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Migrations and Wintering of Cassids (*Coleoptera, Chrysomelidae, Cassidinae*) under the Climatic Conditions of the Ojców National Park

[Pp. 315—340, 7 text-figs.]

Migracje i zimowanie tarczyków (*Coleoptera, Chrysomelidae, Cassidinae*) w powiązaniu z warunkami klimatycznymi w Ojcowskim Parku Narodowym

Миграции и зимовка щитоносок (*Coleoptera, Chrysomelidae, Cassidinae*) в связи в климатическими условиями в Ойцовском Народном Парке

Abstract. In 1966—1967 a study of 4 species of cassids — *Cassida rubiginosa* Müll., *C. vibex* L., *C. viridis* L., *C. flaveola* Thunbg. — was carried out in an area selected in a meadow of *Arrhenatheretum elatioris* in the Sąspowska Valley. The numbers of adult and young specimens of these beetles were noted in successive periods of investigation. In 1967 the marking and recapturing of the cassids under study were also applied. Young beetles were found to stay in the meadow from 2 weeks to 2 months, next, towards the end of the summer and in the autumn, they migrated to a hornbeam forest on the southern slope of the valley, where they wintered, exclusively in the adult stage and in diapause, at a depth of 5—8 cm under the litter. The microclimatic measurements taken in the autumn of 1967 and in the winter of 1968 showed that cassids find more favourable conditions for hibernation in the forest than in the meadow. Thirty-three wintering specimens belonging to 6 cassid species (*Cassida rubiginosa* Müll., *C. vibex* L., *C. viridis* L., *C. flaveola* Thunbg., *C. hemisphaerica* Herbst and *C. nobilis* L.) were found in 320 samples of litter. The re-emigration of the adult beetles from the forest to the meadow takes place in the spring and ends in the first days of July.

I. INTRODUCTION

Studies on the migrations and wintering of cassids were undertaken repeatedly by different authors (Engel, 1932; Palij & Klepikova, 1957; Palij, 1959). They showed that cassids are able to travel a remarkable distance in active flight and that at the end of summer and in the autumn they migrate to wooded regions, where they hibernate under litter — exclusively in the adult stage and in diapause. In the spring they re-emigrate to the biotopes in which they forage and reproduce. These papers, however, lack data concerning the effect of the environmental microclimate on the migrations and wintering of the beetles in question.

The present study is a continuation of the team-work carried out by the Nature Conservation Research Centre in a meadow of *Arrhenatheretum elatioris* and in a forest of *Fagetum carpaticum* in the Ojców National Park in 1964—1965 (Studia ekosystemów..., 1967). The purpose of this study has been to trace out the dependence of the migrations and wintering of cassids on the climatic conditions in the Sąspowska Valley in the Ojców National Park.

II. STUDY AREAS AND METHODS

Study area I (Fig. 1) is a plot of meadow of *Arrhenatheretum elatioris alchemilletosum* (MEDWECKA-KORNAŚ & KORNAŚ, 1963) situated in the bottom of the Sąspowska Valley, which runs from west to east in the Ojców National Park. A cross-section through the valley illustrates its characteristic flat bottom, into which a deep streambed cuts, and steep rocky slopes. The spaces between the crags are occupied by a hornbeam forest of the *Tilio-Carpinetum typicum* subassociation, widely spread in the Ojców National Park and much drier than the *Tilio-Carpinetum stachyetosum* (MEDWECKA-KORNAŚ & KORNAŚ, 1963). Abundant young fir undergrowth occurs in this forest, from its edge half-way up the slope, and contributes to the accumulation of an increasing amount of litter in succeeding years.

The study area is a forest meadow, bordered by the slope of Chełmowa Góra Mt. on the south side and on the north side neighbouring on the slope of Złota Góra Mt. (Fig. 1). The northern bound of the meadow is the bed of the Stream Sąspówka, on the banks of which there are strips of an *Alno-Padion* flood forest (MEDWECKA-KORNAŚ & KORNAŚ, 1963). The Stream Młynówka (Millrace) flows on the south side and in the spell of spring floods and storms partly overflows the south-eastern border of the meadow. The surface of the meadow exhibits some differentiation, especially in its southern part, where the soil is wetter and more alkaline (KARKANIS, 1967). The specific composition of the plant cover of the study area does not virtually differ from the remaining part of the meadow (JANKOWSKA, 1967), except for the presence of *Cirsium oleraceum*, which occurs only in this part. In 1966, i. e., in the third year of the meadow being unmown (it was in the stage of succession, manifested chiefly by a change in the proportions of some species in the meadow sward), the share of *Cirsium oleraceum* increased remarkably, whereas in 1967 some dozen specimens of *Mentha longifolia* appeared within the study area. Hygrophilous species, such as *Alopecurus pratensis*, *Ranunculus repens* and

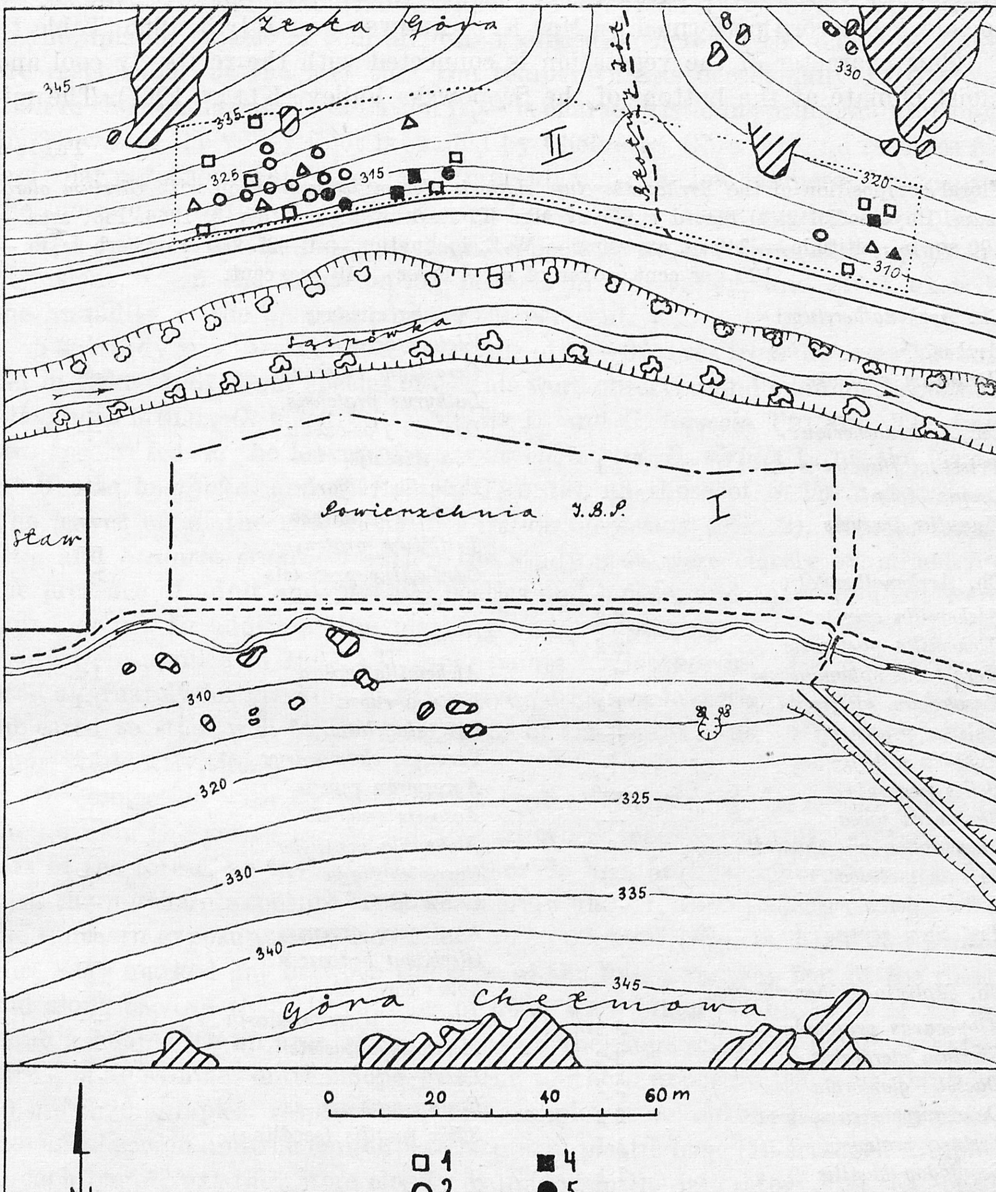

Fig. 1. A diagrammatic drawing showing the topography of the environs of the study area in the Sąspowska Valley in the Ojców National Park. I — study area, II — area in the hornbeam forest *(Tilio-Carpinetum)* where wintering cassids were found.

