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Morphological differentiation of *Limnozetes* Hull, 1916 (Acari: Oribatida: Limnozetidae) in the light of ontogenetic studies

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ABSTRACT. Morphological variability of *Limnozetes* Hull, 1916 was investigated in light of the ontogeny of *L. lustrum* Behan-Pelletier, 1989 and *L. rugosus* (Sellnick, 1923). The adults of this genus are similar, but the nymphs are differentiated, either boat-shaped, with thick and stiff posterior gastronotal setae and rather smooth cuticle, as in *L. lustrum*, or stocky, with thin gastronotal setae and plicate cuticle, as in *L. rugosus*. The adult of *L. lustrum* has ten pairs of notogastral setae, while that of *L. rugosus* has 10 or 11 pairs, which is noted here for the first time in *Limnozetes* and has phylogenetic importance. The morphology of juvenile stages of presented species has not been investigated so far. Moreover *L. lustrum* is recorded for the first time from Europe. Morphological groups within *Limnozetes* are proposed: '*ciliatus* group', with *L. lustrum* and '*rugosus* group', with *L. rugosus*.

KEY WORDS: semi-aquatic Oribatida, *Limnozetes lustrum* Behan-Pelletier, 1989, *L. rugosus* (Sellnick, 1923), setation, juvenile stages, ontogeny

INTRODUCTION

Oribatid mites of the genus *Limnozetes* Hull, 1916 are typically found in transitional, semi-aquatic habitats (BEHAN-PELLETIER, 1989), mainly in wet bogs and at edges of lakes with *Sphagnum*; but also in other mosses and wet meadows. These mites are rather small (270-390µm), but usually abundant, with adults dominating in extracted samples. For example, *L. lustrum* Behan-Pelletier, 1989 reached a density 312 indiv. per 1000cm^3 at the edge of forest lake Bagno Chlebowo (Wielkopolska National Park, Poland, August 19th 2007), with a small fraction (9.4%) being juveniles, while *L. rugosus* (Sellnick, 1923) reached a similar density (367 indiv. per 1000cm^3) at the edge of a small lake in Finse (Norway, September 8th 2006), but its juveniles comprised 36% of the individuals.

Limnozetes has modest species diversity. Of the 14 named species, SUBÍAS (2004) listed only four of them and one subspecies from Europe: *L. amnicus* Behan-Pelletier, 1989, *L. ciliatus* (Schrank, 1803), *L. onondaga* Behan-Pelletier, 1989, *L. rugosus*, and *L. ciliatus foveolatus* Willmann, 1939. WEIGMANN & DEICHSEL (2006) included only three species (*L. amnicus*, *L. ciliatus* and *L. rugosus*) in their key to German fauna. OLSZANOWSKI et al. (1996) recorded two species and one subspecies (*L. ciliatus*, *L. rugosus* and *L. ciliatus foveolatus*) from Poland, but *L. palmerae* Behan-Pelletier, 1989 was subsequently added by SENICZAK et al. (2007), and *L. lustrum* is added here to the Polish and European fauna.

The diagnoses of most *Limnozetes* species are based exclusively on the morphology of adults, which are sometimes strikingly similar to each other and therefore are not easily differentiated. The diagnosis of the type species, *L. ciliatus* (Schrank, 1803) is old, brief and confusing, while the diagnoses of other species have been successively more detailed (three species were described between 1923-1939 and ten species between 1961-1989). For example, BEHAN-PELLETIER (1989) described in detail eight new species from north-eastern North America and diagnoses of six species included the juveniles as well. She described and illustrated the tritonymph of *L. latilamellatus* Behan-Pelletier, 1989, *L. guyi* Behan-Pelletier, 1989, *L. borealis* Behan-Pelletier, 1989, *L. onondaga*, *L. palmerae* and *L. amnicus*, and gave measurements of the other juvenile stages of most species, and ontogeny of leg setation of *L. guyi* and *L. onondaga*. Based on the morphology of adults and juveniles, BEHAN-PELLETIER (1989) gave also a new diagnosis of *Limnozetes*, which indicated that the juveniles differ distinctly from the adults. That is why two morphological groups of nymphs can be distinguished: (1) with a wide gastronotum and stocky body, strongly plicate cuticle and thin gastronotal setae, and (2) with more slender gastronotum and boat-shaped body, weakly plicate cuticle and blade-like setae on the posterior part of the gastronotum. The former group is represented by *L. latilamellatus*, *L. guyi* and *L. borealis*, and the latter group by *L. onondaga*, *L. palmerae* and *L. amnicus*.

In a group of the other species of *Limnozetes*, the morphology of a nymph of *L. ciliatus* was investigated and illustrated by MICHAEL (1880); it is boat-shaped, with rather thick and stiff peripheral setae on the gastronotum, and rather smooth cuticle. HAARLØV (1957) described a purported tritonymph of *L. rugosus*, but the mite was wrongly determined; it belongs to *Zetomimus furcatus* (Pearce and Warb., 1906), which has non-plicate cuticle, three pairs of rather long setae in posterior part of gastronotum, and a unique combination of furrows in this region transverse and longitudinal ones in the shape of the letter T - as shown by SHALDYBINA (1969, 1975) and WEIGMANN & DEICHSEL (2006).

This paper aims to investigate the morphological differentiation of *Limnozetes* by comparing the morphology of adult and all juvenile stages. Moreover ontogeny of *L. lustrum* and *L. rugosus*, species from two different morphological groups of *Limnozetes* (BEHAN-PELLETIER,

1989) is compared. The juvenile stages of these species are described and illustrated for the first time, and new diagnoses of species, with morphological characters of juveniles, are given. This study may, therefore, be helpful in the recognition of species in ecological studies, providing more precise diagnoses, and in further studies on phylogeny of oribatid mites.

MATERIALS AND METHODS

The juvenile stages and adults of *L. lustrum* were collected on the 19th of August 2007 from *Sphagnum* at the edge of forest lake Bagno Chlebowo (53°44'17"N, 16°45'26"E, 65m a. s. l.) in the Wielkopolska National Park, Poland, where this species was numerically more abundant than *L. palmerae*. The juvenile stages and adults of *L. rugosus* were collected from *Sphagnum* at the edge of a small lake in Finse (60°35'17"N, 7°30'18"E, 1245m a. s. l.), Norway, where this species was the only member of *Limnozetes*. The description of morphology and drawings of *L. lustrum* include the dorsal aspect of the larva and tritonymph, anal region of the larva and anogenital region of all nymphal stages, where new segments and setae appear during ontogeny; marginal part of gastronotum of *L. ciliatus* is also illustrated. Whereas fundamental aspects of ontogeny are similar in both species, the description of morphology and drawings of *L. rugosus* are limited to the dorsal aspect of the larva and tritonymph, the anal region of the larva and the anogenital region of the tritonymph. The adults of both species are also investigated to document the full development of setation during ontogeny. Illustrations were prepared from individuals mounted on slides. Terminology used follows that of F. GRANDJEAN, developed in papers referenced by TRAVÉ & VACHON (1975).

RESULTS

Limnozetes lustrum Behan-Pelletier, 1989

Diagnosis

Adult (Fig. 1) is well diagnosed by BEHAN-PELLETIER (1989). Setae *ro* and *le* long and rather thick, seta *in* shorter and thin, seta *ex* small, usually covered by large, oval pedotectum 1 (*pd1*). Bothridium well-developed, sensillus (*ss*) short, clavate, tutorium (*tu*) present. Notogaster with ten small setae, including pair c_2. Pteromorph longer than wide (Fig. 2A). Cupule *ia* between setae *la* and c_2, cupule *im* posterior to seta c_2, cupule *ip* between setae h_1 and p_1, cupule *ih* anterior and cupule *ips* ventrolateral to seta p_3; opisthonotal gland opening (*gla*) between seta h_3 and cupule *ih*. Formulae of legs setae (trochanter to tarsus) and solenidia are: I - 1-4-(3+1)-(4+2)-(15+2); II - 1-4-(3+1)-(4+1)-(14+2); III - 2-3-(1+1)-(3+1)-14; VI - 1-2-2-(3+1)-11; all legs tridactylous. In mites mounted on slides solenidia ω_1 and ω_2 on tarsus I usually separated in distal parts (Fig. 3A).

Juveniles oval, body flesh-colored, cuticle of prodorsum and gastronotum rather smooth, with few plicae. Prodorsum triangular, setae *le* and *in* barbed and pointed, seta *ro* thinner and shorter than setae *le* and *in*, seta *ex* short. Sensillus long, setiform. Larva with 12 pairs of gastronotal setae, similar in shape to seta *in*, while nymphs with 15 pairs of these setae; posterior marginal setae thicker, stiffer and slightly longer than other gastronotal setae.

Morphology of juvenile stages

Prodorsum of larva (Fig. 4) triangular, cuticle rather smooth, with few folds in lateral and posterior part. Seta *ro* rather small and smooth, but setae *le* and *in* longer, stiff and barbed, seta *ex* minute. Bothridium weakly developed, sensillus long, setiform.

Gastronotum with few folds in anterior part, and 12 pairs of setae, including setae h_2 and h_3 positioned near paraproctal valves (Fig. 5A). All setae barbed and rather stiff, except for seta h_3, which is small and smooth; length increases from seta c_1 to h_1; seta h_2 shorter than h_1. Paraproctal valves (segment PS) glabrous. Cupule *ia* posterior to seta c_3, cupule *im* slightly laterally between setae *la* and *lm*, cupule *ip* between setae h_1 and h_2, gland opening *gla* between setae *lp* and h_3. Gastronum slightly wrinkled.

Nymphs slimmer than larva, boat-shaped and flesh-colored. Number of prodorsal setae as in larva, but gastronotum with 15 pairs: pseudanal setae (p_1-p_3) appear in protonymph (Fig. 5B) and remain through ontogeny; seta p_1 thick, stiff, pointed, like seta h_1, other setae thin; all setae smooth or with few barbs. Genital valves of protonymph with one pair of small setae, two pairs are added in deutonymph (Fig. 6A) and two more pairs in tritonymph (Fig. 6B). In deutonymph one pair of small aggenital setae (*ag*) appears posterolateral to genital valves, and three pairs of small adanal setae (ad_1-ad_3) appear on segment AD; all setae small and smooth. Paraproctal atrichosy to proto- and deutonymph, but tritonymph with two pairs of small setae. In nymphs cupules *ia* and *im* as in larva, cupule *ip* slightly laterally positioned between setae h_1 and p_2, while cupules *ih*, *ips* and *iad* lateral to anterior part of paraproctal valves of proto-, deuto- and tritonymph, respectively, each successively pushed laterally during ontogeny. Gland opening *gla* posterolateral to cupule *ih*. Anogenital region of nymphs slightly wrinkled.

