

The morphological differences and the occurrence of *Oulimnius tuberculatus* (P.W.J. Müller, 1806) and *Oulimnius troglodytes* (Gyllenhal, 1827) (Coleoptera: Elminthidae) in Lake Esrom, Denmark.¹

PETER C. DALL

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Populations of *Oulimnius tuberculatus* and *O. troglodytes* in Lake Esrom, Denmark, were examined during 1975-76 and 1979-80 as a part of an investigation of the littoral invertebrate communities. The results are compared with earlier records from the lake. Morphological characteristics combined with length of larval prothorax and imaginal elytra enabled the identification of larval instars and imagines. The III, IV, and V instars and the imagines of *O. tuberculatus* proved significantly bigger than the corresponding of *O. troglodytes*.

O. troglodytes dominates in Lake Esrom. Mean annual densities vary between 30 and 2940 ind m⁻² at the five localities investigated. There is evidence that *O. tuberculatus* has decreased in abundance, probably due to eutrophication of the lake during the past fifty years. Comparisons with other records from Danish lakes show that *O. tuberculatus* is the most common elminthid species in lakes, whereas *O. troglodytes* shows a more sporadic occurrence with dominance in the exposed littoral zones of some eutrophic lakes.

Peter C. Dall, Freshwater Biological Laboratory, Helsingørsgade 51, DK-3400 Hillerød, Denmark.

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Introduction

The invertebrate communities in the littoral zone of Lake Esrom were investigated during 1979-80 as a part of the »Lake Esrom Littoral Research Project«.

Lake Esrom is a mesotrophic, dimictic lake situated in Northern Zealand, Denmark. It covers 17.3 km² and has a maximum depth of 22 m. As regards substrate and vegetation, the shallow littoral zone (0-2

m) is composed of reeds (10%), sandy bottom (10%), and exposed, stony areas (80%). Further details were given in Dall *et al.* (1984), and a summary of the Lake Esrom history and eutrophication was given in Jónasson (1984).

Previous investigations including identification of larvae and imagines of Elminthidae had shown that *Oulimnius tuberculatus* (P.W.J. Müller, 1806) was common in the littoral zone, but that *Oulimnius troglodytes*

(Gyllenhål, 1827) was present also (Berg 1938).

The results presented here include notes on the identification of the two species, and an attempt to trace the possible changes in distribution, together with a status of distribution and abundances in the lake during 1979-80.

Material and Methods

The total available material of larvae and imagines collected at depths of 0-0.5 m in Lake Esrom is shown in Table 1. All samples were collected in areas with a stony substratum and without emergent vegetation. The collections during 1979-80 were made at 5 localities in the lake. Details of sampling methods are given in Berg (1938), Dall (1979, 1981), and Dall *et al.* (1984). Animals collected in 1937 were preserved in ethanol, those collected 1975-80 were stored in 4% formaldehyde.

Collections and available records of individuals from other Danish lakes and the River Suså were included in the investigation in order to examine the regional varia-

tions in size of beetles and the distribution of the two species.

Larvae (III-V instar) and imagines of the two species were identified by use of the characteristics given in Holland (1972). Further, the length of the larval prothorax and the elytron of adults were measured in units of 0.0122 and 0.0197 mm, respectively. In *O. tuberculatus*, the lower of the two bristles on the maxilla is simple and straight. In *O. troglodytes*, both bristles are tufted. In the III instar, the lower bristle is sometimes only bifurcate (Fig. 1B). The bristles on the left and right maxilla are generally differently tufted/branched. It was not possible to distinguish younger larvae (I and II instars) of the two species by means of similar morphological differences (400 x magnification).

Preserved specimens were weighed in clusters of 10-25 individuals in order to estimate mean individual dry weight (D.W.) and ash content of the individual instars, sexes and species.

Results

Identification and size of species and instars

Table 1. The number of individuals of *Oulimnius troglodytes* and *O. tuberculatus* collected in Lake Esrom at depths of 0-0.5 m during the period 1937-1980.

locality	year	<i>O. troglodytes</i>		<i>O. tuberculatus</i>	
		larvae	imagines	larvae	imagines
Kongebro *	1937	—	—	99	—
Sandporten **	1937	8	—	—	—
Nødebo **	1937	1	—	—	—
Dr. Bøge	1975/76	2000	210	671	108
Dr. Bøge	1979/80	71	7	91	5
Kongebro	—	784	184	—	—
Endrup	—	336	51	—	—
Sølyst	—	2414	248	1	—
Tumlinghus	—	797	163	—	—

* K. Berg's transect, leg. et det. K. Berg (Berg, 1938, Primary table XIII).