1 — *Cassida rubiginosa* MÜLL.	4 — *Cassida vibex* L.
2 — *Cassida flaveola* THUNBG.	5 — *Cassida viridis* L.
3 — *Cassida hemisphaerica* HERBST.	6 — *Cassida nobilis* L.

others, also occur in this area. Its floral composition is illustrated by the phytosociological record performed by Mgr K. Jankowska on July 3, 1966 (Table I).

This character of the vegetation is connected with the relatively cool and moist climate at the bottom of the Sąspowska Valley (Klein, 1967). The mi-

Table I

Floral composition of the *Arrhenatheretum elatioris alchemilletosum* stand with *Cirsium oleraceum*. Phytosociological record made by Mgr K. Jankowska on July 3, 1966. Plot area — 100 sq. m., altitude — 340 m, exposure — W-E, inclination — 0—2°. Cover of herb layer — 100 per cent, cover of moss layer — 10 per cent.

Ch. *Arrhenatheretum*:	
Arrhenatherum elatius	+
Geranium pratense	+
Ch. *Arrhenatherion*:	
Trisetum flavescens	1·1
Crepis biennis	+
Knautia arvensis	+
Ch. *Arrhenatheretalia*:	
Alchemilla crinita	2·2
Alchemilla pastoralis	2·2
Heracleum sphondylium	2·1
Taraxacum officinale	1·1
Phleum pratense	+·2
Achillea millefolium	+
Bellis perennis	+
Centaurea jacea	+
Chrysanthemum leucanthemum	+
Galium mollugo	+
Lolium perenne	+
Trifolium repens	+
Ch. *Molinio-Arrhenatheretea*:	
Alopecurus pratensis	3·2
Cirsium oleraceum	3·2
Dactylis glomerata	2·2
Deschampsia caespitosa	2·2
Festuca pratensis	1·1
Leontodon hastilis	1·1
Leontodon hispidus	1·1
Plantago lanceolata	1·1
Ranunculus acer	1·1
Rumex acetosa	1·1
Cirsium rivulare	+·2
Vicia cracca	+·2
Cerastium vulgatum	+
Lathyrus pratensis	+
Lychnis flos-cuculi	+
Poa trivialis	+
Prunella vulgaris	+
Stellaria graminea	+
Trifolium pratense	+
Cardamine pratensis	r
Others:	
Alchemilla glabra	1·1
Festuca rubra	1·1
Primula elatior	1·1
Veronica chamaedrys	1·1
Agropyron repens	+·2
Agrostis vulgaris	+
Alchemila acutiloba	+
Carex contigua	+
Carex hirta	+
Equisetum arvense	+
Glechoma hederacea	+
Lotus corniculatus	+
Lysimachia nummularia	+
Myosotis palustris	+
Plantago media	+
Ranunculus repens	+
Salix fragilis (seedling)	
D *Mnium undulatum*	1·2
Brachythecium sp.	+
Rhytidiadelphus squarrosus	+

croclimatic conditions are moulded under the influence of radiation and insolation. The active surface of the area is the turf, which attains a height of 40 cm in the full vegetation season. Owing to the high slopes the meadow lies in the zone of calm. In the regionalization of the Ojców National Park carried out in respect of its microclimates (Klein, Niedźwiedź & Sztyler, 1965) the present study area has been included in the cool region ofv alley bottoms, marked by its great 24-hour amplitudes, which are about 5—10°C higher than those in the upland. Masses of cool air, often subsisting here all the day and night, are responsible for the fact that the temperature is occasionally 10°C lower than in the upland. Slight radiation frost is characteristic in spring and autumn. In the winter the valley floor is shaded by Chełmowa Góra Mt. and receives far less solar radiation, which fact in conjunction with the low temperatures, causes the snow cover to linger on the average 12—14 days longer than in the upland.

The relative air humidity is high, especially at the time of temperature inversions, when the radiation-fog persists in the valley, and often exceeds the humidity in the open upland by 30 per cent.

This study was carried out at intervals of 15—30 days from April to November in 1966—1967. Four species of cassids were observed and examined: *Cassida rubiginosa* MÜLL., *C. vibex* L., *C. viridis* L. and *C. flaveola* THUNBG. The first two species fed on the leaves of *Cirsium oleraceum*, *C. viridis* L. on the leaves of *Mentha longifolia*, and *C. flaveola* THUNBG. on those of *Stellaria graminea*. The leaves of all the specimens of *Cirsium oleraceum* (Fig. 2), *Mentha longifolia* and *Stellaria graminea* within the study area were closely examined for the presence of adult and juvenile beetles and larvae, and their numbers were noted down. In addition, the marking and recapturing of the beetles under study were applied in 1967. „Wilbra" paints for leather in a few colours were used alternately for marking in successive periods of investigation. These paints appeared to stick well to the wing-cases of the beetles and to be harmless to their vital activities.

In connection with the supposition that at the end of the summer and in the autumn the young beetles migrate from the meadow to their winter-quarters in the forest, an investigation was made in a hornbeam forest on a slope with the northern exposure on November 10 and 11, 1966 and on a slope with the southern exposure from November 20 to 22, 1967 (Fig. 1). Eight horizontal lines were marked out between the edge of the forest and the feet of the rocks and along each of them 10 samples of litter were taken (at intervals of 3·5 m, using a hoop with an area of 1/8 sq. m) on the slope with the northern exposure and 40 samples on the slope with the southern exposure; thus we obtained 80 and 320 samples, respectively. The samples were screened using an entomological screen and the contents were put in plastic bags (10 screened samples in each bag). Next they were closely examined in the laboratory and the specimens of cassids present in them were picked out.

In order to determine the amount of dry matter and free water in the body of cassids of the species examined, the specimens of freshly hatched beetles, the beetles migrating to their winter-grounds and those hibernating, 10 from each group, were weighed and dried for 2 days in a dryer at a temperature of 85°C and next for an hour at 105°C. They were, in turn, weighed to an accuracy of 0·1 mg on an analytical balance and the percentages of dry matter and free water were calculated.

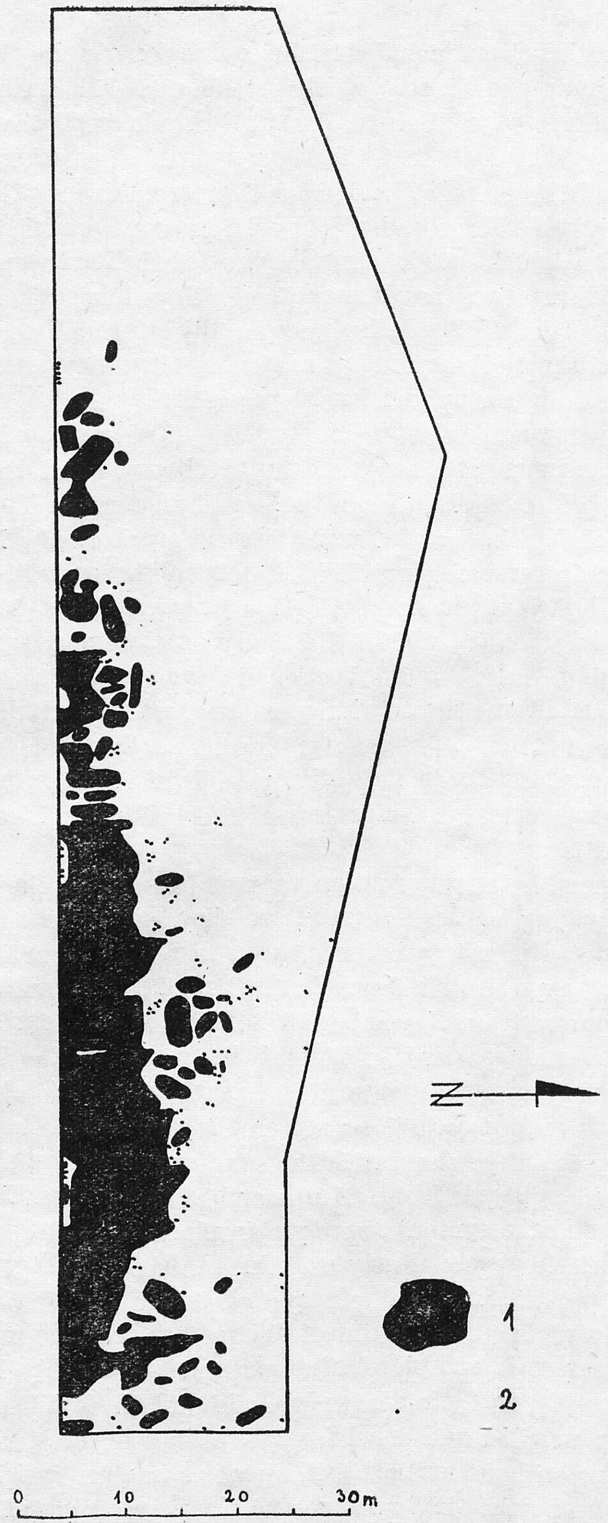

Fig. 2. Range of *Cirsium oleraceum* in the study area in the *Arrhenatheretum elatioris alchemilletosum* meadow in the Ojców National Park. 1 — continuous range, 2 — single specimens

Two series of microclimatic measurements were made in the meadow and forest (November 20—22, 1967 and February 5—7, 1968) to obtain data for the close determination of the conditions in which the cassids hibernated. The study included air temperatures (at heights of 1, 5, 20 and 150 cm), soil temperatures (at depths of 0, 5, 10 and 20 cm), thickness of snow cover and other weather factors.