Dorsal aspect of all nymphs is shown in Fig. 7 (tritonymph). Prodorsum with few folds in lateral and posterior part, gastronotum with rare folds, mainly between setae c_1 and *dp*. Bothridium and sensillus generally as in larva, central gastronotal setae (c_1 and *d*-series) thin but other setae thick and stiff; all setae smooth; setae c_3, *l*- and *h*-series and p_1 assume peripheral position on gastronotum (Fig. 8A). Prodorsal and gastronotal setae of nymphs of *L. lustrum* relatively shorter than in larva. Setae *l* on tibia I and seta *ft* 'on tarsus I thick and rather short; in mites mounted on slides solenidia ω_1 and ω_2 usually separated in distal part (Fig. 9A).

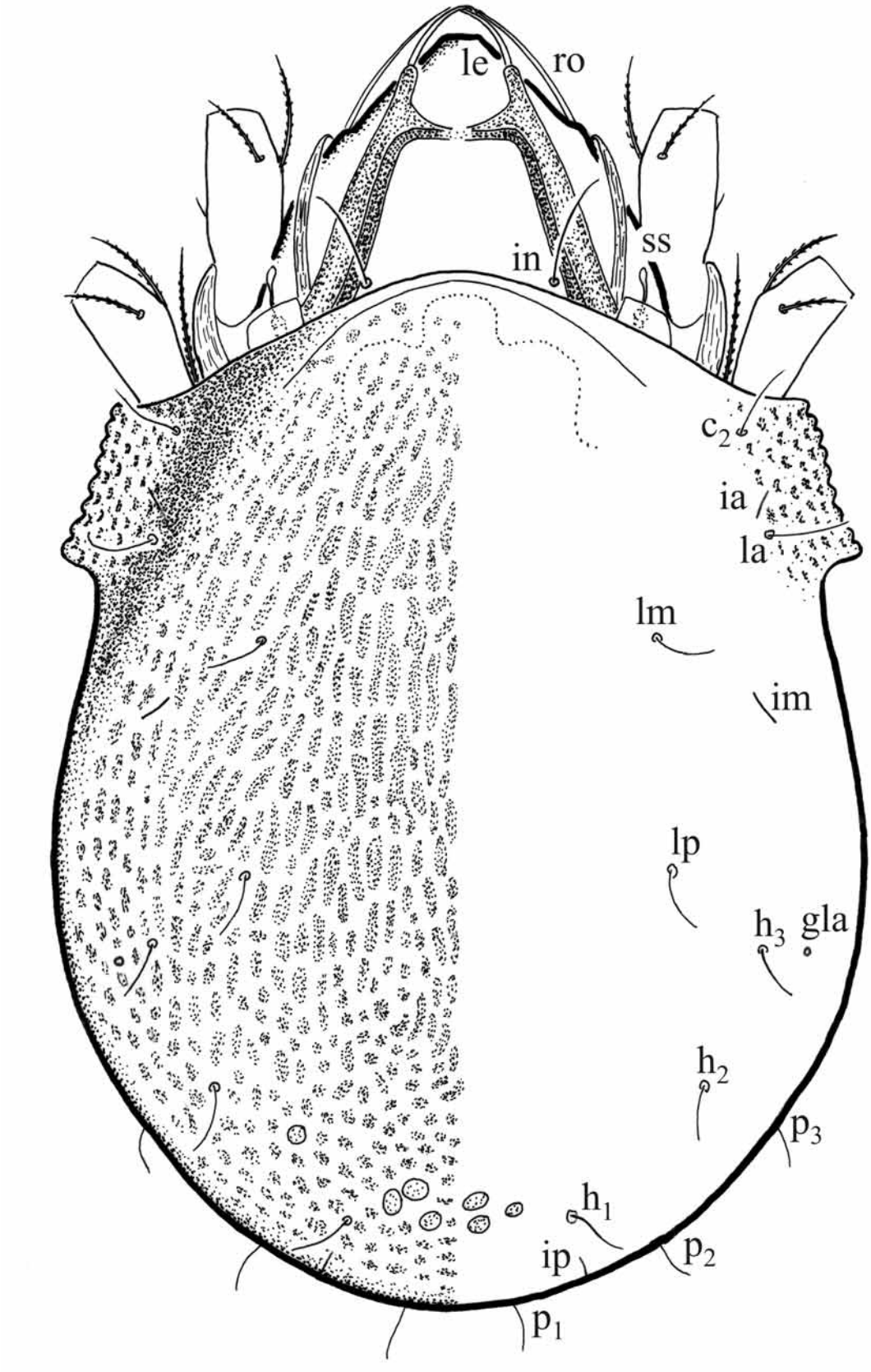

Fig. 1. *Limnozetes lustrum*, adult, dorsal aspect (legs partially drawn).

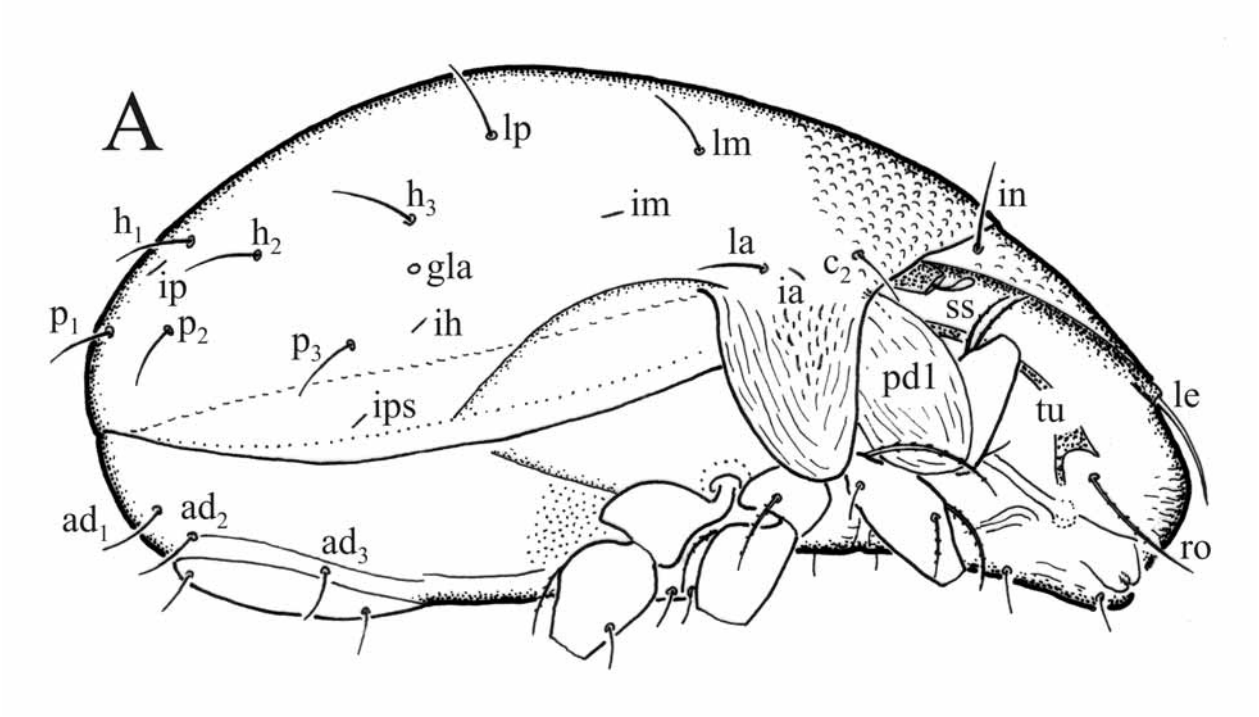

Fig. 2. – Lateral aspect of adult (legs partially drawn): A - *Limnozetes lustrum*,

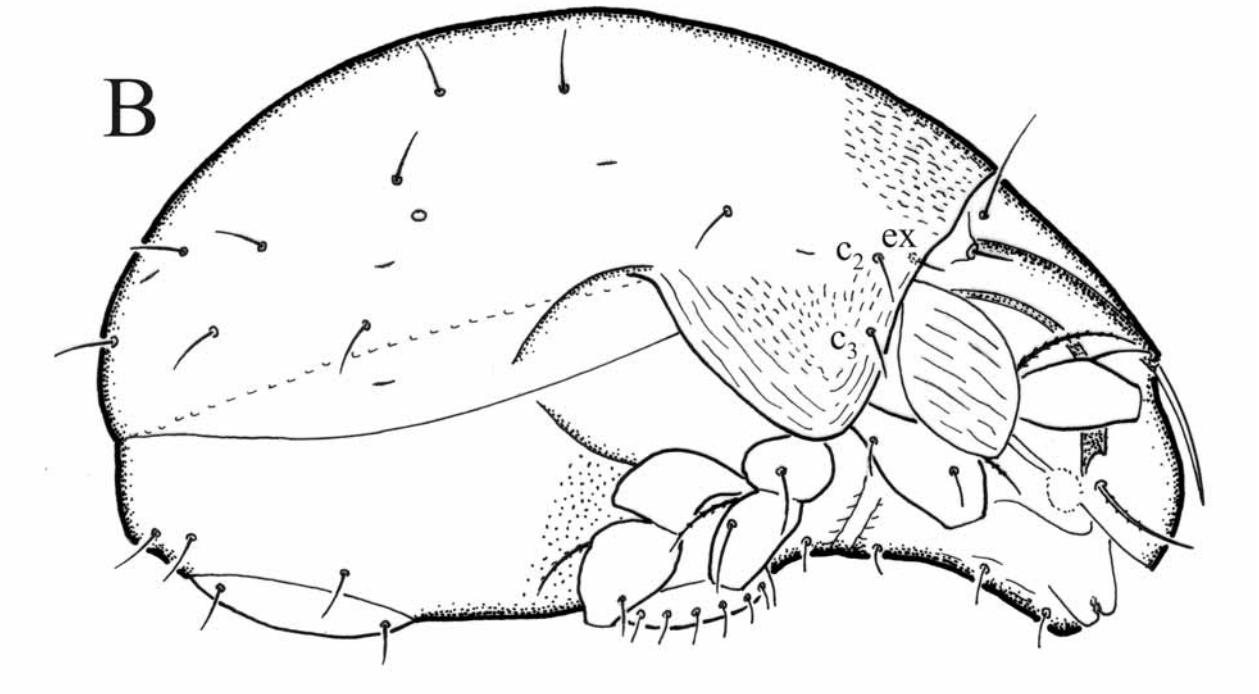

Fig. 2. – Lateral aspect of adult (legs partially drawn): B - *L. rugosus*.