** leg. K. Berg, det. by author.



Fig. 1. The right maxilla of *O. troglodytes*. Variations in the lower tufted bristle of the fifth instar larvae (A), and in the third instar (B). The bristle in the fourth instar is almost similar to (A). The indicated scale is 0.1 mm.

Measurement of the larval prothorax enabled identification of all five instars of *O. troglodytes* (Table 2). All III, IV, and V instar larvae and all imagines found in the material collected during 1979/80 at the stations Kongebro, Endrup, and Tumlinghus were *O. troglodytes*, and it is consequently assumed that I and II instars collected at these localities were *O. troglodytes* also. The same applies for individuals collected at Sølyst, where only one IV instar larvae of *O. tuberculatus* was found. At Dr. Bøge, all I and II instar larvae which had a prothorax longer than found for *O. troglodytes* were considered as being *O. tuberculatus*

(Table 2). Only 40 of the individuals collected at Dr. Bøge during 1979-80 were I and II instars.

The histograms in Fig. 2 and Fig. 3 emphasize the differences in the size of larvae and imagines of the two species. The material collected at Dr. Bøge during 1975-76 only included V, IV, and a few III instar larvae. Some of the biggest larvae and a few imagines were then identified as *O. tuberculatus*, and this is the reason why this species is the only one mentioned in Dall *et al.* (1984).

Very few specimens of *O. tuberculatus* were collected in 1979-80 (Fig. 3), but those sampled in 1975-76 showed very little overlap in size of the elytra of the two species. There was no significant difference in size of males and females in *O. troglodytes* (F-test, test of means for $N > 50$), though, at least in Lake Esrom, the females tended to be slightly bigger than males in terms of length of the elytron (Table 3). The mean individual D.W. showed the same trend (Table 4). The sex ratios of imagines and their temporal variations in occurrence at the five localities were tested, but all differences proved non-significant implying a 1:1 sex ratio and no significant variations in occurrence.

It was expected that the maximum weight of *O. troglodytes* larvae should be about 0.2 mg D.W. equal to the maximum weight of imagines, but it appears that the weighings of *O. troglodytes* larvae by pooling did not include enough of those which were ready to pupate. Otherwise, mean D.W. of the larval instars of *O. troglodytes* increased at least tenfold from the I to the V instar. Determinations of ash content showed significant species-specific differences in case of the IV and V instars and imagines (t-test, $P < 0.05$). It also appeared that the smaller instars have a relatively much higher ash content, but only a few *O. troglodytes* of these instars were available for weighings.