To find whether the occurrence of wintering cassids in the litter depends on its thickness, the thickness of the layer of fresh litter (Aoo') and that of putrefying litter derived from the previous year (Aoo'') were measured in 3 zones: a) along the forest edge, b) half-way up the slope, and c) at the foot of the rocks. Twenty measurements were taken along each line.

III. RESULTS

1. Microclimatic Conditions

Air temperature has a great effect on the activity of cassids. It is supposed that +13·0°C is the threshold value above which the activity of these beetles increases remarkably. In April (Table II) the prevailing temperatures in the meadow are higher than +13·0°C and they provide favourable bioclimatic conditions for cassids, which at this time begin to re-emigrate from the winter-quarters to the meadow.

Towards the end of the vegetation season the meadow in the Sąspowska Valley has considerably worse climatic conditions than those in the hornbeam forest on the southern slope. It does not receive energy from the direct solar radiation any longer, because it lies within the range of the shadow of Chełmowa Góra Mt. In the second half of August and in September slight radiation frost and temperature inversions, connected with it, occur very often, whereas higher temperatures and more favourable humidity conditions prevail in the hornbeam forest, situated higher up the slope, where insolation is great (KLEIN, MS.). The early autumnal slight radiation frost markedly worsens the bioclimatic conditions in the meadow, where, as will be seen from Table III, in 1966—1967 the minimum September air temperatures never exceeded the threshold value of +13·0°C. These low temperatures probably exert an influence on the migrations of the cassids to the wooded region.

When microclimatic measurements were being taken in November 20—22, 1967, the weather was under the influence of an anticyclone. Owing to radiation and the influx of masses of cool polar-maritime air the temperature fell below 0°C throughout southern Poland. It was the first attack of winter. As a result of temperature inversions caused by night clearing up and calm in the Ojców National Park, the temperature at the bottom of the Sąspowska Valley (in the meadow) fell to —6·0°C. The frosty weather persisted till mid-day on November 21, 1967, when masses of far warmer air flowed in so that even at

Table II

April air temperatures in the meadow taken 5 cm above the ground at 1.00 p. m.

Year \ Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Mean
1966	10,2	6,5	3,2	18.8	20,0	26,8	27,4	16.0	24,8	17,6	14,0	14,8	5 2	18,6	19.8	23,0	7,2	11,6	21,2	26,0	13,8	17,6	22,6	27,8	25,6	24,0	13,8	25,0	26,5	28,4	18,6
1967	12,6	10,0	8,0	10,2	11,8	7,0	10,0	11,6	25,6	23,5	24,5	26.8	17,8	11,0	16,5	23,8	24,5	18,0	8,0	17 5	20,5	8,0	11,3	8,2	1,5	6,5	13.8	10,5	23,5	23,5	14,9

Table III

Minimum September air temperatures in the meadow taken 5 cm above the ground

Year \ Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	15	25	27	28	29	30	Mean
1966	12,2	6,2	6,2	6,2	5,0	7,4	5,6	7,4	3,2	4,0	4,0	4,6	6,2	10,2	3,6	5,2	2,2	0,4	—0,6	—1,2	0,2	1,8	4,0	7,2	4,6	5,8	6,0	7,8	6,4	7,0	5,0
1967	8,2	7,2	8,0	8,0	8,3	7,5	7,6	9,8	9,0	12,0	9,5	12,7	13,5	6,5	6,5	8,0	8,5	13,0	9,0	5,5	5,5	6,7	3,0	2,5	5,2	8,5	13,0	12,0	2.5	1,2	7,9

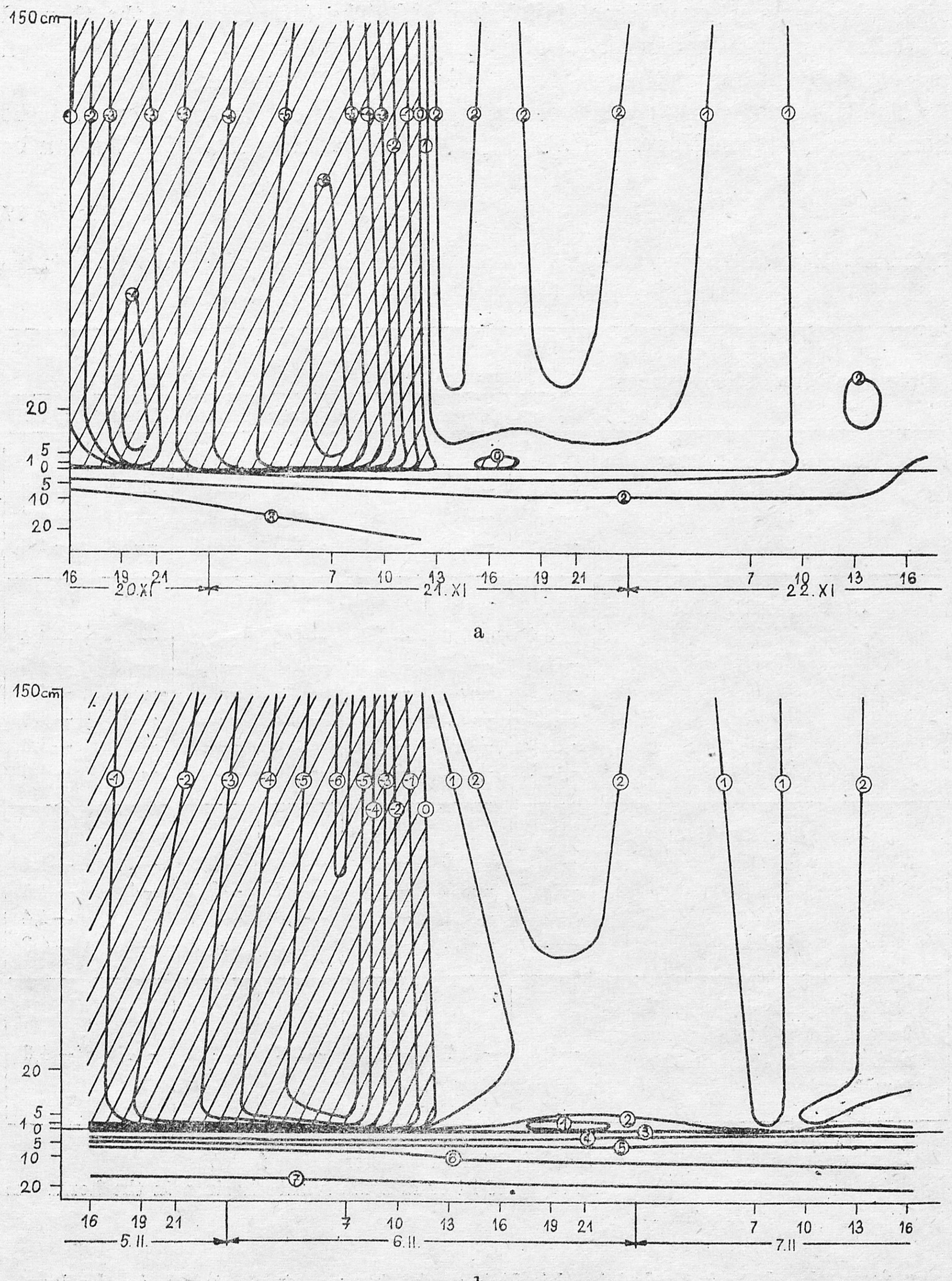

Fig. 3. Air and soil thermo-isopleths during the autumnal series of microclimatic measurements in the bottom of the Sąspowska Valley in November 20—22, 1967.
a) meadow, b) hornbeam forest on southern slope.
Areas of temperatures below 0°C are hatched.

night the temperature did not fall below 0°C. The differences in the thermal stratification of the ground layer of atmosphere also decreased. They have been presented by means of thermo-isopleths in Figure 3 a and b.