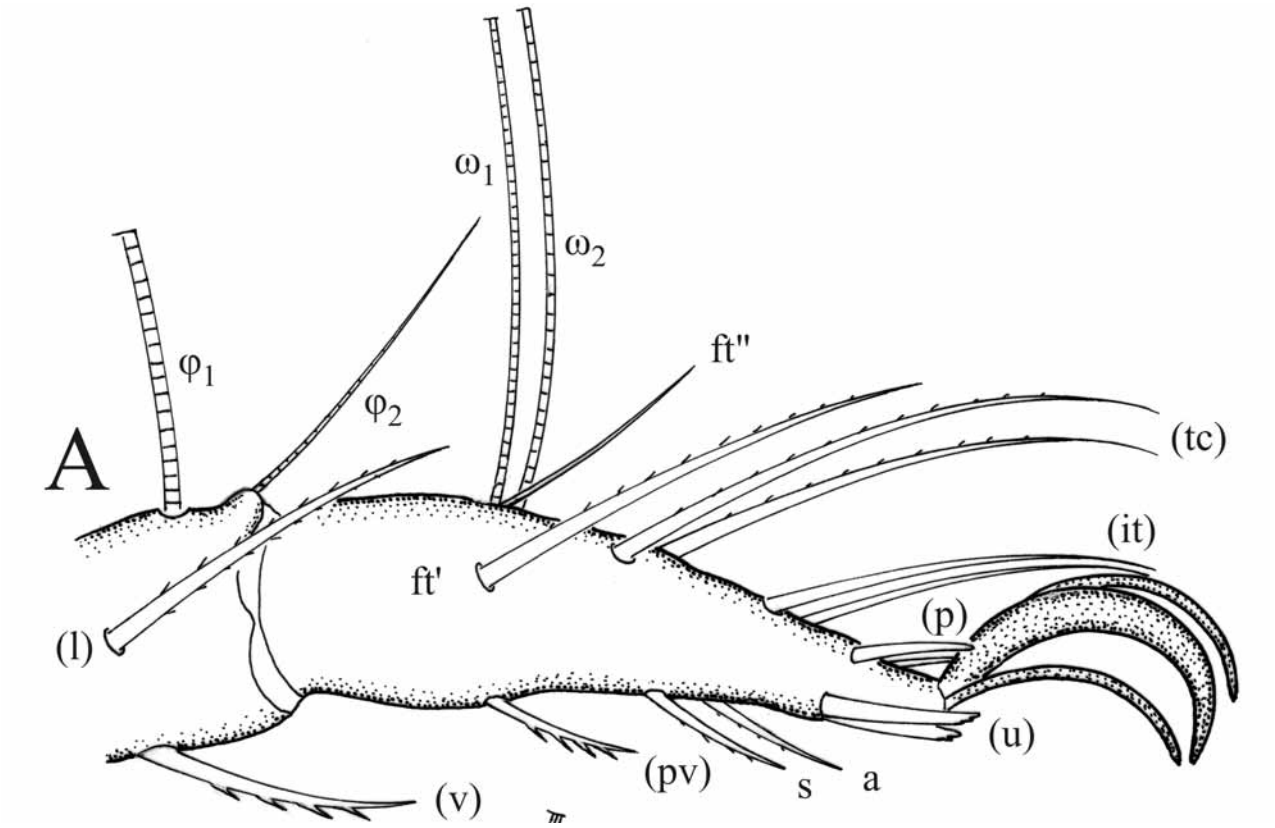

Fig. 3. – Tarsus I of adult, antiaxial aspect: A - *Limnozetes lustrum*.

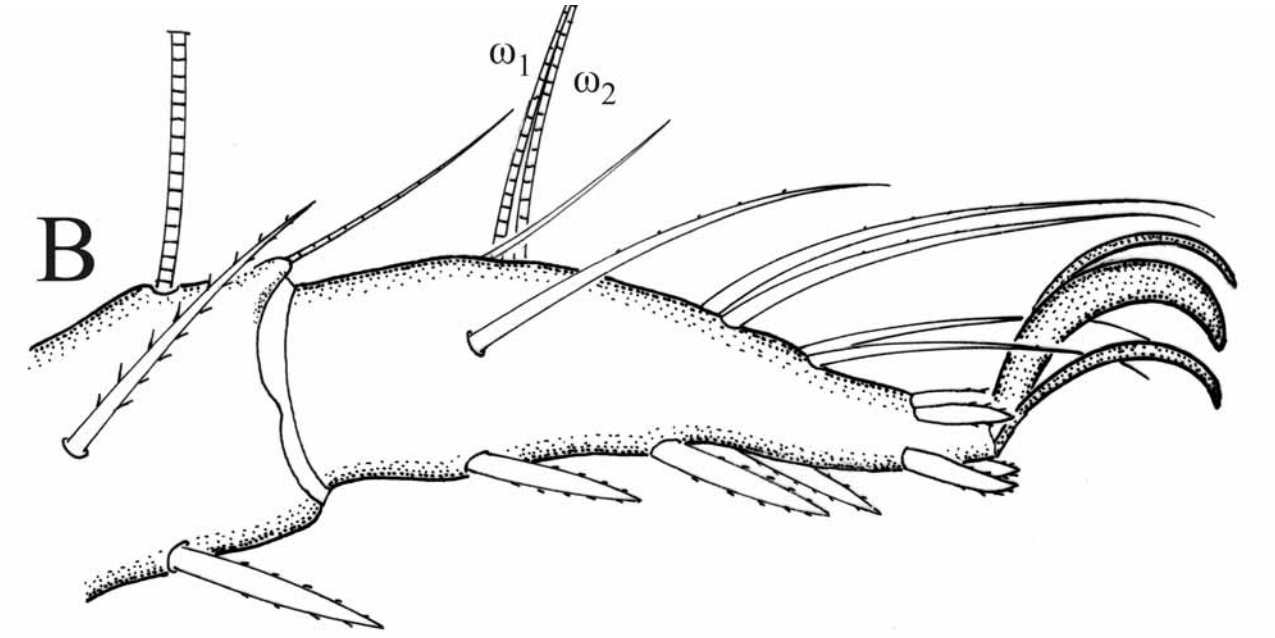

Fig. 3. – Tarsus I of adult, antiaxial aspect: B - *L. rugosus*; pairs of setae in parentheses, some setae are not illustrated.

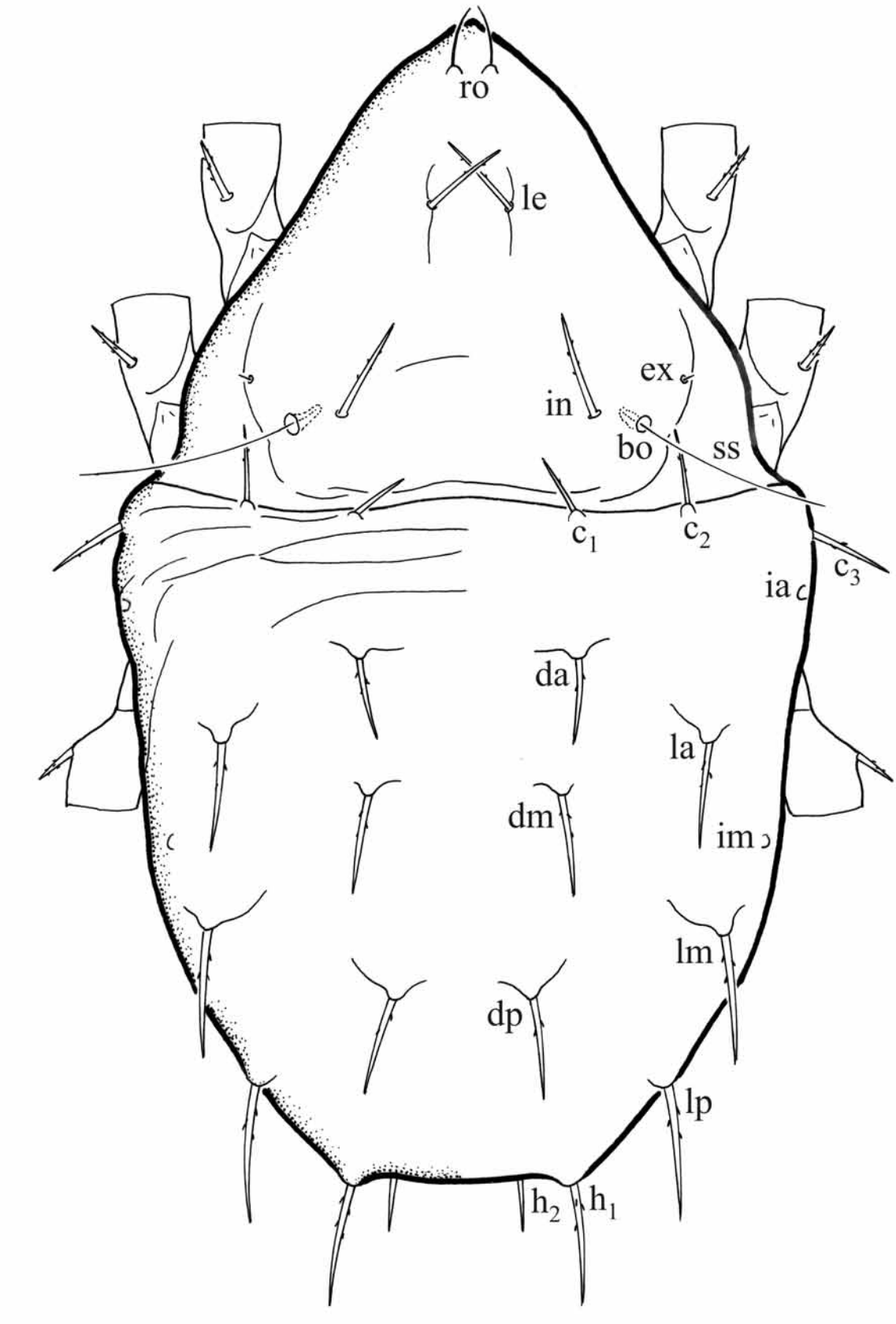

Fig. 4. – *Limnozetes lustrum*, larva, dorsal aspect (legs partially drawn).