The populations in Lake Esrom

The estimated variations in distribution and

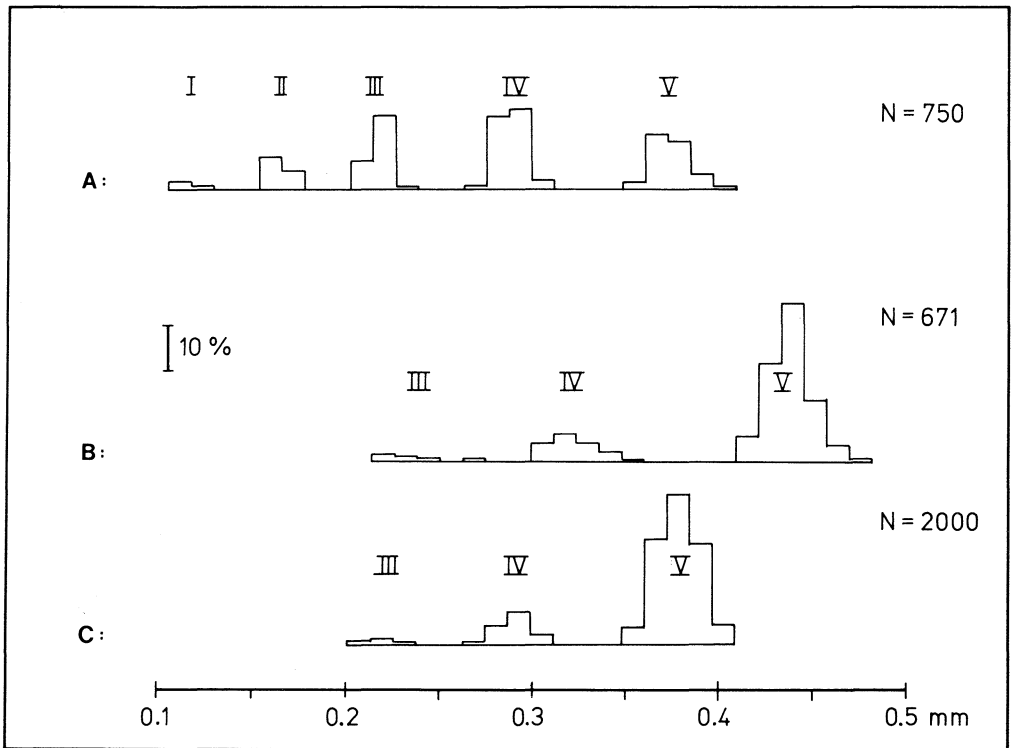


Fig. 2. The percentage composition of size classes of *Oulimnius* spp. larvae according to the length of the prothorax, measured in units of 0.0122 mm. A, part of the material of *O. troglodytes* collected during 1979-80 at Sølyst. B, *O. tuberculatus* collected at Dr. Bøge during 1975-76. C, *O. troglodytes* from the same locality.

abundance of the two species of *Oulimnius* spp. in Lake Esrom is summarized in Fig. 4. The small samples from Sandporten and Nødebo in 1937 contained nine larvae of *O. troglodytes*, and Berg (1938) mentioned that, »Larvae which probably belong to *Limnius* [*Oulimnius*] *troglodytes* have been shown to be present in the lake, but the imagines have not been found«. All individuals collected during 1937 at Kongebro were *O. tuberculatus*, and Berg (*op. cit.*) further stated that, »the *Limnius* species, which lives there [in Lake Esrom] in great numbers on the stones covered with filiform algae, is in the main *L. tuberculatus*«. It thus appears that both species were present in the lake during the thirties, but *O. tuberculatus* dominated.

During 1975-76 both species were present in the surf zone at Dr. Bøge on the western shore, but the estimated mean annual abun-

dances in Fig. 4 are minimum values, because mainly IV and V instar and imagines were collected from the samples. The same applies for Berg's estimate of abundance. In 1937 sieving was made with a 600 µm mesh-size, and most of the smaller larvae were probably lost this way.

Both species were rather common at Dr. Bøge during 1975-76, and this was confirmed by the results from 1979-80. However, the results also show that the population of *O. troglodytes* is small compared to the other four localities in the lake. The histograms in Fig. 4 emphasize the dominance of this latter species, and more so, considering that *O. tuberculatus* was missing at Kongebro during 1979-80.

So far, it appears that *O. tuberculatus* has diminished in distribution and numbers, while *O. troglodytes* is established with den-