The differences in air and soil temperatures between the meadow and the hornbeam forest on November 20—22, 1967 are given in Table IV. As can be

Table IV

Differences between the temperatures in the meadow and those in the hornbeam forest in the autumn (November 20—22, 1967)

Date and Time of Measurement	Differences in Air Temperatures			Differences in Soil Temperatures			
	150 cm	20 cm	1 cm	0 cm *	5 cm **	10 cm	20 cm
November 20, 1967							
15·40	—0,4	—1,2	—1,0	—2,6	—3,1	—3,2	—3,8
18·40	—1,8	—1,8	—2,4	—2,9	—2,5	—3,3	—4,0
20·40	—1,0	—1,6	—1,2	—2,6	—3,6	—3,4	—4,0
November 21, 1967							
6·40	0,0	—0,9	—1,1	—2,6	—3,8	—3,8	—4,4
9·40	—1,0	—1,8	—2,0	—2,5	—3,9	—3,9	—4,5
12·40	—0,8	—0,8	—0,2	—2,4	—3,9	—3,9	—4,6
15·40	—0,5	—0,2	—0,8	—2,1	—3,7	—3,8	—4,5
18·40	+0,4	+0,1	—0,6	—2,0	—3,7	—3,7	—4,6
20·40	+0,1	+0,1	—0,7	—2,0	—3,6	—3,6	—4,6
November 22, 1967							
6 40	—0,1	—0,6	—0,8	—1,8	—3,6	—3,6	—4,4
9·40	—0,4	—0,2	—0,9	—1,7	—3,5	—3,6	—4,4
12·40	—0,1	+0,1	—0,3	—1,3	—3,4	—3,5	—4,4
15·40	—0,1	—0,1	—0,6	—1,8	—3,3	—3,3	—4,3
Mean differences between the temperatures in the meadow and those in the hornbeam forest	—0,4	—0,7	—1,0	—2,2	—3,5	—4,0	—4,3

Explanations: * — at the surface of litter in the hornbeam forest
** — between the layer of litter and the humus horizon in the hornbeam forest

seen from the data included in this Table, the temperatures taken in the hornbeam forest were higher nearly all the time, especially the temperatures of the zone of hibernation of the cassids clearly showed some advantage of the forest, where they were higher by 3·5—4·0°C and provided more favourable conditions for the beetles to winter than in the meadow.

The occurrence of young fir undergrowth and numerous dry branches, fallen from the trees, makes it possible for litter to accumulate in a large amount on the floor of the forest. It plays the role of a thermoinsulator and prevents the heat of the soil (accumulated in the summer) to radiate and, on the other hand, protects the zone of hibernation of the cassids effectively against the invasion of cool air late in the autumn and in the winter.

Measurements of the microclimatic conditions in the winter (February 5—7, 1968) were taken during the period of weather influenced by an extensive cyclonic trough. A line of the occlusion travelled over Poland. As a result, the weather was changeable, the cloudiness, slight at the beginning, increased with time. Moreover, masses of warm air came from over the Mediterranean.

The continuous snow cover lay on the northern slopes, on the bottom of the Sąspowska Valley, in the gorges and gullies. The southern slopes, the wide bottom of the Prądnik Valley and partly the slopes with the eastern and western exposures were covered by patches of snow, especially in shaded areas. Remains of snow persisted also in the mixed forests in the upland region (Fig. 5). The study area in the meadow was covered with a layer of snow, 30 cm thick, whereas in the hornbeam forest, where the wintering cassids were found, it had melted. An exception was the floor of the Błotny Dół Gorge, where there was still a 10-centimetre layer of snow and not a specimen of the wintering cassids was found (cf. Figs. 1 and 5).

The thermal air and soil conditions in the study areas as well as those included by way of an example from another area on a northern slope (where no wintering cassids were found) are presented in Figure 4a, b and c. The least favourable conditions were in the meadow, where the lowest air and soil temperatures were recorded. In spite of a fairly thick snow cover, the earth was frozen to a depth of 15 cm. On the other hand, the temperatures appeared very favourable in the hornbeam forest, where, especially in the daytime, they were far higher. The maximum temperature on the surface of the litter was +8·3°C on February 6, 1968, whereas the temperature taken in the meadow at the same time was —1·0°C (under the snow cover). The differences between the temperatures of the meadow and hornbeam forest are given in Table V.

The favourable insolation in the hornbeam forest, about 30 per cent greater than in the Sąspowska Valley (Klein et al., 1965) and, consequently, the higher air and soil temperatures and the shorter subsistence of the snow cover (snow in the hornbeam forest disappears about 20 days earlier than in the meadow) make the conditions in the forest more favourable for cassids to hibernate than those in the meadow.

2. Migrations and Wintering of Young Beetles

The observations made in the spring showed that the first specimens of adult beetles (the ones which had overwintered) of *Cassida rubiginosa* Müll. and *C. vibex* L. appear in the study area in the meadow in the first half of April

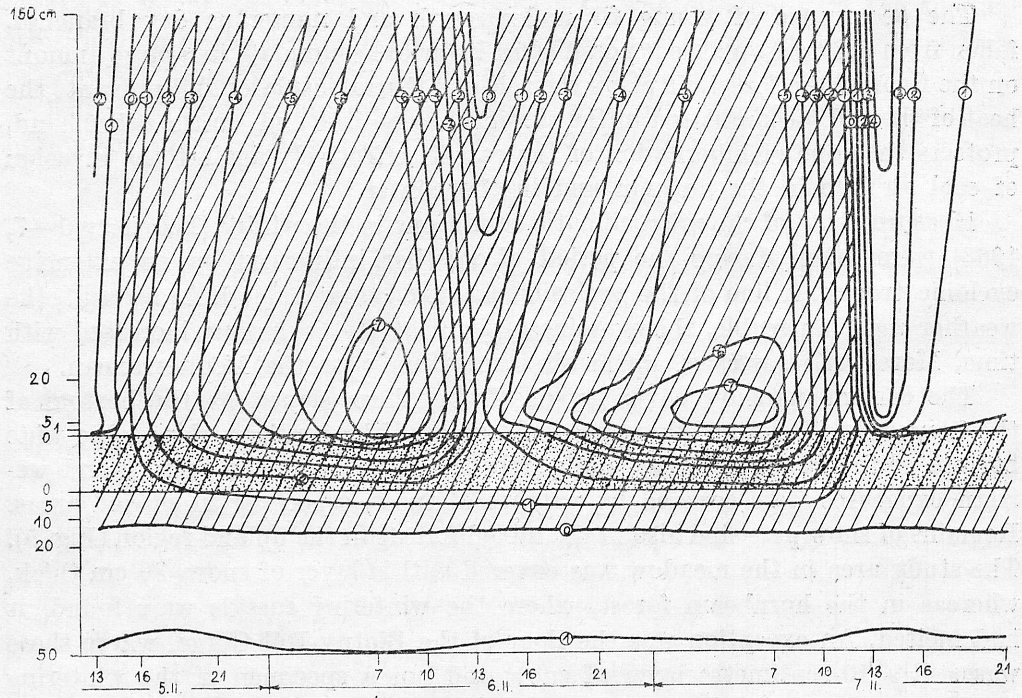
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Fig. 4a

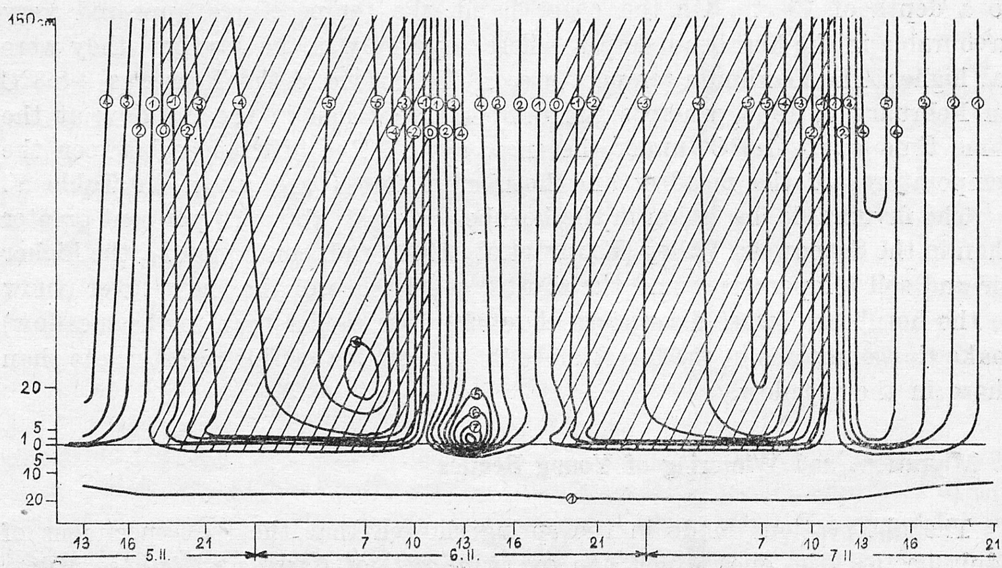
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Fig. 4b