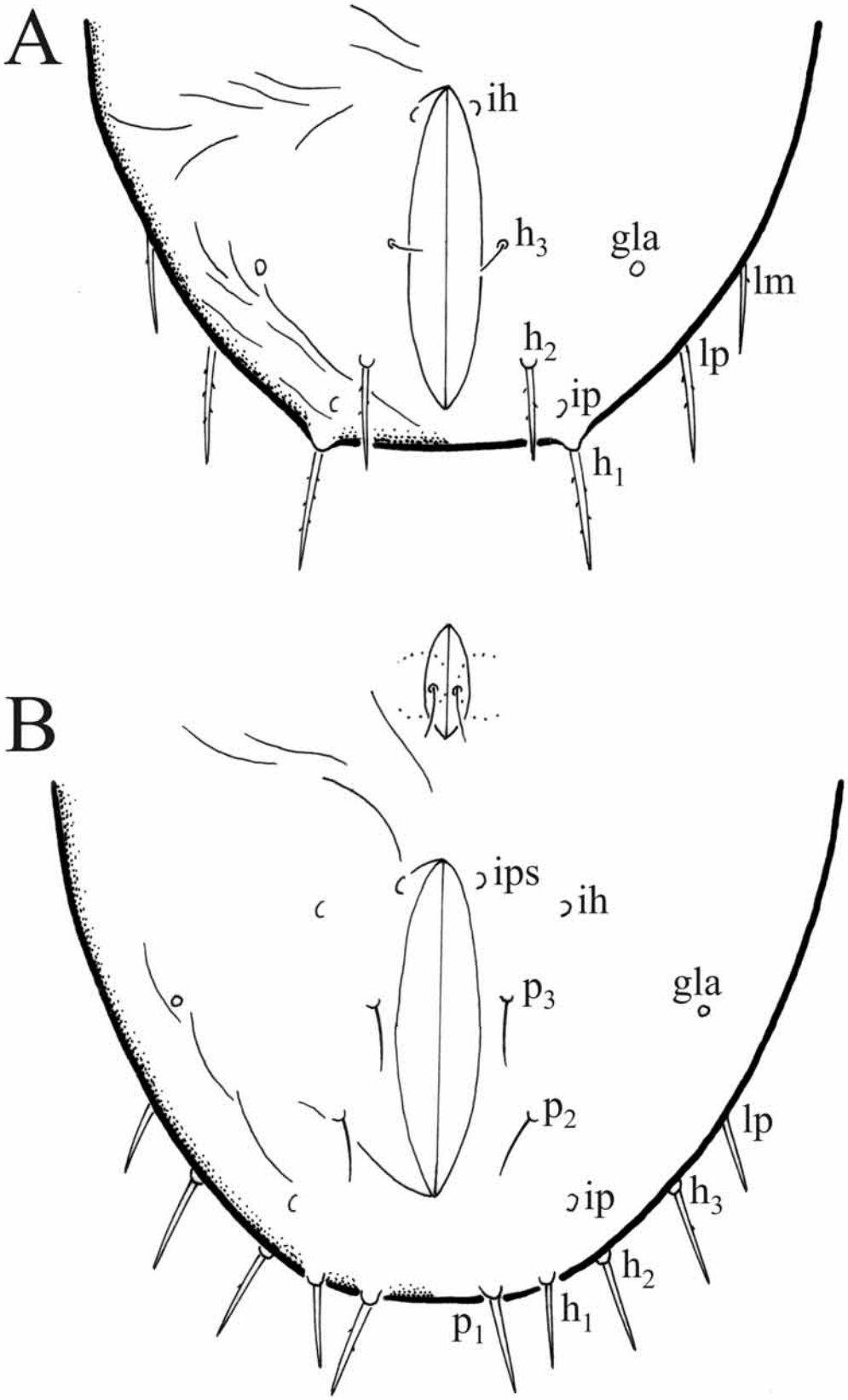

Fig. 5. – *Limnozetes lustrum*: A - anal region of larva, B - anogenital region of protonymph.

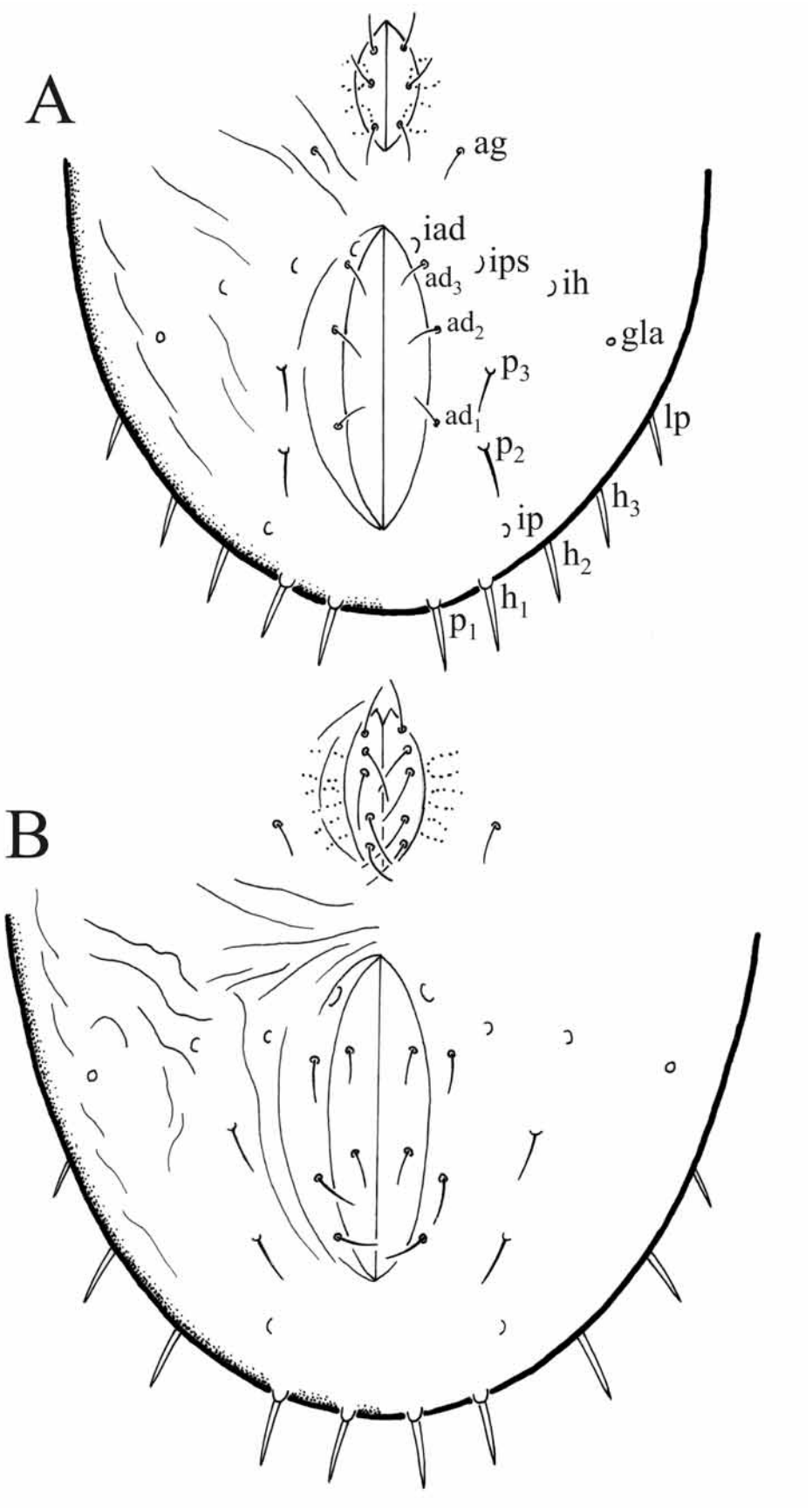

Fig. 6. – *Limnozetes lustrum*, anogenital region: A - deutonymph, B - tritonymph.

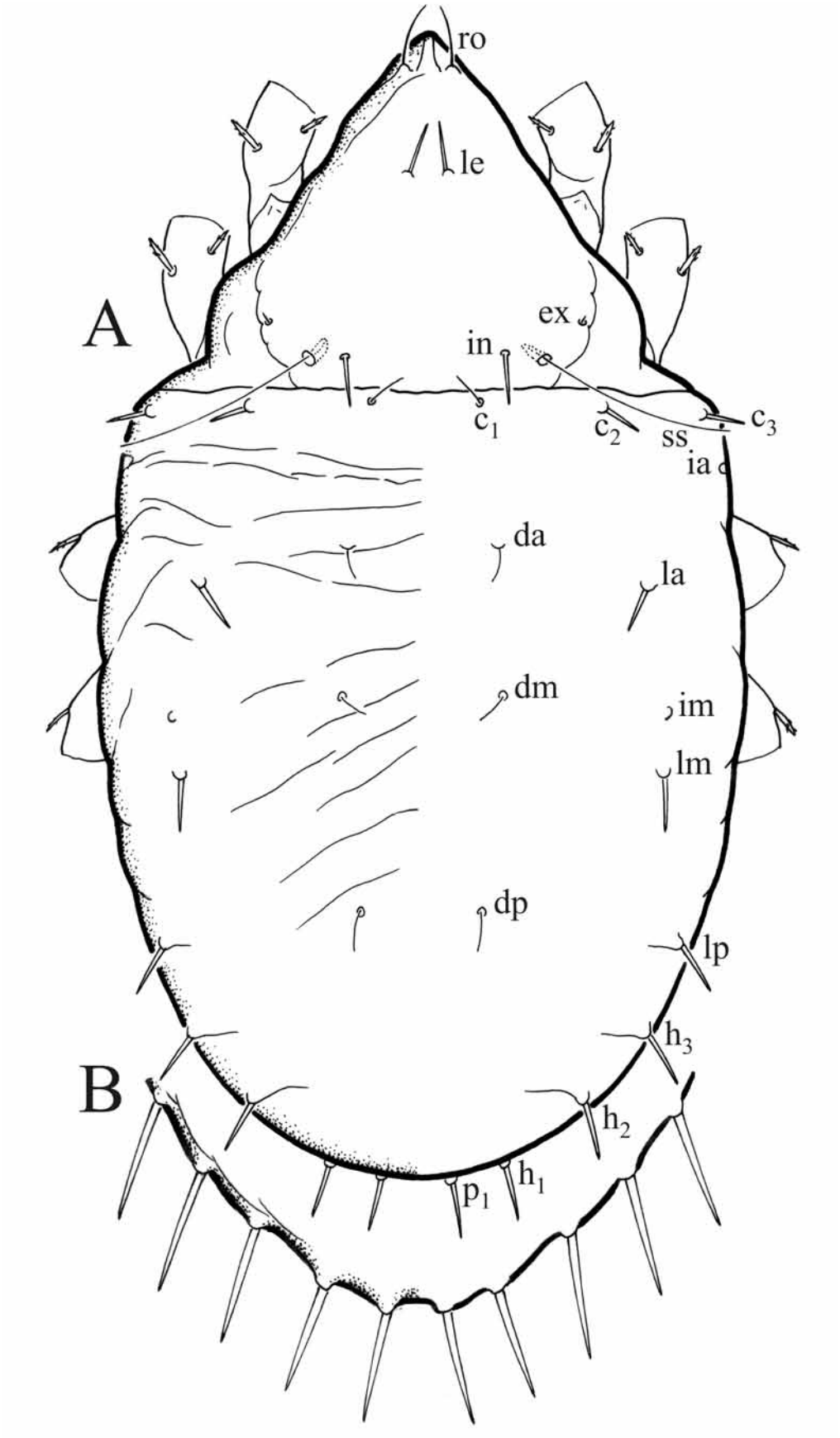

Fig. 7. – Tritonymph, dorsal aspect: A - *Limnozetes lustrum*, B - *L. ciliatus*, marginal part of gastronotum.