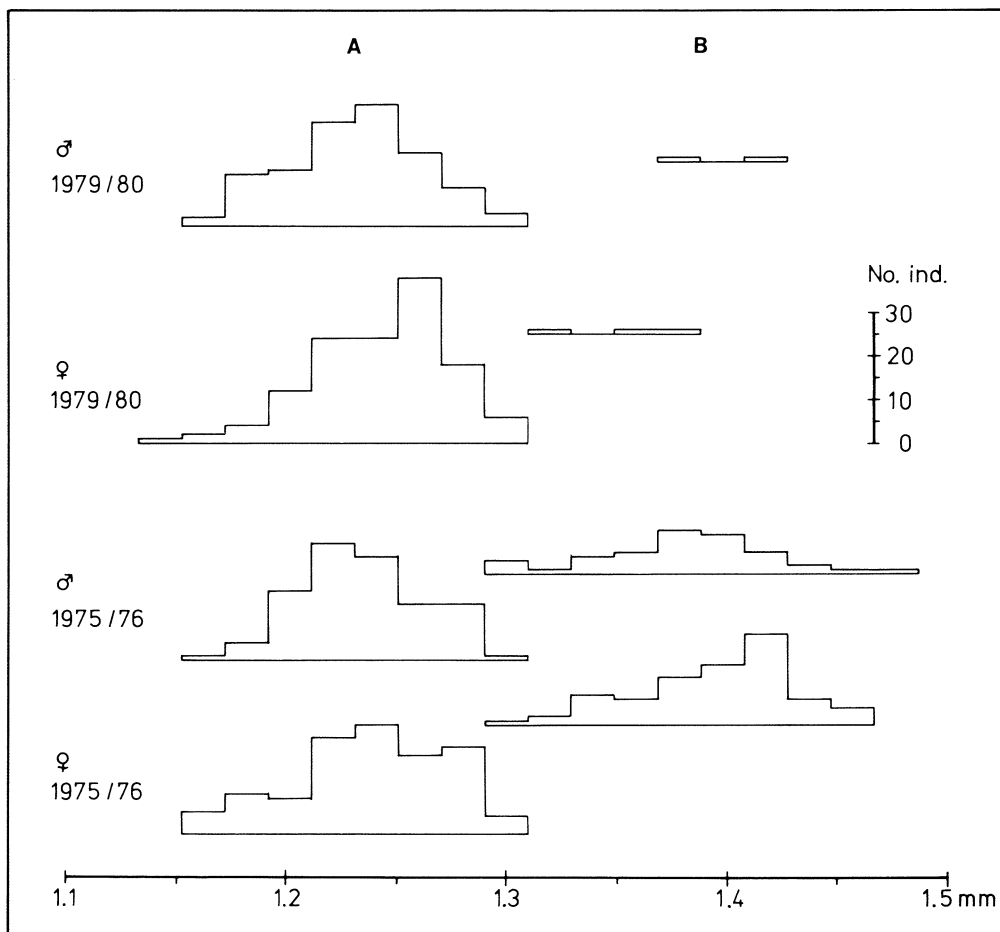


Fig. 3. Histograms showing the variations in the length of male and female elytron measured in units of 0.0197 mm. A, *O. troglodytes*. B, *O. tuberculatus*.

se populations in most of the exposed littoral zone in the lake.

Regional variations

Limited material of larvae and imagines from other Danish lakes and the River Suså watershed were examined also. Measurements of imaginal elytra showed only minor, non-significant variations between lakes (Table 3), but it appears that *O. troglodytes* can dominate in the more eutrophic lakes, while *O. tuberculatus*, which is more common and also occurs in running water, is found in a variety of lakes (Hansen 1973,

M. Hansen pers. comm.). The data for the distribution in lakes are summarized in Table 5. Recent investigations in lakes in Central Jutland have shown unexpected high numbers of *Riolus cupreus* (P.W.J. Müller, 1806) (Leonhard & Mahler 1987).

Discussion

Holland (1972) gives the length of the final instar prothorax as 0.395-0.450 mm and 0.365-0.405 mm for *O. tuberculatus* and *O. troglodytes*, respectively. These values are rather similar to the results from Lake Esrom in Table 2, except that there was no

Table 2. Variations in length (mm) of larval prothorax and imaginal elytron. Only upper limits are available for I and II instars of *O. tuberculatus*. Lake Esrom 1975-1980.

instar	N	<i>O. troglodytes</i>		N	<i>O. tuberculatus</i>	
		mean	range in mm		mean	range in mm
I	17	0.113	0.110 – 0.122	5	–	? – 0.134
II	81	0.163	0.146 – 0.171	11	–	? – 0.195
III	195	0.214	0.195 – 0.232	27	0.237	0.220 – 0.268
IV	532	0.289	0.268 – 0.305	112	0.321	0.305 – 0.354
V	1923	0.377	0.354 – 0.403	531	0.438	0.415 – 0.476
females	230	1.241	1.143 – 1.300	68	1.398	1.320 – 1.458
males	207	1.233	1.182 – 1.300	37	1.381	1.300 – 1.478

Table 3. Average lengths and 95% C. L. of elytra (mm) of beetles collected in Lake Esrom compared to individuals from other Danish localities. »m«, males; »f« females.

