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The distribution of relict crustaceans in Finland: new observations and some problems and ideas concerning relicts

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The article summarizes observations of relict malacostracan species made mainly in the lake region of Finland. In addition to geographical location, maximum depth, lake area and altitude, human activity also has an effect on the occurrence of given species. *Pontoporeia affinis* seems to be the most sensitive to human interference, and this and *Pallasea quadrispinosa*, which is not as sensitive, have returned to areas in Lake Päijänne that were earlier more polluted. *Mysis relicta* has the widest environmental amplitude in different lakes, while *Gammaracanthus lacustris* occurs only in largest, deepest and cleanest lakes. *Pallasea* should be included in the fauna of the Baltic. The question is raised of whether the concept of relict species should be broadened to include also some other cold-stenotherm species, in particular certain calanoids, harpacticoids and rotifers, and also meiobenthic species. It seems that at least *Pallasea* might be able to immigrate to areas situated higher up. The reason for the absence of *Saduria entomon* in the large lakes of Finland has not been ascertained, and the advantages and disadvantages attached to transferring it and comparable relict or other species are not generally known in sufficient detail.

1. Introduction

Malacostracan relict crustaceans have been studied at the University of Jyväskylä with regard to their distribution and their relations to environmental factors, and observations have also been made during other investigations concerned with the effects of pollution on the communities of benthic invertebrates in large lakes, the effects of acidification on the fauna of small forest lakes and the enrichment of the environmental contaminants in aquatic food chains. Some problems and ideas concerning relicts in general are also discussed here.

2. Distribution and relation to the environment

Särkkä (1976) presented 44 new records of relict crustaceans in 25 lakes in the Kymijoki river basin, since when *Gammaracanthus lacustris* has been found in two localities in southern Finland, Lake Toisvesi in Virrat (Särkkä unpubl.) and the Luonteri basin of Lake Saimaa (Meriläinen 1985). According to Segerstråle (1956a, b) this species was known to inhabit 10 large Finnish lakes, but it has now been observed in 15 lakes. This, the rarest species of the malacostracan crustaceans, occurs only in the largest and deepest lakes in Finland (maximum depth more than 44 m, average lake area about 400 km^2, Särkkä 1976). It has been found even in the slightly eutrophicated northern areas of Lake Päijänne (Särkkä 1979b), and has sometimes been highly abundant in samples taken with fish trawls in clean areas in the southern parts of the lake.

Pallasea quadrispinosa, quite a common species in the larger Finnish lakes, even in slightly polluted areas, has also been found in some small forest lakes, the minimum lake area in which it has been observed being 17 ha and the smallest maximum depth of the lake 6 m (Meriläinen & Hynynen 1988). The highest altitude in Central Finland for a lake with *Pallasea* was 147 m a.s.l. The species has been found only in lakes with a minimum pH above 5.6, but it is sufficiently rare in small lakes that it cannot be used as an indicator species in the assessment of lake acidification. Meriläinen (1984) found several individuals of *Pallasea* in the Baltic Sea, in the coastal areas of the Bothnian Bay approx. 20 km from the mouth of the River Kyrönjoki, at a salinity of about 3.5‰. The species has been reported once before from the Gulf of Bothnia (Segerstråle 1956a), but was later omitted from the fauna of the Bothnian Bay (Segerstråle 1960, Haahtela 1964).

Pontoporeia affinis seems to be the most sensitive of the malacostracan relict species with regarding to human interference. In the 1950's it was to be found in all parts of Lake Päijänne (Valovirta 1959), but due to increasing loading from the wood-processing industry in late 1960's and 1970's it disappeared from the eutrophicated or organically loaded areas of the northern and central parts of the lake (Särkkä 1979b). Since then loading has decreased considerably and both this species and *Pallasea* have returned to the areas originally inhabited by them (Meriläinen 1987). *P. affinis* has also been found recently in a humic lake (Kiimasjärvi) in the Saarijärvi waterway system (Särkkä 1987a), where it had earlier been assumed to be absent (Särkkä 1976).

Mysis relicta was shown to be very common in lakes with a maximum depth of more than 10 m and also to live in very humic lakes (Särkkä 1976). The smallest lake in which we have found it is Lake Ahvenusjärvi (Mouhijärvi commune) (area 18 ha, depth 23 m). The minimum pH observed in a lake inhabited by this species has been 5.4 (Meriläinen & Hynynen 1988). In Lake Päijänne *Mysis* has a very large environmental amplitude and it is most abundant in mildly loaded areas (Särkkä 1979b, Meriläinen 1987). Due to its great mobility, it seems to be able to enlarge its distributional area within a given lake.