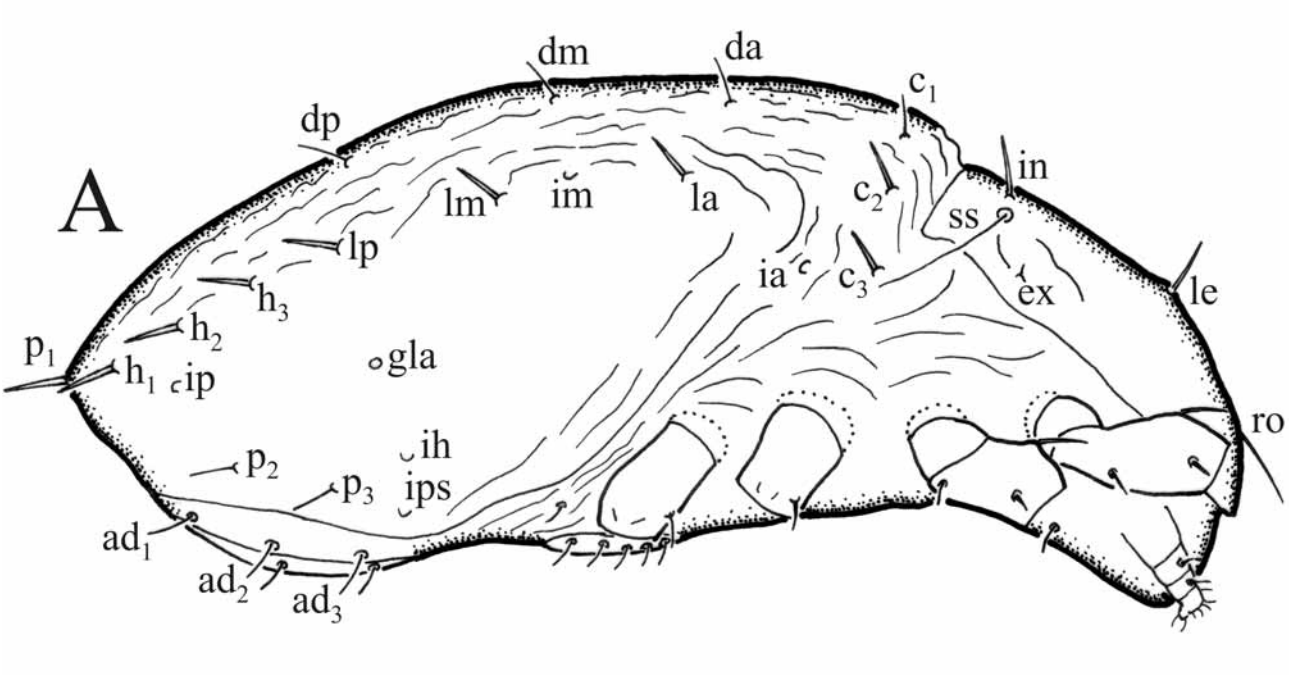

Fig. 8. – Lateral aspect of tritonymph (legs partially drawn): A - *Limnozetes lustrum*.

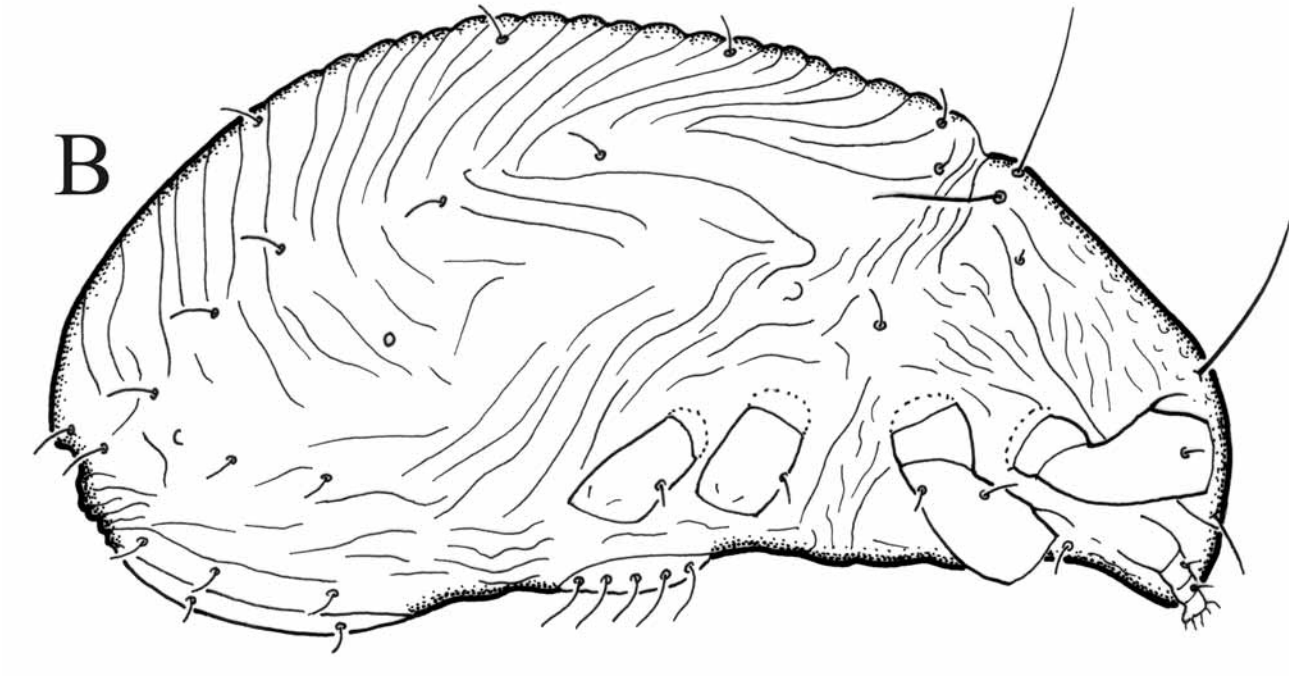

Fig. 8. – Lateral aspect of tritonymph (legs partially drawn): B - *L. rugosus*.

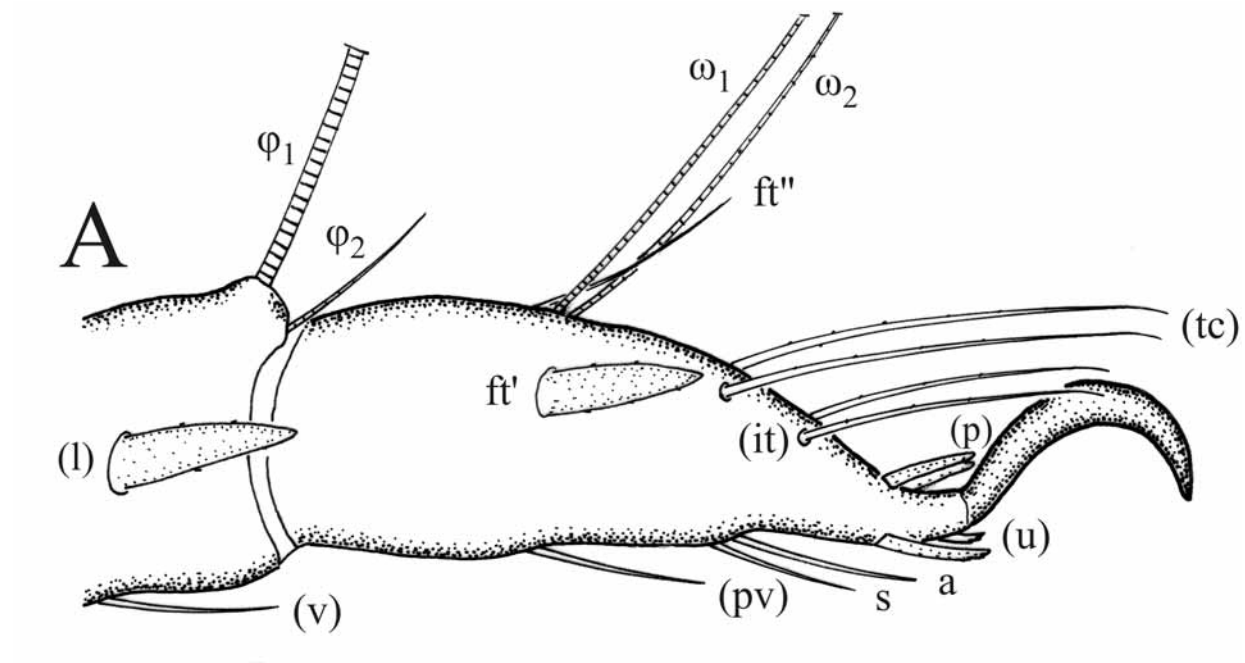

Fig. 9. – Tarsus I of tritonymph: A - *Limnozetes lustrum*, antiaxial aspect.

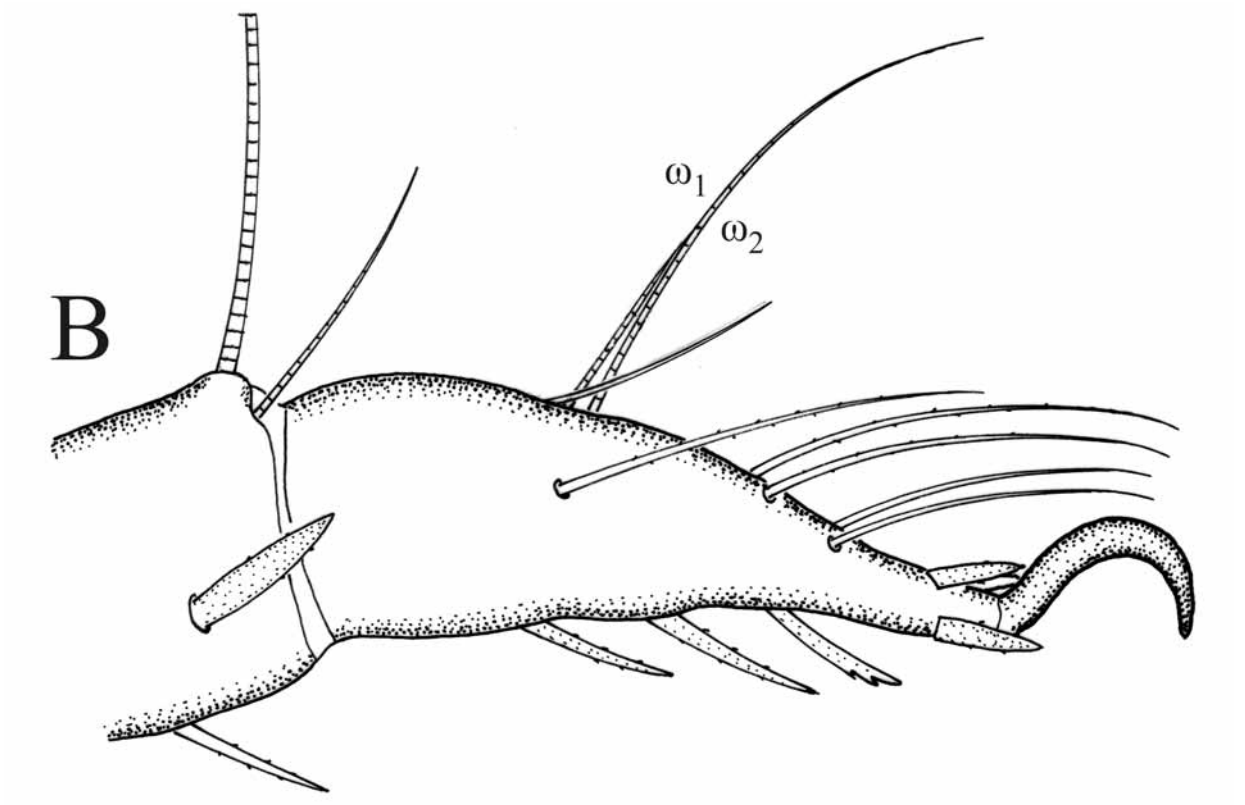

Fig. 9. – Tarsus I of tritonymph: B - *L. lustrum*, region of solenidia, C - *L. rugosus*, antiaxial aspect; pairs of setae in parentheses, some setae are not illustrated.