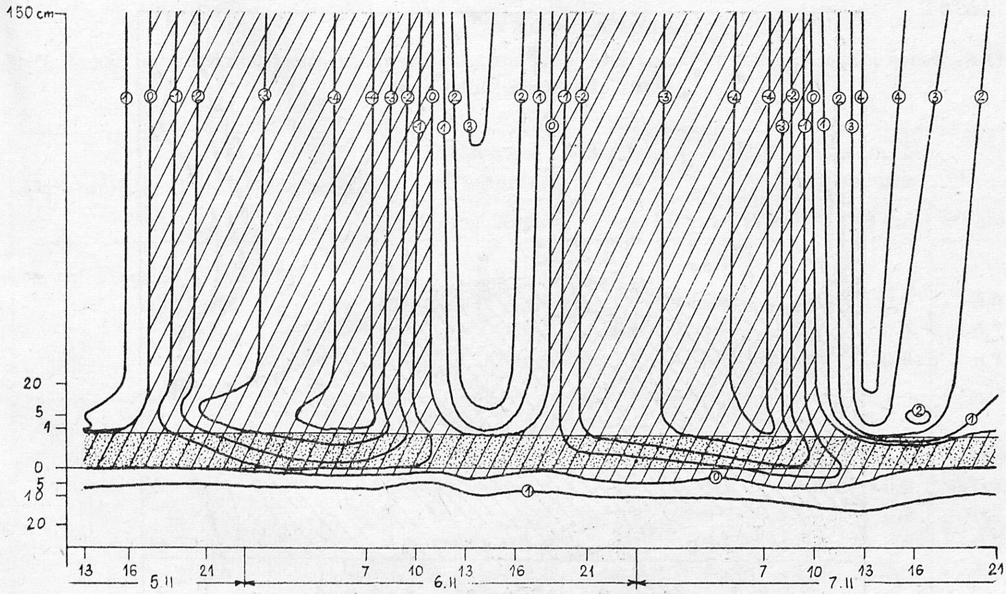


Fig. 4c

Fig. 4. Air and soil thermo-isopleths during the winter series of microclimatic measurements in February 5—7, 1968.
a) meadow in the bottom of the Sąspowska Valley, b) hornbeam forest on the southern slope, c) shady maple forest on the northern slope.
Areas of temperatures below 0°C are hatched. Dots indicate the thickness of snow cover.

(Fig. 6a and b), and towards the end of this month and at the beginning of May they come flying from their winter-quarters in increasing numbers. The application of the method of marking and recapturing (1967) showed that new unmarked beetles appear in successive periods of study (Table VI). This allows us to draw a conclusion as to the re-emigration of cassids from the forest in the spring. The maximum of re-emigration occurs in the first half of May and the process becomes completed at the beginning of July. It was, besides, realized that the adult beetles of *Cassida rubiginosa* MÜLL. and *C. vibex* L. perish in masses except for a slight percent, from mid-May on, so that towards the end of summer they are hardly met with in the study area.

The first specimens of young (newly emerged) beetles of *Cassida rubiginosa* MÜLL. were seen towards the end of June and those of *C. vibex* L. in the first half of July (Fig. 7a and b). The former appear in maximum numbers in the second half of August and the latter in the first half of September.

These investigations suggest (cf. Figs. 6a, b and 7a, b) that *Cassida rubiginosa* MÜLL. is very numerous in the study area, *C. vibex* L. not numerous, and *C. viridis* L. and *C. flaveola* THUNBG. rare (this is why it was impossible to examine their fenology closely). These observations quite agree with the results obtained by PALIJ and KLEPIKOVA (1957). *Cassida viridis* L. was, in

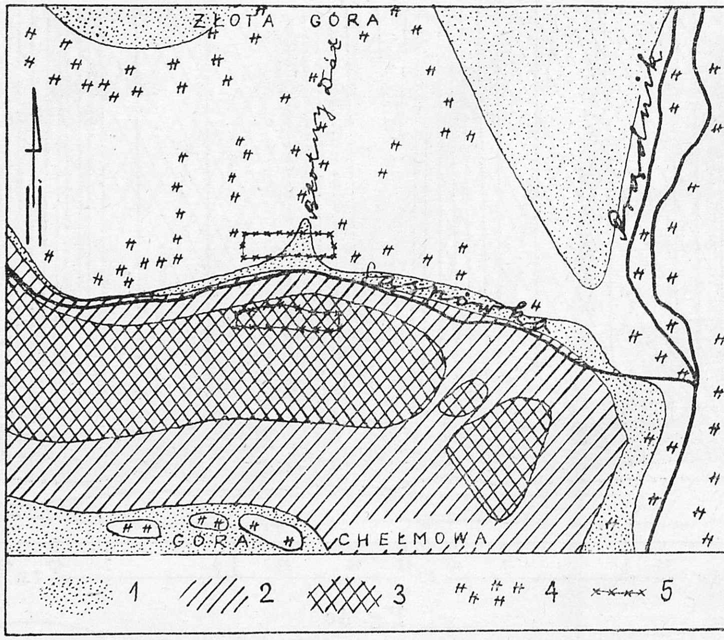


Fig. 5. A map showing the extent of snow cover in the environs of the Sąspowska Valley on February 5, 1968.
1 — snow cover 0—10 cm thick, 2 — snow cover 10—20 cm thick, 3 — snow cover 20—30 cm thick, 4 — single patches of snow, 5 — boundary of the study areas

addition, observed out of the study area, but was not found to be numerous there.

Cassids begin migrating to their winter-grounds as early as the end of summer, when food still abounds in the meadow, which fact suggests that this phenomenon is governed by climatic conditions. It is supposed that there are 2 main causes of the migration of young cassids to wooded areas: one of them may be a difference in air humidity as early as the end of summer and the other is undoubtedly a drive at finding as convenient a place for hibernation as possible. This opinion is supported by the results obtained by Kuznecov-Ugamski (1929) on the migrations of ladybirds and by Chroliński (1963) on those of weevils. Moreover, it was found that the cassids caught in the spring and autumn attempt to fly, which would indicate that their migrations are dependent on the seasons. Chroliński (1963) observed this phenomenon in weevils and considered it to be an expression of an increased excitement in the nerve centres which in the spring and autumn actuate the flights from one biotope to another.

The migration of young cassids begins in the second half of August, proceeds intensely in September, and comes to an end at the beginning of October (Table VII). Experiments with marking and recapturing the beetles (1967) showed that 1) young beetles of *Cassida rubiginosa* Müll. and *C. vibex* L. which

Table V

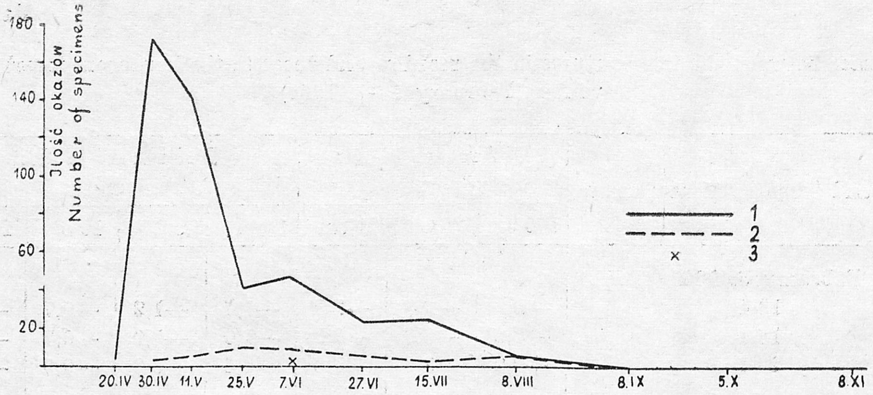
Differences between the temperatures in the meadow and those in the hornbeam forest in the winter (February 5—7, 1968)