Except for *Gammaracanthus*, the relict malacostracan species in Lake Päijänne are usually more abundant in the upper profundal area (20–40 m) than in the deepest parts of the lake (> 60 m). *Pallasea* is also often found on shallow bottoms. In a quantitative study of the littoral zoobenthos between depths of 0.5 and 6 m in Lake Konnevesi (Särkkä 1983) *Pallasea* was found at depths of 4–6 m in May and 3–6 m in August, while *Pontoporeia* was found only in May at 5 m. The numbers of both species varied between 0 and 3 individuals in 3 hauls with an Ekman grab, which corresponds to a maximal abundance of 40 ind./m^2.

It seems that a sledge is the most useful equipment for observing the occurrence of relict malacostracans in qualitative sampling, although *Pontoporeia* is often found better with an Ekman grab.

Relict crustaceans were included in studies on the enrichment of environmental contaminants in the food chain of Lake Päijänne in the 1970's (Särkkä et al. 1978, Särkkä l979a), but the

Table 1. Average mercury, PCB and total DDT (ng/g wet weight) in *Mysis relicta* compared with averages in profundal benthic animals in general and bivalves in Lake Päijänne in 1972–1974 (Särkkä 1979a).

	Mercury	PCB	DDT
Mysis relicta	43	35	14
Benthic animals	103	43	15
Bivalves	48	24	5

concentrations of "classical environmental contaminants" in *Mysis relicta* (Table 1) did not differ essentially from those in profundal zoobenthos in general or from the average concentrations in bivalves.

3. Should the concept of relict species be enlarged?

The notion that relict crustaceans other than *Pallasea* have marine ancestors whereas the *Pallasea* is indigenous to Lake Baikal is widely accepted (Segerstråle 1982) and the distribution of relict species in Europe is well known (Segerstråle 1956a, 1957, Illies 1978). The relict type distribution as shown in Limnofauna Europaea (Illies 1978) covers areas nos. 14–18 and 20–23

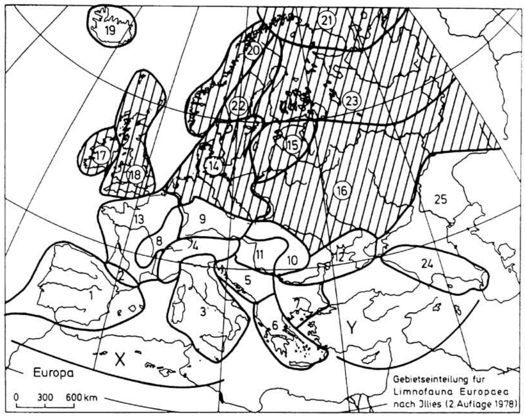

Fig. 1. The biogeographical division of Europe used in Limnofauna Europaea (Illies 1978). "Relict" areas shaded.

Table 2. Distribution of relict crustaceans and some other aquatic invertebrates in Europe according to Limnofauna Europaea (Illies 1978) (see Fig. 1). + = occurring, – = not occurring.

Region no:	14	15	16	17	18	20	21	22	23	Other
Malacostraca										
Gammaracanthus lacustris Sars	+	–	–	–	–	+	+	+	+	
Pallasea quadrispinosa Sars	+	+	–	–	–	+	+	+	+	
Pontoporeia affinis Lindström	+	+	–	–	–	+	+	+	+	
Saduria entomon (L.)	+	–	–	–	–	–	–	–	+	
Mysis relicta Loven	+	+	+	+	+	+	+	+	+	
Calanoida										
Limnocalanus macrurus Sars	+	+	–	–	+	+	+	+	+	25
Heterocope borealis (Fischer)	–	+	+	–	–	+	+	+	+	4, 9
Cyclopoida										
Cyclops kolensis Lillj.	+	+	+	–	–	–	+	–	+	
Cyclops lacustris Sars	+	+	+	–	–	+	–	–	+	
Cyclops scutifer Sars	+	+	+	–	–	+	+	+	+	
Diacyclops abyssicola (Lillj.)	+	–	–	–	–	+	–	+	+*	
Harpacticoida										
Moraria duthiei (Scott)	+	+	+	–	+	+	+	+	+	4
Rotifera										
Notholca caudata Carl.	+	–	–	–	–	+	–	+	+	4
Notholca cinetura Skor.	+	–	+	–	+	+	–	–	+	
Synchaeta grandis Zach.	+	+	+	–	+	+	–	+	+	4, 9–12
Synchaeta lakowitziana Lucks	+	+	–	–	–	+	+	+	+*	4, 13

**Diacyclops abyssicola* and *Synchaeta lakowitziana* are absent from region no. 23 according to Illies (1978) but have been found in lakes in Finland.