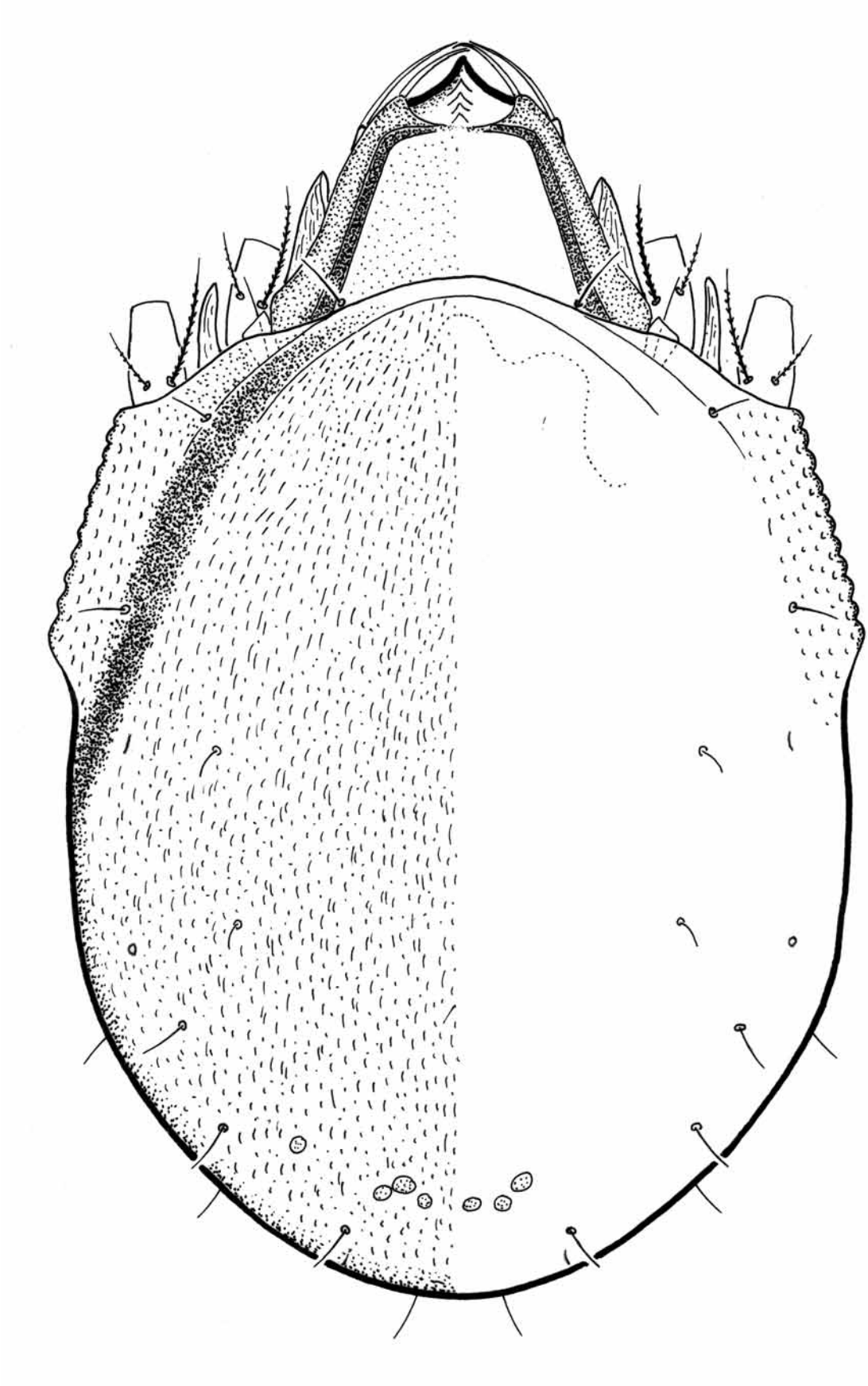

Fig. 10. – *Limnozetes rugosus*, adult, dorsal aspect (legs partially drawn).

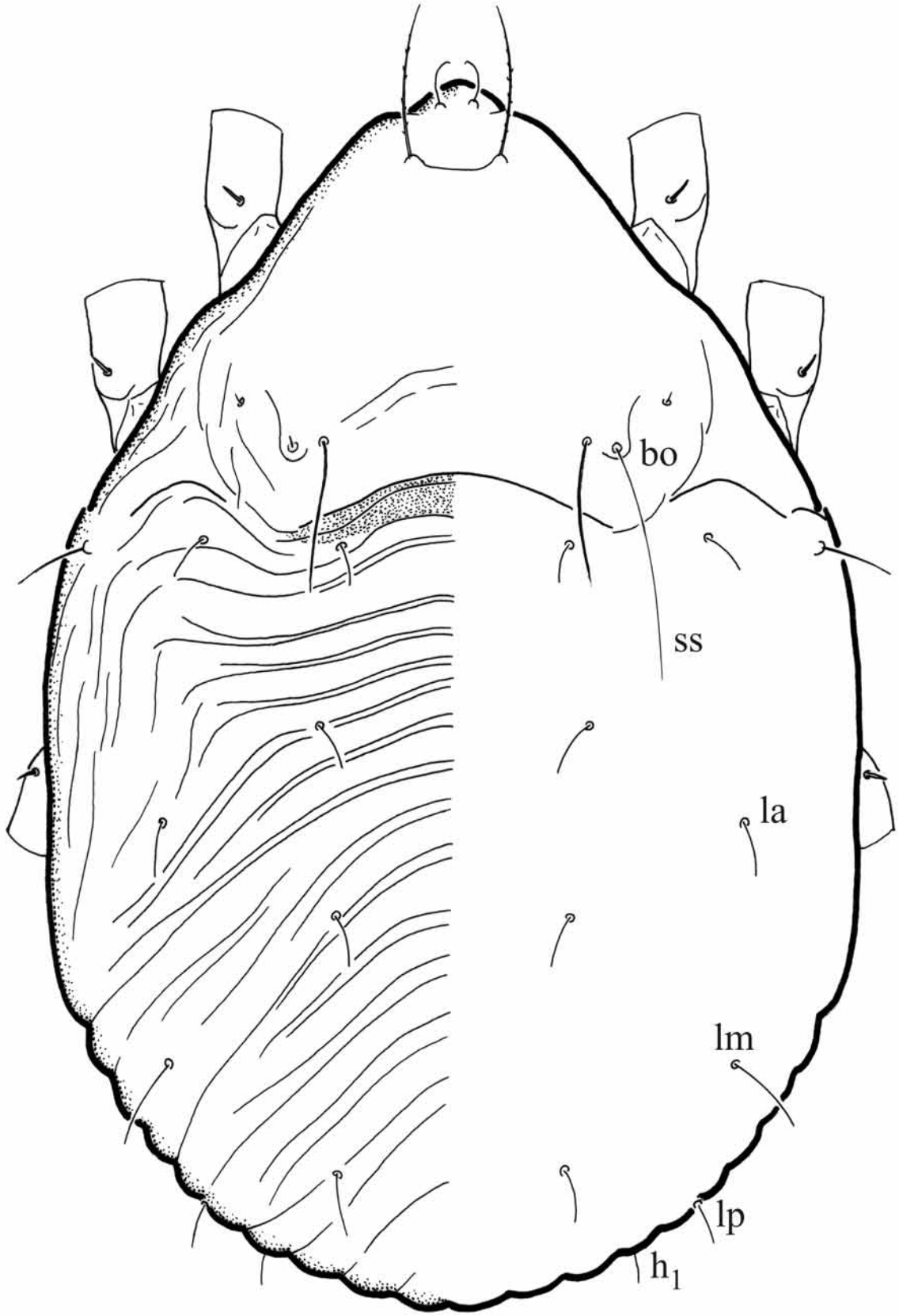

Fig. 11. – *Limnozetes rugosus*, larva, dorsal aspect (legs partially drawn).