Date and Time of Measurement	Differences in Air Temperatures			Differences in Soil Temperatures			
	150 cm	20 cm	1 cm	0 cm *	5 cm **	10 cm	20 cm
February 5, 1968							
13·40	—2,2	—2,8	—2,3	—1,7	—1,2	—0,7	—0,9
15·40	—3,8	—3,5	—2,9	—1,0	—1,0	—0,7	—0,7
20·40	+0,2	—2,0	—1,2	—0,6	—0,3	—0,9	—0,7
February 6, 1968							
6·40	—0,6	—1,8	—2,9	+1,0	—0,9	—1,4	—0,8
9·40	—1,8	—4,4	—4,0	—1,2	—1,5	—0,8	—0,8
12·40	—3,7	—6,3	—5,4	—9,3	—1,5	—0,9	—0,7
15·40	—3,4	—5,8	—4,1	—2,4	—1,5	—0,9	—0,7
20·40	—1,6	—2,0	—3,0	—0,8	—1,6	—1,1	—0,7
February 7, 1968							
6·40	—0,2	—1,8	—2,6	0,0	—0,9	—1,1	—0,7
9·40	—0,7	—0,8	—2,0	—0,8	—1,3	—1,0	—0,6
12·40	—0,4	—1,8	—2,2	—2,6	—0,8	—0,8	—0,7
15·40	—1,7	—2,3	—2,5	—2,0	—1,0	—0,8	—1,7
20·40	+0,2	+0,2	+0,2	—0,4	—1,1	—0,7	—1,7
Mean differences between the temperatures in the meadow and those in the hornbeam forest	—1,5	—2,7	—2,7	—1,7	—1,1	—0,9	—0,9

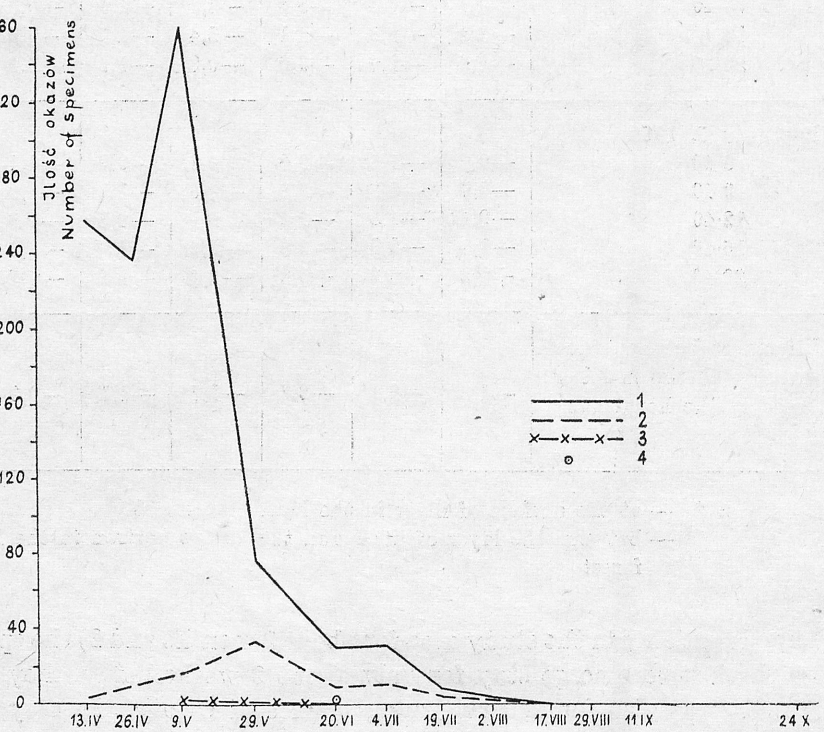
Explanations: * — at the surface of litter in the hornbeam forest
** — between the layer of litter and the humus horizon in the hornbeam forest

have emerged first stay in the study area for about 2 months and 2) the specimens that were the last to emerge stay for only about 2 weeks before they migrate to a forest. It was also found that young beetles of *C. vibex* L. stay in their feeding-grounds longest of all the cassid species examined, which fact is also confirmed by the data presented by PALIJ and KLEPIKOVA (1957).

The amount of free water in the body of cassids migrating to their winter-quarters decreases remarkably and reaches its lowest value in the whole extent of life of these beetles (cf. Table VIII a, b and c). No biochemical analyses for the demonstration of the content of fats and protein nitrogen in the dry matter were made, but on the basis of the data presented by WĘGOREK (1957) for the Colorado beetle and by WILSKI (1953) for the pea beetle it is supposed that the



a



b

Fig. 6. Fluctuations in the number of adult cassid imagines in the *Arrhenatheretum elatioris alchemilletosum* meadow:
a) in the vegetation season of 1966
b) in the vegetation season of 1967 [1]
1 — *Cassida rubiginosa* MÜLL.
2 — *Cassida vibex* L.
3 — *Cassida flaveola* THUNBG.
4 — *Cassida viridis* L.

[1] The method of marking and recapturing was applied in 1967.

Table VI

The number of adult cassid imagines determined by the method of marking and recapturing in 1967

Cassid species	Specimens \ Study period		April 13	April 26	May 9	May 29	June 20	July 4	July 19	August 2	August 17
Cassida rubiginosa MÜLL.	marked		257	218	348	48	22	20	5	2	—
	recaptured	I		17	1	1	—	—	—	—	—
		II			10	3	—	—	—	—	—
		III				24	3	1	—	—	—
		IV					5	8	1	—	—
		V						2	—	—	—
		VI							2	—	—
		VII								1	—
		VIII									—
Cassida vibex L.	marked		3	9	16	32	5	8	1	1	—
	recaptured	I		1	—	—	—	—	—	—	—
		II			—	—	—	—	—	—	—
		III				1	—	—	2	—	—
		IV					4	2	—	—	—
		V						—	—	—	—
		VI							—	—	—
		VII								—	—
		VIII									—
Cassida viridis L.	marked		—	—	—	—	1	—	—	—	—
	recaptured	V						—	—	—	—
Cassida flaveola THUNBG.	marked		—	—	2	1	—	—	—	—	—
	recaptured	III				—	—	—	—	—	—
		IV					—	—	—	—	—

Explanations: I — recapture of specimens marked on April 13
II — recapture of specimens marked on April 26
III — recapture of specimens marked on May 9
IV — recapture of specimens marked on May 29
V — recapture of specimens marked on June 20
VI — recapture of specimens marked on July 4
VII — recapture of specimens marked on July 19
VIII — recapture of specimens marked on August 2

fat content of dry matter increases considerably, which is of great importance to the wintering beetles.

The cassids' winter-grounds were found in the hornbeam forest on the southern slope of the Sąspowska Valley (Fig. 1). These beetles hibernate, exclusively as imagines in diapause, in putrefying litter derived from the previous year and covered by a layer of newly fallen leaves. These data are supported

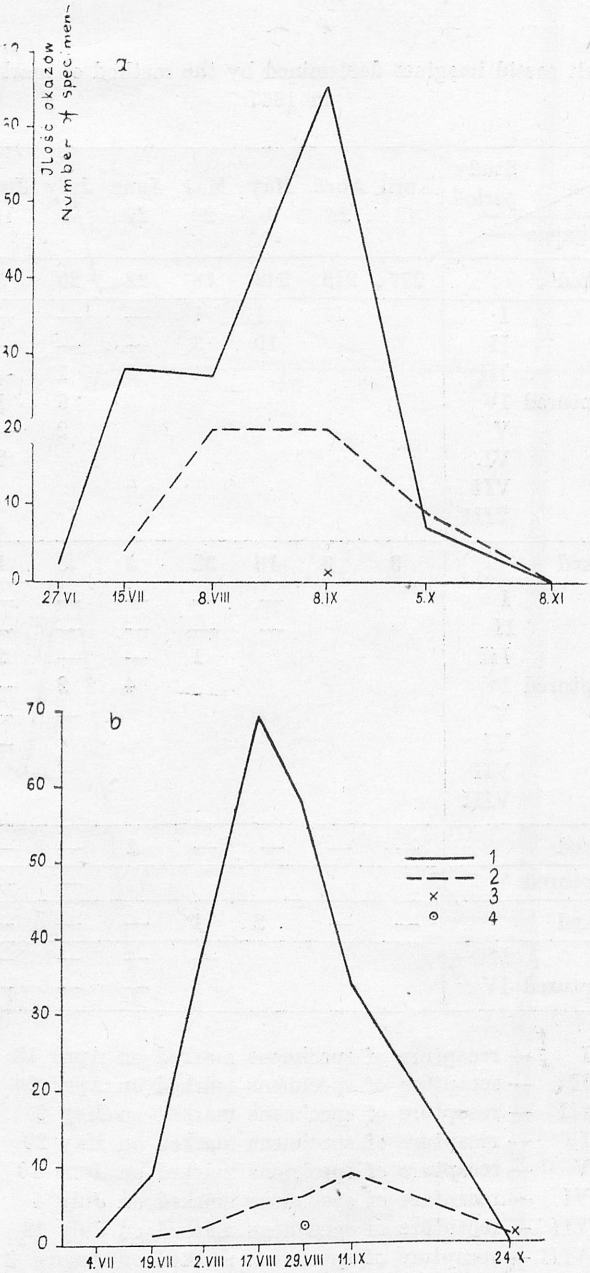


Fig. 7. Fluctuations in the number of young cassid imagines in the *Arrhenatheretum elatioris alchemilletosum meadow*:
a) in the vegetation season of 1966
b) in the vegetation season of 1967 [1]
1 — *Cassida rubiginosa* MÜLL.
2 — *Cassida vibex* L.
3 — *Cassida flaveola* THUNBG.
4 — *Cassida viridis* L.