(Fig. 1 and Table 2), viz. Northern Europe and Great Britain. There are also some other mainly cold stenotherm aquatic species which have similar distributions, however (Table 2), even though their home areas have not been elucidated as thoroughly as those of the relict malacostracans. *Heterocope borealis*, a calanoid copepod like *Limnocalanus macrurus*, extends its distribution somewhat further south that the boreal relict type area, but so does *Limnocalanus*, which is found in area 25.

The four cyclopoid copepod species mentioned in Table 2 have an entirely relict-like distribution. According to Lang (1948, p. 1609), the following harpacticoid copepod species have been considered possible glacial relicts: *Bryocamptus zschokkei* (Schmeil), *B. cuspidatus* (Schmeil), *B. echinatus* (Mrazek), *Elaphoidella gracilis* (Sars), *Moraria brevipes* (Sars), *M. duthiei* (T. & A. Scott), *M. mrazeki* T. Scott and *Paracamptus schmeili* (Mrazek). Of these, *B. echinatus*, *M. brevipes*, *M. duthiei* and *P. schmeili* live in the deep profundal zone of Lake Päijänne (Särkkä 1987b), and all the others except *Moraria duthiei* have quite a wide distribution in Europe (according to Limnofauna Europaea). Most of these canthocamptid harpacticoids probably also live in environments other than deep profundal bottoms of lakes, although information on their most characteristic environments is in many cases lacking.

Of the other benthic species in the profundal zones of lakes, e.g. the bivalve *Pisidium conventus*, the oligochaete *Stylodrilus heringianus* and some other species, most seem to have quite a wide distribution in Europe.

Most species of rotifers have resting eggs which are resistant to desiccation and thus are very liable to be transferred by wind in particular from one drainage basin to another. Pejler (1962) nevertheless thought that the rotifer species *Notholca caudata* Carlin could be a relict. If that is true, there could be also other species of rotifer which may be relicts. There are in fact some other rotifer species that have a more or less similar geographical distribution to *Notholca caudata* (Table 2).

Thus, in addition to the "classical relicts", it is possible that *Heterocope borealis* among the calanoids, *Cyclops kolensis*, *C. lacustris*, *C. scutifer* and *Diacyclops abyssicola* among the cyclopoids, possibly *Moraria duthiei* among the harpacticoids and *Notholca cinetura* as well as *N. caudata* among the rotifers may be relicts, and the distribution of the more eurythermic *Synchaeta grandis* and *S. lakowitziana* also seems to be somewhat relict-like but more enlarged. As far as the benthic animals are concerned, the small-sized meiofauna species, which are still less wellknown in general, could contain relicts, as probably as do the larger macrofauna species.

4. Other problems and opinions

It is probable that the relict malacostracans *Mysis*, *Pontoporeia* and *Gammaracanthus* may not be able to use lotic waters for immigrating up brooks, whereas *Pallasea*, which is often found in rivers and rapids (Segerstrale 1956a), was also found in a small forest brook at an altitude of 140 m during a lotic water research course held at our university. The site was located between two small lakes with surface levels of 143 and 116 m. The upper lake is very small, having an area of about 10 ha, which may imply that the species can immigrate through small waterways to areas situated higher up. It naturally cannot cross the divides between separate watercourses, but some more accurate distribution studies might be justified in the Suomenselkä region between Kymijoki river basin and the area discharging into the Bothnian Bay, for instance.

It also seems that in addition to the maximum altitudes in different regions, the minima of the maximum depths of lake required, minima of the lake areas and effects of the various water quality parameters are not known sufficiently well for each relict crustacean species.

It is also not known why *Saduria entomon* does not occur in the largest lakes in Southern Finland such as Lake Saimaa and Lake Päijänne, even though it is found in Lake Ladoga and some of the large lakes in Sweden. Is this due to its distributional history or to the physico-chemical properties of the water or both?

Acclimatization of relicts to new lakes has been achieved in particular with *Mysis*, *Pallasea* and *Gammaracanthus* in Swedish lakes (Fürst 1981), with good or sometimes less good results.

Pontoporeia is also important as a food for fish and could be transferred. The justification for transferring *Saduria entomon* has not been discussed thoroughly. It could be a significant food item for the burbot (*Lota vulgaris*) for instance, but it could reduce numbers of *Pontoporeia* and in this way be harmful to the fish and to fishing. Other new species from among the Pontocaspian or Baikalian fauna could also come into question, e.g. those which have been widely tested in the Soviet Union (Yanushevich 1966), but newly transplanted species could act as hosts for parasites, the facts about which are not generally known in sufficient detail.

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