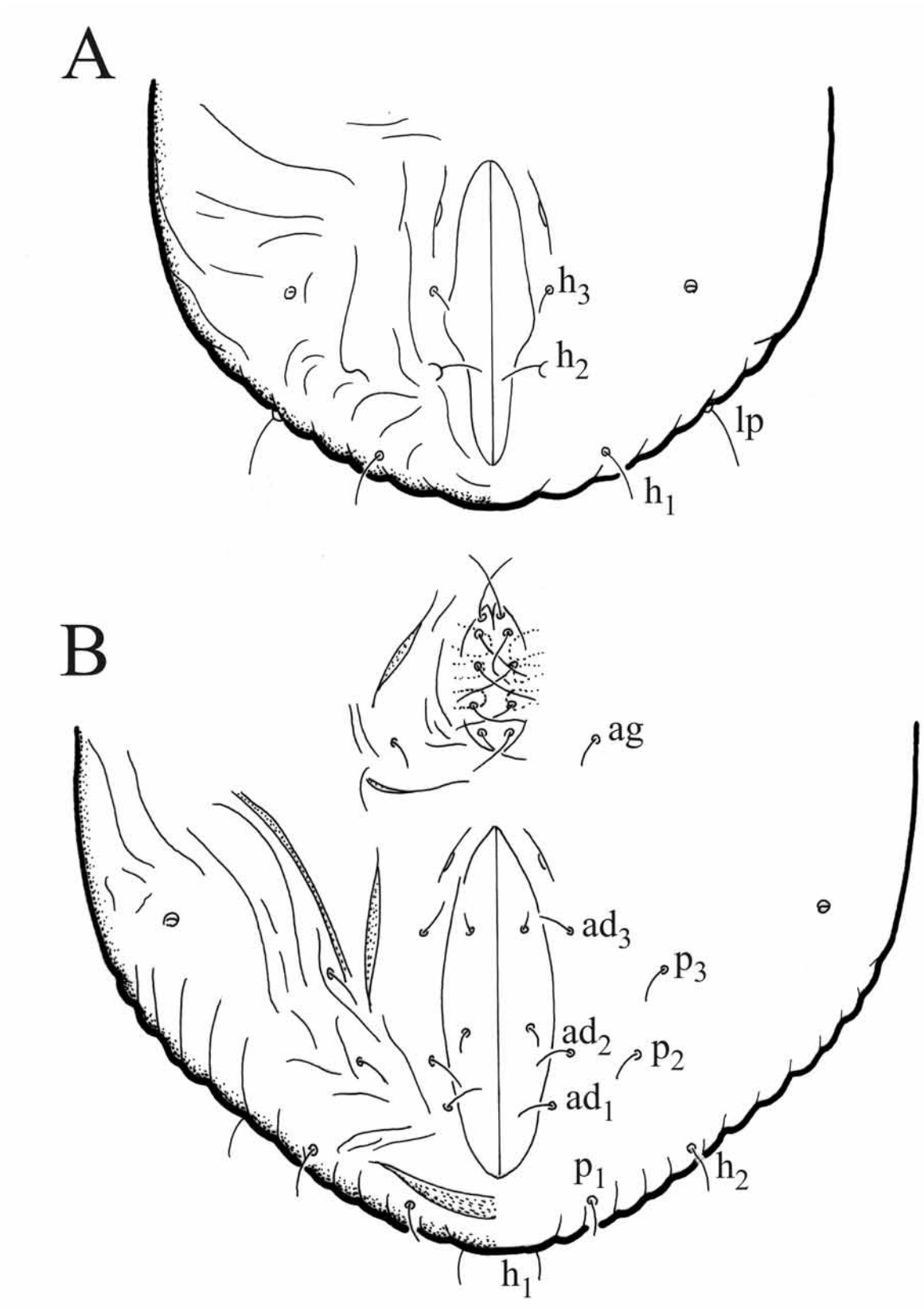

Fig. 12. – *Limnozetes rugosus*: A - anal region of larva, B - anogenital region of tritonymph.

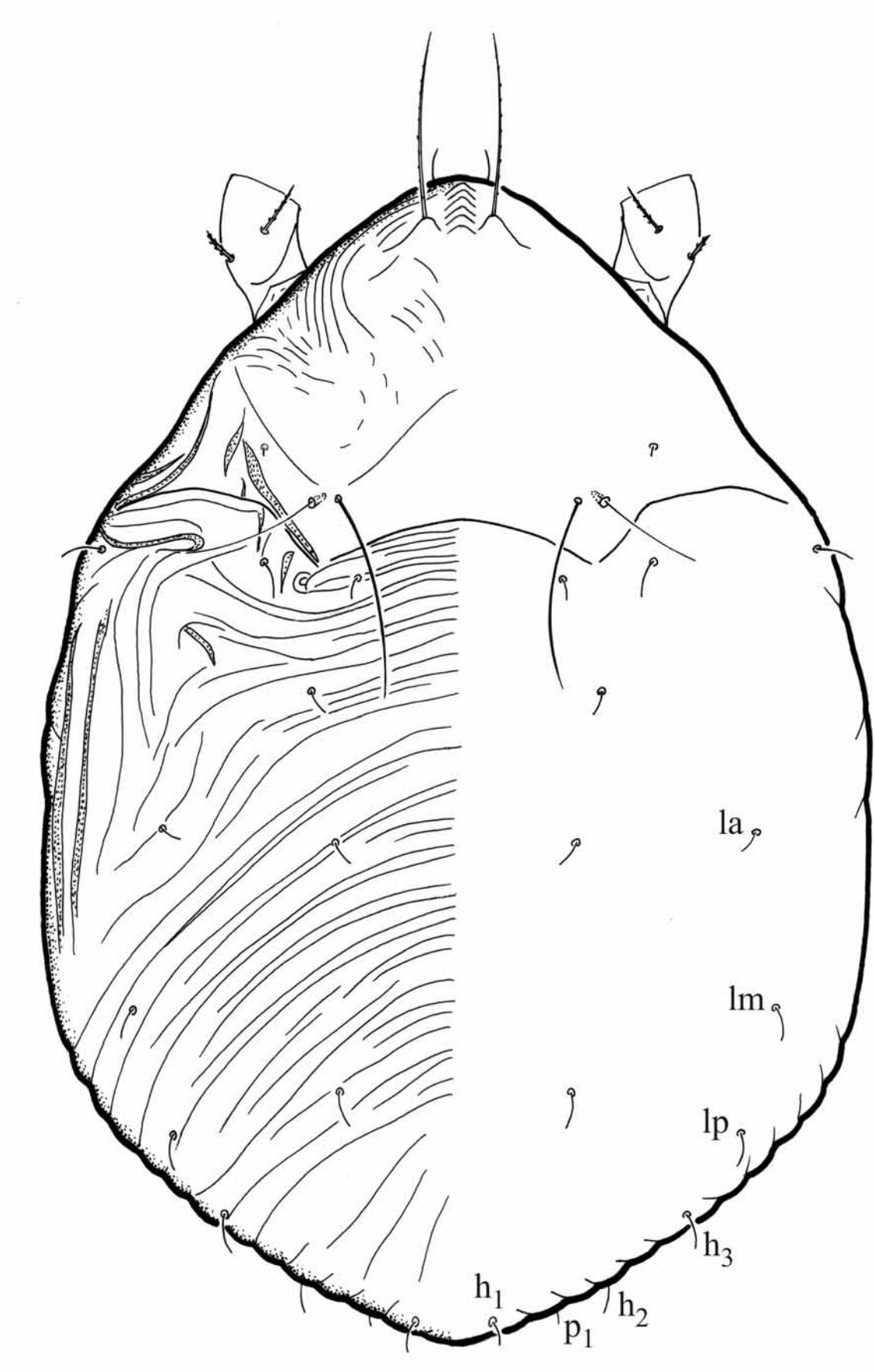

Fig. 13. – *Limnozetes rugosus*, tritonymph, dorsal aspect (legs partially drawn).

Summary of ontogenetic transformations

The numbers of setae on the prodorsum remain similar during ontogeny, but in the adult setae *ro*, *le* and *in* are distinctly longer than in the juveniles. In the juveniles the bothridium is weakly developed, with long, setiform sensillus, while it is well developed in the adult, with a short, clavate sensillus. During ontogeny the number of gastronotal setae increases from 12 pairs in the larva to 15 pairs in the nymphs, but the adult loses the *d*-series setae and two pairs of *c*-series setae, compared to the tritonymph, leaving only seta c_2, so the total number of notogastral setae is 10 pairs.

The gastronotal formula of *L. lustrum* (larva to adult) is 12-15-15-15-10, and is consistent with GRANDJEAN (1949), the formula of genital setae is 1-3-5-6 (protonymph to adult), and the formula of aggenital setae is 0-0-1-1-1 (larva to adult). The setal formula of segments PS-AN is 03333-0333-022, respectively, and is consistent with GRANDJEAN (1949), while that of paraproctal setae is 0-0-0-2-2 (larva to adult). The formula of coxisternal setae is 3-1-2 (larva), 3-1-2-1 (protonymph), and 3-1-2-2 (deutonymph, tritonymph and adult). In the larva, seta *1c* is scaliform and covers Claparéde's organ (GRANDJEAN, 1963).

Distribution and ecology

Limnozetes lustrum has been considered a northern Nearctic species (SUBÍAS, 2004), but instead it seems to be a Holarctic species. It lives in wet *Sphagnum* bogs (BEHAN-PELLETIER, 1989), but in Poland inhabits edges of lakes with *Sphagnum* and seems to be common in Pomerania. It was recorded from Wielkopolski National Park (lake Bagno Chlebowo), Tuchola Forest [lake Dury 1 (53°38'20"N, 18°21'14"E, 102m a. s. l.), lake Kozie 1 (53°41'20"N, 17°53'33"E, 119m a. s. l.), lake Kozie 3 (53°41'10"N, 17°52'58"E, 116m a. s. l.) and lake Łyse (53°40'53"N, 18°26'11"E, 87m a. s. l.)], and Brodnica Landscape Park [lake Okonek (53°23'08"N, 19°24'29"E, 84m a. s. l.)]

Limnozetes rugosus (Sellnick, 1923)

Diagnosis

Adult (Fig. 10) similar to other European species, but larger (Table 1), with more convex notogaster and pteromorphs wider than longer. Notogaster usually with 10 pairs of setae, including seta c_2, but some adults also retain pair or one seta c_3 on pteromorph (Fig. 2B). Location of cupules *ia*, *im*, *ip* and *ih*, and gland opening *gla* as in *L. lustrum*. Pedotectum 1 (*pd1*) large, oval. Formula of legs setae (trochanter to tarsus) and solenidia is: I - 1-4-(3+1)-(4+2)-(15+2); II - 1-4-(3+1)-(4+1)-(14+2); III - 2-3-(1+1)-(3+1)-14; VI - 1-2-0-(3+1)-10. In mites mounted on slides solenidia ω_1 and ω_2 on tarsus I usually joined in medial and distal parts (Fig. 3B). Legs tridactylous.

Juveniles stocky, yellow-brown, with plicate cuticle. Prodorsal setae *le* and *in* rather long, seta *ro* distinctly shorter, seta *ex* minute. Bothridium weakly developed, sensillus long, setiform, commonly broken. Setae on gastronotum and anogenital region short and smooth.

Morphology of larva and tritonymph

Prodorsum of larva (Fig. 11) triangular, lateral and posterior parts plicate. Seta *ro* short, smooth and curved, setae *le* and *in* distinctly longer; seta *le* with small barbs, seta *in* smooth; seta *le* on apophysis; seta *ex* minute. Bothridium weakly developed, sensillus setiform, often broken.

Gastronotal region with 12 pairs of setae, including setae h_2 and h_3 positioned near paraproctal valves (Fig. 12A); length decreases from seta h_1 to h_3. Other gastronotal setae short and smooth. Gastronotum plicate.

Shape of tritonymph body (Figs 12B; 13) and prodorsal setae, bothridium and sensillus as in larva. Setae *in* and *le* rather long, *in* curved posteriorly (Fig. 8B). Gastronotum with 15 pairs of setae; all setae small, thin and smooth, locations of setae as in *L. lustrum*. Genital valves of tritonymph (Fig. 12B) with 5 pairs of small setae, seta *ag* present. Two pairs of small setae on paraproctal valves, adanal (ad_1-ad_3) and pseudanal (p_1-p_3) setae slightly longer; all setae smooth. Lateral and posterior parts of prodorsum, gastronotum and anogenital region plicate. Cupule *ia* posterior to seta c_3, cupules *im* and *ip* difficult to observe in plicate cuticle; cupules *ih*, *ips* and *iad* lateral to anterior part of paraproctal valves of proto-, deuto- and tritonymph, respectively. Setae *l* on tibia I thick and rather short, but seta *ft'* on tarsus I thin and long; in mites mounted on slides solenidia ω_1 and ω_2 usually joined in medial and distal parts (Fig. 9A).

