Zool.* 71, p. 649—78.
- Gry, H. (1960): *Thys Geologi*. — *Ent. Medd.* 30, p. 20—25.
- Haarlov, H. (1947): A new modification of the Tullgren apparatus. — *J. Anim. Ecol.* 16, p. 115—21.
- (1957): Microarthropods from Danish soils. Systematics. — *Spolia Zool. Mus. Hauniensis* 17, p. 1—60.
- (1960): Microarthropods from Danish soils. Ecology, Phenology. — *Oikos. Suppl.* 3, p. 1—176.
- Hale, W. G. (1964): Experimental studies on the taxonomic status of some members of the *Onychiurus armatus* species group. — *Rev. Ecol. Biol. sol*, I, p. 501—10.
- Hüther, W. (1962): Beitrag zur Gattung *Willemia* Börner. — *Beitr. Ent.* 12, p. 511—26.
- Jensen, Carlo F. (1958): Topografisk oversigt over indvande i Thy. — *Flora og Fauna* 64, p. 123—63.
- Kaiser, E. W. (1958): Indvande i Thy inddelt efter deres kemiske særpræg. — *Flora og Fauna* 64, p. 164—84.
- Lawrence, P. N. (1961): A survey of the Collembola of the Burren, Co. Clare, Ireland. — *Ent. Gazette* 12, p. 143—68.
- (1962): A review of Bagnall's Hypogastrura types. — *Ent. Gazette* 13, p. 132—51.
- Linnaniemi, W. M. (1907): Die Apterygotenfauna Finlands. I. Allgemeiner Teil. — *Acta Soc. Scient. Fennicae* 34, p. 1—134.
- (1912): Die Apterygotenfauna Finlands. II. Spezieller Teil. — *Acta Soc. Scient. Fennicae*, 40 (5).
- Macfadyen, A. (1954): The invertebrate fauna of Jan Mayen Island. — *J. Anim. Ecol.* 23, p. 261—97.
- Mayer, H. (1957): Biologie und Ethologie einheimischer Collembolen. — *Zool. Jahrb. (Syst.)* 85, p. 501—70.

- Murphy, D. H. (1958): Notes on *Isotomurus* with a redescription of *Isotoma antennalis* (Bagnall). — *Ann. Mag. nat. Hist.* 13th ser. 1, p. 677—81.
- Nosek, J. (1960): *Arrhopalites gisini* sp. n. — *Zool. Listy, Folia Zool.* 9, p. 167—69.
- Palissa, A. (1960): Beiträge zur Ökologie und Systematik der Collembolen von Salzwiesen. 2. Teil. — *Deut. Ent. Z.* 7, p. 357—413.
- Poole, T. B. (1961): An ecological study of the Collembola in a coniferous forest soil. — *Pedobiologia* 1, p. 113—37.
- (1963): The effect of some environmental factors on the pattern of distribution of soil Collembola in a coniferous woodland. — *Pedobiologia* 2, p. 169—82.
- (1964): A study of the distribution of soil Collembola in three small areas in a coniferous woodland. *Pedobiologia* 4, p. 35—42.
- Rusek, J. (1963): Zweiter Beitrag zur Kenntnis der Apterygoten-Fauna der Mährisch-Schlesischen Beskiden. — *Acta Musei Sillesia*, ser. A, 12.
- Schaller, F. (1951): Zur Ökologie der Collembolen des Mainzer Sandes. — *Zool. Jb. (Syst.)* 79, p. 449—513.
- Selga, D. (1962): Tres especies nuevas de Collembolos del puerto de Navacerrada, (Guadarrama). — *Publ. Inst. Biol. aplic.* 33, p. 33—41.
- Stach, J. (1947—1963): The apterygotan fauna of Poland in relation to the world-fauna of this group of insects. — Kraków.
- Strenzke, K. (1963): Die Arthropodensukzessionen im Strandanwurf mariner Algen unter experimentell kontrollierten Bedingungen. — *Pedobiologia* 3, p. 95—141.
- Szeptycki, A. (1964a): Two new species of Collembola from Wolin Island. — *Polskie Pismo Ent.* 34, p. 171—76.
- (1964b): Apterygota of the Wolin Isle. Pt. II. The sea beach and dunes. (Polish, Engl. summary). — *Badania Fizjograficzne nad Polska Zachonia* 14, p. 7—34.
- Thamdrup, H. M. (1939): Studier over jyske heders økologi. I. Hedebundens fugtighedsforhold. — *Acta Jutlandica*. 11. suppl.
- Tuxen, S. L. (1931): Danske Protura. — *Ent. Medd.* 17, p. 306—11.
- (1949): Über den Lebenszyklus und die postembryonale Entwicklung zweier dänischer Proturengattungen. — *Kgl. da. Vid. Selsk. Biol. Skr.* 6, 3, p. 1—39.
- (1960): Hanstedreservatets Entomologi. Indledning. — *Ent. Medd.* 30, p. 1—19.
- (1964): *The Protura*. — Paris. 360 pp.
- Weis-Fogh, T. (1947/48): Ecological investigations on Mites and Collemboles in soil. — *Natura Jutlandica* 1, p. 135—270.

Yosii, R. (1963): On some Collembola of Hindokush, with notes on *Isotoma Bourl.* and its allies. — Res. Kyoto Un. Sci. Exp. to the Karakoram and Hindokush 1955, vol. 4, p. 3—42.