locality	sex	<i>O. tuberculatus</i>			<i>O. troglodytes</i>		
		N	mean	C. L.	N	mean	C. L.
Lake Esrom 1975 – 1980	m	37	1.381	±0.013	207	1.233	±0.004
	f	68	1.398	±0.009	230	1.241	±0.004
Lake Skanderborg 1986	m	18	1.371	±0.021	12	1.230	±0.021
	f	16	1.397	±0.024	15	1.237	±0.018
Lake Hampen 1986	m	19	1.410	±0.023	–	–	–
	f	19	1.409	±0.017	–	–	–
River Susaa 1976	m	46	1.400	±0.012	–	–	–
	f	21	1.400	±0.018	–	–	–

overlap in size of the two species in Lake Esrom. Total length of the imagines from Lake Esrom is within the ranges given in Olmi (1978) and Holland (*op. cit.*). The characteristics of imagines given in Steffan (1961) do not include size of the elytra.

About 15 of the approximately one thousand imagines examined showed different colouration of the cuticula or atypical shape

of the male genitalia. A few light brown individuals of both species were observed during autumn. According to Holland (*op. cit.*), these were probably newly emerged beetles. Some of these and a few other males showed diverging shape of parameres, but were identified according to the shape of the aedeagus.

It appears that *O. tuberculatus* is frequent

Fig. 4. Diagram of Lake Esrom showing the location of the sampling sites and the estimated mean annual abundances of *Oulimnius* spp. A, samples collected in 1937. B, samples from Dr. Bøge during 1975-76. C, results of the 1979-80 investigation.

in streams and rivers, and on stony lake shores in a variety of lakes, whereas *O. troglodytes* is rare, and especially so in running water (Holland 1972). In Denmark it predominates in more eutrophic lakes (M. Hansen pers. comm.). Sympatric occurrence has been shown in rivers (Berthélemy & Ductor 1965), and in a number of lakes, but in Lake Esrom specifically it seems that the abundance of *O. tuberculatus* has diminished and vice versa in case of *O. troglodytes*. This trend may be a result of increased eutrophication during the past fifty years since the first quantitative records from the lake. However, there are no records of species-specific interactions, and apparently nothing is known about differences in requirements or in response to changes in the environment.

Acknowledgements

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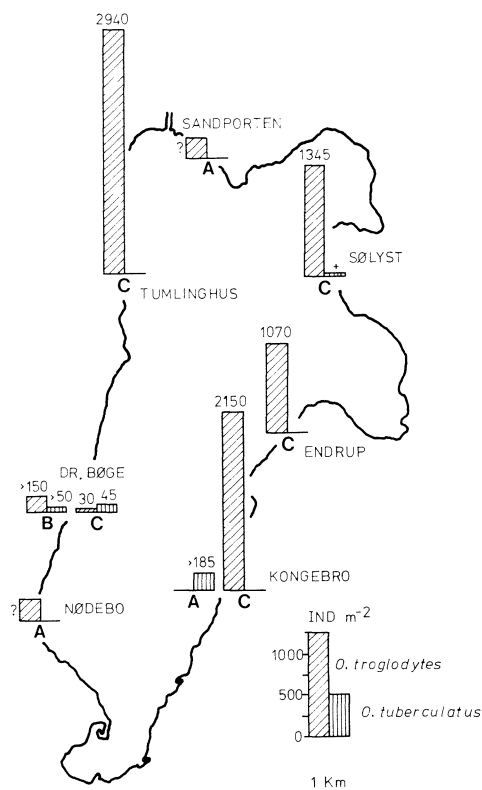


Table 4. Mean individual dry weight (D.W.) in mg of larvae and imagines. The animals were weighed in clusters of 10 – 25 individuals.

The range in weight shows means of clusters with relatively small and big individuals, respectively. Ash content as % of D. W.

instar	<i>O. troglodytes</i>			<i>O. tuberculatus</i>		
	mean D.W.	range	% ash	mean D.W.	rangeN	% ash
I	0.013	–	(25.0)	–	–	–
II	0.015	0.013 – 0.018	(32.3)	–	–	–
III	0.023	0.019 – 0.028	13.6	0.024	–	–
IV	0.048	0.038 – 0.055	4.2	0.058	–	1.7
V	(0.133)	0.096 – 0.157	4.3	0.237	0.213 – 0.252	2.9
females	0.189	0.181 – 0.201	4.0	0.229	0.224 – 0.231	2.1
males	0.185	0.181 – 0.190	3.9	–	–	–