Ontogenetic transformations

The ontogeny of prodorsal and gastronotal setae, bothridium and sensillus is similar to that of *L. lustrum*. Compared to the tritonymph, the adult loses the *d*-series setae and usually two pairs of *c*-series setae, leaving seta c_2, but some specimens retain a pair of c_3 or unilaterally one seta on the pteromorph. The formulae of genital setae, aggenital setae, segments PS-AN, paraproctal setae and coxisternal setae are similar to those of *L. lustrum* (Table 2), while the formula of gastronotal setae is 12-15-15-15-(10-11).

Distribution and ecology

Limnozetes rugosus has been considered a northern European species (SUBÍAS, 2004; WEIGMANN, 2006). It lives in wet *Sphagnum* bogs (WILLMANN, 1931; SELLNICK, 1960; SITNIKOVA, 1975; SUBÍAS, 2004; WEIGMANN, 2006), and at the edges of forest lakes with *Sphagnum*. In Poland it was recorded from Tuchola Forest [lake Dury 1, lake Dury 2 (53°38'20"N, 18°21'22"E, 104m a. s. l.), lake Dury 4 (53°37'56"N, 18°21'42"E, 102m a. s. l.), lake Kozie 1, lake Kozie 3, lake Łyse, lake Małe Gacno (53°47'11"N, 17°33'10"E, 143m a. s. l.) and lake Wielkie Gacno (53°47'32"N, 17°33'27"E, 133m a. s. l.)].

TABLE 1

Measurements of some morphological characters of juvenile stages of *Limnozetes lustrum* and *L. rugosus* (mean measurements of 10 specimens in μm): larva (L), protonymph (PN), deutonymph (DN), tritonymph (TN) and adult (AD), nd – not developed, [a]/ – if present.

Species	Morphological characters	Developmental stages				
		L	PN	DN	TN	AD
L. lustrum	Body length	198	247	284	335	350
	Body width	108	160	163	169	225
	Length of : seta *le*	13	9	13	12	45
	seta *in*	15	10	12	18	28
	seta c_3	15	10	11	17	lost
	seta *da*	12	9	8	12	lost
	seta *dp*	18	10	8	13	lost
	seta *lp*	21	18	17	20	17
	seta h_1	20	15	16	19	18
	genital opening	nd	17	27	35	40
	anal opening	46	59	70	86	68
L. rugosus	Body length	215	257	304	350	390
	Body.width	147	175	211	257	251
	Length of : seta *le*	31	31	44	48	27
	seta *in*	28	31	47	54	38
	seta c_3	9	9	9	9	14[a]
	seta *da*	8	8	8	8	lost
	seta *dp*	7	9	8	8	lost
	seta *lp*	12	13	13	13	8
	seta h_1	10	9	9	9	9
	genital opening	nd	20	29	38	50
	anal opening	57	67	77	92	79

TABLE 2

Chosen morphological characters of *Limnozetes lustrum* and *L. rugosus*.

Morphological characters		*L. lustrum*	*L. rugosus*
Adult :	presence of seta c_3	absent	absent or present
	shape of pteromorph	longer than wider	wider than longer
	solenidia ω_1 and ω_2 on tarsus I	usually separated	usually joined
	shape of setae *pv*, *s*, *a* on tarsus I	thin	rather thick
Juveniles :	pattern of cuticle	rare folds	plicate
	colour of body	flesh-colored	yellow-brown
Larva :	shape of setae *lm*, *lp*, h_1	thick, stiff	thin
Nymphs :	shape of : body	boat shaped	stocky
	setae of *h*-series, p_1	thick, stiff	thin
	solenidia ω_1 and ω_2 on tarsus I	usually separated	usually joined
	shape of setae *pv*, *s*, *a* on tarsus I	thin	rather thick
	setae *l'* on tibia I	thick	thin
	Formulae of gastronotal setae	12-15-15-15-10	12-15-15-15-(10-11)

DISCUSSION

Adults of *L. lustrum* and *L. rugosus* are, at first glance, similar to each other, while their juvenile stages are morphologically differentiated. The juveniles of the former species are flesh-colored, with more slender body and cuticle with few folds, while those of the latter species are yellow-brown, stocky, with plicate cuticle. Additionally, the nymphs of *L. lustrum* are boat-shaped, with rather thick and stiff peripheral setae on the gastronotum, like those of *L. onondaga*, *L. palmerae* and *L. amnicus*, which were described by BEHAN-PELLETIER (1989). To this group belongs also *L. ciliatus*, the nymph of which is generally similar to that of *L. lustrum*, but has longer peripheral setae on the gastronotum (Fig. 7B) and more genital setae (GRANDJEAN, 1951b; SENICZAK & SENICZAK, 2009). The nymphs of *L. amnicus*, *L. ciliatus*, *L. lustrum*, *L. onondaga* and *L. palmerae* seem to be similar to typical aquatic species of *Hydrozetes* (SENICZAK et al., 2007; 2009; SENICZAK & SENICZAK, 2007), whose nymphs are also boat-shaped, with thick and stiff setae on the posterior part of gastronotum.

In contrast, the juveniles of *L. rugosus* are stocky and have thin gastronotal setae, as are those of *L. latilamellatus*, *L. guyi* and *L. borealis*, which were described by BEHAN-PELLETIER (1989). Stocky body, short gastronotal setae and plicate cuticle are also found among the juveniles of Achipteriidae (SENICZAK & SENICZAK, 2007). The ontogeny of setation in *L. lustrum* and *L. rugosus* is generally similar, except for retention of a pair, or singleton seta c_3 in a number of adult specimens in the latter species. Among 750 investigated adults of this species collected from *Sphagnum* at the edge of a small lake in Finse (Norway), 4.8% of population had a pair of setae c_3, 18.4% of population had one seta c_3, and the other individuals lost these setae.

Presence of seta c_3 in some adults of *L. rugosus* has been noted here for the first time in *Limnozetes* and may be considered ancestral, and also could be argued to be derived, in the concepts of GRANDJEAN (1949; 1951a; 1968). In the higher Oribatida (Brachypylina or Circumdehiscentiae) often two pairs of *c*-setae (c_1, c_3) are subject to loss in the adult during phylogeny, relative to the tritonymph, such that only seta c_2 remains, as in *L. lustrum*. However, there are two possible sequences of loss of these setae during phylogeny. According to GRANDJEAN (1951a, 1968) first pair c_3 is lost and then pair c_1; such a pattern occurs in the adults of the subfamily Sphaerozetinae (SENICZAK et al., 1990) sensu SHALDYBINA (1975). In contrast, SHALDYBINA (1972) considered pair c_1 to be lost first, and then pair c_3; this pattern of loss of notogastral setae is observed in *Hydrozetes* Berlese, 1902 (SENICZAK et al., 2007; SENICZAK & SENICZAK, 2008a, b). Therefore, we can question which pattern of loss of notogastral setae occurs in the adult of *L. rugosus*. The answer may lie in the fact that *Limnozetes* and *Hydrozetes* – while different in many ways – may be closely related.

GRANDJEAN (1951b) compared the morphology of *Limnozetes* and *Hydrozetes* with that of some other aquatic genera of oribatid mites and considered the former genus to be more closely related to the latter than to the other brachypyline genera. In most oribatid species the formula of genital setae is 1-3-5-6, while some species of *Limnozetes* and the '*lacustris* group' of *Hydrozetes* express genital neotrichy. For example, the formula of *Limnozetes ciliatus* is 2-4-6-7 (GRANDJEAN, 1951b; SENICZAK & SENICZAK, 2009), and that of *Hydrozetes parisiensis* Grandjean, 1948 is 2-(4-5)-(6-7)-(7-8) (SENICZAK et al., 2009). If we compare the nymphs of European species of *Limnozetes* (except *L. rugosus*) and *Hydrozetes*, they are boat-shaped and have rather strong peripheral setae at least on the posterior part of the gastronotum, as noted for *L. lustrum*. The sensillus has undergone some level of regression in *Limnozetes* and *Hydrozetes*, both in the juvenile stages and in the adult. Moreover these genera share a tendency to parthenogenesis, which occurs in all hitherto known species of *Limnozetes*, in the '*lacustris* group' of *Hydrozetes* (SENICZAK et al., 2009) and the other taxa with plicate nymphs show parthenogenesis, e.g., *Tectocepheus* sp.

BEHAN-PELLETIER (1989) compared the morphology of adult and juvenile stages of *Limnozetes* and *Hydrozetes*, and also considered these genera closely related. She envisioned character transformations in *Limnozetes* that led to the absence of an alary carina and the presence of pteromorphs in the adults, a slimmer body shape and thinner setae in the juveniles, and reduction of some leg setae.

Based on the observations of GRANDJEAN (1951b) and BEHAN-PELLETIER (1989), *Limnozetes* is closely related to *Hydrozetes*, and presents a similar pattern of loss of notogastral setae in the adult, e.g. the first of the *c*-series to regress is pair c_1, and then pair c_3. However, these genera differ markedly in the regression of the dorsocentral series of setae. In *Hydrozetes* all setae of the *d*-series are retained by adults, regardless of the presence or absence of c_1 and c_3, while in adults of *Limnozetes* these setae are always absent, despite the variable presence of c_3 in *L. rugosus*. In some other families, the presence or absence of dorsocentral setae is quite variable as well. For example, in the ceratozetid subfamily Sphaerozetinae sensu SHALDYBINA (1975) first c_1 was regressed, then pair c_3 and then the dorsocentral setae (SENICZAK et al., 1990). The loss of setae *da* and *dm* in this group has small systematic value, and in *Fuscozetes setosus* (C. L. Koch, 1941) it is the source of variability in the number of notogastral setae (SENICZAK et al., 1990), while seta *dp* is lost in a closely related species - *F. tatricus* Seniczak, 1993, and only alveolus of this seta remains (SENICZAK, 1993).

Limnozetes lustrum and *L. rugosus* differ also in the number and shape of some setae on legs, which is consistent with the findings of BEHAN-PELLETIER (1989), who also observed different patterns of leg setation in the investigated species. In the adult of *L. lustrum* mounted on slides solenidia ω_1 and ω_2 on tarsus I are usually separated, like in the adult of *L. onondaga* (BEHAN-PELLETIER, 1989), while in *L. rugosus* they are usually joined in medial and distal parts, similar to the adult of *L. guyi* (BEHAN-PELLETIER, 1989). However, this morphological character needs more study on the other species of *Limnozetes*.

Based on the number of notogastral setae of adults, which has systematic value, and morphology of nymphs, we can divide the species of *Limnozetes* into two groups: '*ciliatus* group' (*L. amnicus*, *L. ciliatus*, *L. lustrum*, *L.*

onondaga and *L. palmerae*) and '*rugosus* group' (*L. borealis*, *L. latilamellatus*, *L. guyi* and *L. rugosus*). The '*ciliatus* group' includes the adults with ten pairs of notogastral setae, and boat-shaped nymphs, with rather thick and stiff peripheral setae on the gastronotum and rather smooth cuticle. The '*rugosus* group' comprises the adults with 10–11 pairs of notogastral setae, and stocky nymphs, with thin gastronotal setae and plicate cuticle.

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