[1] The method of marking and recapturing was applied in 1967.

Table VII

The number of young cassid imagines determined by the method of marking and recapturing in 1967

Cassid species	Specimens \ Study period	July 4	July 19	August 2	August 17	August 29	September 11	October 24
Cassida rubiginosa MÜLL.	marked	1	9	39	66	50	27	—
	recaptured I		—	—	—	—	—	—
	II			—	—	—	3	—
	III				3	1	—	—
	IV					6	—	—
	V						4	—
	VI							—
Cassida vibex L.	marked	—	1	2	4	5	8	1
	recaptured II			—	—	—	1	—
	III				1	—	—	—
	IV					1	—	—
	V						—	—
	VI							—
Cassida viridis L.	marked	—	—	—	—	2	—	—
	recaptured V						—	—
Cassida flaveola THUNBG.	marked	—	—	—	—	—	—	1

Explanation: I — recapture of specimens marked on July 4
II — recapture of specimens marked on July 19
III — recapture of specimens marked on August 2
IV — recapture of specimens marked on August 17
V — recapture of specimens marked on August 29
VI — recapture of specimens marked on September 11

by the studies carried out by KLEINE (1914), RAMMNER (1934 and 1937), ENGEL (1932) and PALIJ and KLEPIKOVA (1957).

The wintering beetles found represented 6 cassid species, i. e., *Cassida rubiginosa* MÜLL. (10 specimens), *C. vibex* L. (3), *C. viridis* L. (3), *C. flaveola* THUNBG. (11), *C. hemisphaerica* HERBST (5) and *C. nobilis* L. (1). It is a striking fact that there were as many as 11 specimens of *C. flaveola* THUNBG., which was very rarely encountered in the study area. Perhaps, in the vegetation season this species occurs also on *Stellaria holostea*, which grows in abundance in the hornbeam forest. So far, neither *C. nobilis* L. nor *C. hemisphaerica* HERBST has been observed in the meadow.

While the litter samples were still being screened in the field, it was noted that the specimens of wintering cassids were being found under litter, at a depth

Table VIII

a. Mean free water content in newly emerged cassids

Date of Analysis	Species	No. of Specimens	Percentage Water Content
August 1, 1967	*Cassida rubiginosa* MÜLL.	10	81,37
	Cassida vibex L.	10	81,51
	Cassida viridis L.	10	85,67

b. Mean free water content in cassids migrating to winter-quarters

Date of Analysis	Species	No. of Specimens	Percentage Water Content
August 31, 1967	*Cassida rubiginosa* MÜLL.	10	53,51
	Cassida vibex L.	10	52,65
	Cassida viridis L.	10	51,84

c. Mean free water content in wintering cassids and other chrysomelids

Date of Analysis	Species	No. of Specimens	Percentage Water Content
November 21, 1967	*Cassida rubiginosa* MÜLL.	10	55,06
	Cassida vibex L.	3	52,95
	Cassida viridis L.	3	52,43
	Cassida flaveola THUNBG.	10	55,58
	Cassida hemisphaerica HERBST	5	50,29
	Cassida nobilis L.	1	53,34
	Lema sp.	10	55,00
	Phyllotreta sp.	10	58,17

of 5—8 cm, their back turned towards the ground surface. It was besides observed that beetles of all the cassid species found wintered singly, not in aggregations. The authors who have made studies on cassids do not state at what depth these beetles hibernate. On the other hand, VASILIEV (1963) claims that the pest of the Manchurian walnut, *Gastrolina thoracica* BALY from the family *Chrysomelidae*, winters at a depth of 5—6 cm under forest litter, which data come close to the results of the present study.

It is noteworthy that most of the wintering cassids were collected in the zone extending from the edge of the forest half-way up the slope (Fig. 1). This fact suggests that there is positive correlation between the thickness of the layers of litter (Table IX) and the occurrence of beetles hibernating in it. The sums of the mean values of thickness of both the litter layers are somewhat higher for the edge of the forest and the zone half-way up the slope than those for the region of rocks, where only a few beetles were found.

Table IX

Thickness of litter layers in cm

Aoo′ — fresh litter, Aoo″ — putrefying litter from preceding years

Site of Study	Mean Thickness of Litter Layers Calculated from 20 Points of Measurements, in cm		Sum of Mean Values of Thickness of Both Litter Layers for 20 Points of Measurements, in cm
	Aoo″	Aoo″	
Forest edge	3,7	4,1	7,8
Half-way up the slope	4,1	4,5	8,6
At the foot of rocks	3,6	3,3	6,9

Although in the course of the investigation carried out in 1967 altogether 216 young beetles from 4 cassid species were marked and 320 litter samples were screened in the autumn, not a specimen marked was found among the cassids taken in the winter-quarters. To be sure, the paint on the wing-cases of the beetles may have been rubbed off, when they were forcing their way through the litter but, on the other hand, the number of beetles marked formed only a small proportion of the whole population and thus the probability of recapturing them in the winter-quarters was slight.

Metabolic processes run in the bodies of wintering cassids (especially the combustion of fats) and result in the generation of water. Its amount increases gradually during hibernation (Table VIIIc). A comparison of the data concerning the average percentage free water content for newly emerged cassids, for the specimens migrating to their winter-grounds and for those wintering there (Table VIIIa, b and c) with the data for the Colorado beetle (Węgorek, 1957) shows clearly that these values are very much alike in different members of the family *Chrysomelidae*. The data presented in Table VIIIc for *Cassida vibex* L., *C. viridis* L., *C. hemisphaerica* Herbst and *C. nobilis* L. are not quite exact, since they were calculated for less than 10 specimens of particular species. We failed to collect more specimens of these beetles.

SUMMARY

1. Young beetles of the cassid species under study stay on the host plants from 2 weeks to 2 months and next they migrate to their winter-quarters in wooded areas. In the spring they re-emigrate from the forest to the meadow.

2. The cassid species examined hibernate exclusively as imagines in diapause under litter, at a depth of 5—8 cm. In our case they wintered in the proximity of the study area, in a hornbeam forest on the southern slope of the Sąspowska Valley.
3. In the autumn migration season the percentage free water content of the body of cassids falls from 81—85 per cent to 51—53 per cent. In the bodies of wintering beetles the amount of free water increases gradually.
4. It may be stated on the basis of microclimatic measurements that cassids find remarkably more favourable conditions for wintering in the hornbeam forest than in the meadow. Higher air and soil temperatures occurred in the hornbeam forest in nearly all study periods.
5. The advantage of the hornbeam forest in respect of microclimate is manifested, among other things, by its greater insolation than in the meadow (by about 30 per cent), shorter subsistence of snow cover (it disappears about 20 days earlier than in the meadow) and earlier commencement of the vegetation season (the liverwort *Hepatica nobilis* and lungwort *Pulmonaria obscura* are already in flower in the hornbeam forest, while the opposite slope is covered by a continuous snow layer and the last patches of snow are disappearing from the meadow).
6. Cassids find favourable conditions for wintering in the hornbeam forest owing to the relatively thick layer of litter, which accumulates among the low fir saplings and dry branches fallen from the trees. The litter acts as a thermo-insulator, preventing the soil from radiating its heat, accumulated in the summer, and protecting against the invasion of cool air in the spells of late autumn and early spring ground frost, when there is no stabilized snow cover. Additional heat energy, contributing to the favourable thermal conditions of hibernation of cassids, is generated as a result of microbiological processes occurring in this layer.

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STRESZCZENIE

Powyższe badania są kontynuacją zespołowych prac, przeprowadzonych przez Zakład Ochrony Przyrody w latach 1964—1965 na łące *Arrhenatheretum elatioris* i w lesie *Fagetum carpaticum* w Ojcowskim Parku Narodowym („Studia ekosystemów...", 1967).

Przeprowadzano je w latach 1966—1967 na wybranej powierzchni na łące *Arrhenatheretum elatioris* w Dolinie Sąspowskiej (ryc. 1). Skład florystyczny badanej powierzchni przedstawia zdjęcie fitosocjologiczne (tab. I). W okresie od kwietnia do listopada w odstępach 15—30 dniowych obserwowano 4 gatunki tarczyków: *Cassida rubiginosa* MÜLL. i *C. vibex* L. na liściach *Cirsium oleraceum* (ryc. 2), *C. viridis* L. na liściach *Mentha longifolia* i *C. flaveola* THUNBG.

na liściach *Stellaria graminea*. W kolejnych terminach badań przeglądano liście wszystkich okazów roślin *Cirsium oleraceum*, *Mentha longifolia* i *Stellaria graminea* znajdujących się na tej powierzchni, notowano liczebność znajdywanych okazów dojrzałych oraz młodych chrząszczy. W 1967 r. zastosowano dodatkowo znakowanie i powtórny odłów badanych gatunków chrząszczy.