Table 5. A summary of the estimated relative abundances of Elminthidae in Danish lakes. »+«, present; »++++«, abundant. The lakes are given in approximate order of increasing eutrophy. Data collected during 1973-1986. *, S. Leonhard (pers. comm.); **, M. Hansen (pers. comm.); other data by author (unpubl.).

lake	<i>O.tuber- culatus</i>	<i>O. tro- glodytes</i>	<i>Riolus cupreus</i>
Kvie	+		
Lange	+		
Hampen	+++		
Vester Vandet	+		
Jels *	+++		
Nors	+		
Ove	+		
Julsø *	++		+
Tjele Langsø *	+++	+	
Esrom	+	++++	
Hald *	+++	+++	++
Buresø **	++	++	
Skanderborg	+++	++	
Tissø	++	+++	
Maribo Søndersø	+		
Virket	+		
Stilling-Solbjerg **	+++	++++	+

valuable advice and criticism. The investigation was supported by a grant from the Danish Natural Science Research Council.

Sammendrag

I forbindelse med en større undersøgelse af bundfaunaen i bredzonen i Esrom Sø gennemførtes der i 1979-80 en kvantitativ indsamling af invertebrater på fem lokaliteter med eksponeret brændingskyst (Dall *et al.* 1984). Resultaterne her vedrører larver og imagines af billeslægten *Oulimnius* sp. Forekomst og hyppighed af arterne *O. tuberculatus* og *O. troglodytes* sammenlignes med tidligere fund i Esrum Sø (Tabel 1, Fig. 4). Målinger af pronotums længde hos larvestadier og længde af dækvinger på imagines (Tabel 2) viser, at III, IV og V larvestadie samt imagines af *O. tuberculatus* er signifi-

kant større end tilsvarende hos *O. troglodytes* (Fig. 2). Med hensyn til imagines er der tilmed næsten ikke overlapning i størrelsesfordelingerne for de to arter (Fig. 3).

Arternes forekomst i Esrom Sø viser gennemsnitlige individtætheder af *O. troglodytes* på 1000-3000 ind m⁻² på fire af de fem undersøgte lokaliteter, mens individtætheden på den sydvestlige lokalitet, Dronningens Bøge, næppe overstiger 100 ind m⁻². Dette er samtidig den eneste lokalitet, hvor *O. tuberculatus* forekommer i antal (50 ind m⁻²). Sammenligning med undersøgelser i 1937 tyder på, at *O. tuberculatus* har været langt hyppigere (Berg 1938), men at *O. troglodytes* har tiltaget voldsomt i udbredelse i løbet af de sidste 40-50 år.

O. tuberculatus er udbredt i vandløb og søer over hele landet, mens *O. troglodytes* kun er registreret fra en halv snes næringsrige søer i Jylland og på Sjælland (Tabel 5).

Forekomsterne af *O. troglodytes* kan, sammenholdt med den formodede udvikling i Esrom Sø, således tyde på, at arten har præferens eller konkurrencemæssige fordele i eutrofe søers brændingszone. Der er imidlertid næppe tvivl om, at artens udbredelse også i væsentlig grad er et resultat af manglende geografisk spredning.

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Anmeldelse

Carl H. Lindroth, 1985, 1986: The Carabidae (Coleoptera) of Fennoscandia and Denmark. Fauna Entomologica Scandinavica, Vol. 15, Bind 1 & 2. E.J. Brill/Scandinavian Science Press Ltd., Leiden, Copenhagen. 497 sider + 8 farveplantesjer, 514 svart/hvit tegninger. Bind 1: 80 Hfl, Bind 2: 80 Hfl.

Da Lindroth døde i 1979 etterlot han seg et uferdig manuskript til en 3dje utgave av sitt bestemmelsesverk for Nordens carabider. Andre utgave utkom i 1961 i serien Svensk Insektfauna. Foruten en revidering av nomenklatur, tabeller og tekst inkluderte manuskriptet 9 nye arter fra tidligere finske territorier i øst. Takket være bearbeiding og redigering fra en rekke spesialister kan verket presenteres i sin nåværende form.

I 1961-utgaven henviste Lindroth til sitt monumentale verk »Die Fennoskandische Carabidae I, II og III«, når det gjaldt detaljer i artenes utbredelse og levevis. I den nye utgaven er avsnittene »Distribution« og »Biology« under hver enkelt art