W wyniku przeprowadzonych badań poznano sezonowe wahania liczebności dojrzałych (ryc. 6a, 3b) i młodych (ryc. 7a i b) chrząszczy tarczyków. Stwierdzono, że na wybranej powierzchni *Cassida rubiginosa* MÜLL. występuje bardzo licznie, *C. vibex* L. nielicznie, a *C. viridis* L. i *C. flaveola* THUNBG. rzadko. Metoda znakowania i powtórnego odłowu wykazała, że dojrzałe chrząszcze *Cassida rubiginosa* MÜLL. i *C. vibex* L. reemigrują już w pierwszej połowie kwietnia na łąkę, gdzie znajdują korzystne warunki (tab. II) dla swego rozwoju. Maksimum reemigracji występuje w połowie maja, a zakończenie z początkiem lipca (tab. VI). Dojrzałe chrząszcze giną masowo od połowy maja tak, że z końcem lata nie spotyka się ich w obrębie powierzchni.

Przyczyną migracji młodych chrząszczy na zimowanie w rejony leśne są niskie temperatury występujące na łące już z końcem sierpnia i we wrześniu (tab. III). Migracja młodych chrząszczy tarczyków rozpoczyna się w drugiej połowie sierpnia, intensywnie przebiega we wrześniu i ustaje u *Cassida rubiginosa* MÜLL. z początkiem października, u *C. vibex* L. z końcem tego miesiąca (tab. VII). Znakowanie i powtórny odłów wykazały, że: (1) młode chrząszcze, które wylęgły się najwcześniej, przebywają na powierzchni około 2 miesięcy, (2) okazy, które pojawiły się najpóźniej, przebywają tylko około 2 tygodni. W ciele tarczyków migrujących na zimowanie spada znacznie ilość wody wolnej, następnie wzrasta stopniowo w okresie zimowania (tab. VIII).

Zimowiska tarczyków stwierdzono w lesie grądowym na południowym zboczu Doliny Sąspowskiej (ryc. 1). Zimują one — wyłącznie w stadium imago i w stanie diapauzy — w butwiejącej ściółce przykrytej świeżo opadłymi liśćmi, na głębokości 5—8 cm. Przesiano 320 prób ściółki i znaleziono łącznie 33 zimujące okazy z 6 gatunków tarczyków: *Cassida rubiginosa* MÜLL., *C. vibex* L., *C. viridis* L., *C. flaveola* THUNBG., *C. hemisphaerica* HERBST., *C. nobilis* L. Stwierdzono, że istnieje korelacja dodatnia między grubością warstw ściółki (tab. IX) a występowaniem w niej zimujących chrząszczy (ryc. 1).

Przeprowadzono badania mikroklimatyczne jesienią (20—22. XI. 1967) na łące i w grądzie oraz zimą (5—7. II. 1968) na łące, w grądzie oraz w lesie jaworowym (zbocze północne). Stosunki termiczne powietrza i gleby badanych powierzchni w jesieni przedstawiono przy pomocy termoizoplet na ryc. 3a i 3b, w zimie na ryc. 4a, 4b, 4c. Różnice temperatur powietrza i gleby między łąką i grądem jesienią przedstawiono w tab. IV, zimą w tab. V. Mapkę zalegania pokrywy śnieżnej w dniu 5. II. 1968 r. ilustruje ryc. 5.

Powyższe badania wykazały, że najbardziej korzystne warunki dla zimowania tarczyków występują w grądzie. Uprzywilejowanie grądu przejawiało się w tym, że prawie we wszystkich terminach badań wystąpiły tu wyższe temperatury powietrza i gleby. Ze względu na znaczenie krótsze zaleganie pokrywy śnieżnej i bardzo korzystne usłonecznienie znajdują tarczyki lepsze warunki do zimowania w grądzie niż na łące.

РЕЗЮМЕ

Исследования проведено в 1966—1967 гг. на избранной поверхности луга *Arrhenatheretum elatioris* в Сонсповской Долине в Ойцовском Народном Парке (фиг. 1). Флористический состав исследованной поверхности представляет фитосоциологический снимок (табл. I). В период от апреля до ноября в 15—30 дневных промежутках проведено наблюдения за 4 видами щитоносок: *Cassida rubiginosa* Müll. и *C. vibex* L. на листьях *Cirsium oleraceum* (фиг. 2), *C. viridis* L. на листьях *Mentha longifolia*, а *C. flaveola* Thunbg. на листьях *Stellaria graminea*. В очередных сроках исследований просматривались листья на всех экземплярах растений *Cirsium oleraceum, Mentha longifolia* и *Stellaria graminea,* находящихся на этой поверхности, отмечалась численность найденных зрелых особей, а также молодых жуков. В 1967 г. проведено добавочное мечение и повторный отлов исследованных видов жуков.

В результате проведённых исследований удалось узнать сезонные колебания численности зрелых (фиг. 6а, 6б) и молодых (фиг. 7, а и б) жуков щитоносок. Установлено, что на избранной поверхности, *Cassida rubiginosa* Müll. появляются в большом количестве, *C. vibex* L. в небольшом количестве, а *C. viridis* L. и *C. flaveola* Thunbg. — редко. Метод меток и повторного отлова показал, что зрелые особи жуков *Cassida rubiginosa* Müll. и *C. vibex* L. повторно эмигрируют уже в первой половине апреля на луг, где находят благоприятные условия (табл. II) для своего развития. Максимум реэмиграции наступает в половине мая, а окончание в начале июля (табл. VI). Зрелые жуки массово погибают так, что в конце лета они не встречаются на этой поверхности.

Причиной миграции молодых жуков на зимовку в лесные районы являются низкие температуры, отмеченные на лугу уже в конце августа и в сентябре (табл. III). Миграция молодых жуков щитоносок начинается во второй половине августа, интенсивно пробегает в сентябре и останавливается у *Cassida rubiginosa* Müll. в начале октября, у *C. vibex* L. в конце этого месяца (табл. VII). Разметка и повторный отлов показали, что: (1) молодые жуки, которые появились раньше всех, находятся на пробной поверхности около 2 месяцев, (2) особи, которые появились позже всех, находятся на поверхности только около 2 недель. В теле щитоносок, мигрирующих на зимовку, значительно понижается количество свободной воды, а затем постепенно повышается в период зимовки (табл. VIII).

Зимовки щитоносок установлено в лиственном смешанном лесу *(Tilio-Carpinetum)* на южном склоне Долины Сонсповской (фиг. 1). Зиму проводят они — исключительно в стадии имаго и в состоянии диапаузы — в гниющей подстилке

(прикритой свежеопавшими листьями) на глубине 5—8 см. Просеяно 320 проб подстилки и найдено в сумме 33 зимующие особи из 6 видов щитоносок: *Cassida rubiginosa* Müll., *C. vibex* L., *C. viridis* L., *C. flaveola* Thunbg., *C. hemisphaerica* Herbst, *C. nobilis* L. Установлено существование положительной корреляции между толщиной слоёв подстилки (табл. IX) и присутствием в ней зимующих жуков (фиг. 1).

Проведено микроклиматические исследования осенью (20—22. XI. 1967) на лугу и в лиственном смешанном лесу, а также зимой (5—7. II. 1968) на лугу, в лиственном смешанном лесу и в платановом лесу (на северном склоне). Термические соотношения воздуха и почвы, исследованных поверхностей, осенью представлено на термоизоплетах (фиг. 3а и 3б), зимой на фиг. 4а, 4б, 4ц. Разницы температур воздуха и почвы между лугом и лиственным смешанным лесом осенью показано в табл. IV, зимой в табл. V. Карту снежного покрова 5. II. 1968 г. показано на фиг. 5.

Вышеупомянутые исследования доказали, что наиболее благоприятные условия для зимовки щитоносок были в лиственном смешанном лесу. Привилегирование лиственного смешанного леса проявлялось тем, что почти во всех сроках исследований здесь отмечено более высокие температуры воздуха и почвы. Так как в лиственном смешанном лесу снежный покров лежит короче и инсоляция лучщая, щитоноски находят лучшие условия для зимовки в лиственном смешанном лесу чем на лугу.

ERRATA

Page Strona	Line Wiersz	Instead of Jest	Read Ma być
316	13	в климатическими	с климатическими
319	1	ofv alley	of valley
338	7	(ryc. 6a, 3b)	(ryc. 6a, 6b)
338	14	z końcem lata nie spotyka się ich	z końcem lata prawie nie spotyka się ich
339	26	в конце лета они не встречаются	в конце лета они почти не встречаются

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