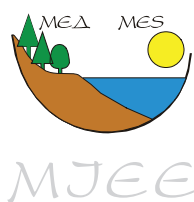


## Invasive species of Amphipoda (Crustacea, Malacostraca) in Ohrid Lake Basin (Contribution to the Knowledge of the Amphipoda 265)

Инвазивни видови од Amphipoda (Crustacea, Malacostraca) во базенот на Охридското Езеро (265. Прилог кон познавањето на Amphipoda)

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Fauna of Amphipoda in ancient Ohrid Lake in Macedonia is highly endemic, with nearly 12 endemic species of various origin. Among non endemic species in Ohrid Lake two species are invasive species: *Orchestia cavimana* Heller, 1865 (sensu auct.), originated from the sea and *Gammarus roeselii* Gervais, 1835 originated from SE Europe and Asia Minor.

*Orchestia cavimana* is recent invader, observed in Ohrid Lake at the first time in 1998 and now this species settles numerous shores of the Lake, covered by gravel and sand.

*Gammarus roeselii* invaded Ohrid Lake probably after the last Glacial period, and it was observed in Ohrid already in 1924. This species settled numerous small torrents and springs along the entire Lake Ohrid, often in mixed populations with native species. It penetrated also into the Lake itself on some shores (Struga) till 20 m depth. The present molecular and genetic investigations of both species suggest that probably several taxa exist under the names *Orchestia cavimana* (sensu auct.) and *Gammarus roeselii* (sensu auct.). The influence of both taxa on the native Amphipoda species in Ohrid Lake is still unknown.

**Key words:** Amphipoda, *Gammarus roeselii*, *Orchestia cavimana*, invasive species, Ohrid Lake, Macedonia

Фауната на Amphipoda во старото Охридско Езеро во Македонија е високо ендемична, со околу 12 ендемични видови со различно потекло. Помеѓу неендемичните, два видови се инвазивни: *Orchestia cavimana* Heller, 1865 (sensu auct.) со морско потекло и *Gammarus roeselii* Gervais, 1835 (sensu auct.) со потекло од југоисточна Европа и Мала Азија.

*Orchestia cavimana* е скорешен инвазивен вид, откриен во Охридското Езеро дури во 1998 година, а денеска овој вид населува бројни делови од езерскиот брег покриени со чакал и песок.

*Gammarus roeselii* го населил Охридското Езеро веројатно после последното Глацијално Доба, а бил откриен во езерото уште во 1924 година. Овој вид населува многубројни мали потоци и извор долж целиот брег на Охридското Езеро, често во мешани популации со автохтоните видови. Овој вид продрел на некои делови од брегот (Струга) до 20 m длабочина.

Моменталните молекуларни и генетски истражувања сугерираат дека веројатно постојат повеќе таксони во рамките на денешните видови *Orchestia cavimana* и *Gammarus roeselii*. Влијанието на овие два вида врз автохтоните видови од Amphipoda во Охридското Езеро е се уште непознато.

**Клучни зборови:** Amphipoda, *Gammarus roeselii*, *Orchestia cavimana*, инвазивни видови, Охридско Езеро, Македонија.

## Introduction

Macedonia was always considered as very attractive destination for discovery and study of its very interesting and relatively highly endemic fauna and flora, including fauna of Amphipoda. The fauna of Amphipoda in Macedonia is very rich, with known 6 families, 6 genera and over 40 species and subspecies, mostly endemic. Among them, in Ohrid Lake are present over 12 endemic species of Amphipoda.

First data about Amphipoda from Ohrid Lake basin in Macedonia, was presented by Spandl (1924) who mentioned *Niphargus* cf. *stygius* for the springs above Monastery near the Ohrid Lake, and *Gammarus roeselii* from Ohrid Lake and the springs near Ohrid. Later, several other authors mentioned or described new species from Ohrid Lake (Schäferna, 1926; Karaman, S., 1929a, 1929b, 1931, 1943; Schellenberg, 1943; Karaman, G., 1963, 1976a, 1976b, 1985, 1989).

The present fauna of Amphipoda in Ohrid Lake basin is consisting mainly from the endemic subterranean and epigeal species originated from the Lake itself, as well as the species settling the adjacent freshwaters before the formation of the Lake. Some species are developed through speciation from the ancestors settled already these waters (various *Gammarus* species) or they were developed into a new species after the invasion the Lake through speciation and isolation (*Synurella longidactylus* Karaman, S., 1929a).

Among all these species known from the Ohrid Lake basin, there are the species originated out of Balkan peninsula, species invaders from other zoogeographical regions and penetrating later into the Ohrid Lake thanks the present various favorable conditions. We intended to paid our attention to these invaders who can have a negative influence on the domestic (native) fauna.

## Material and methods

The studied material was partially collected by the author during over 40 years, and partially based on the samples collected by various other scientists and collectors (from the Museum of Natural History in Skopje, from the Hydrobiological Institute in Ohrid, etc.), as well as based on samples collected by Stanko L. Karaman, who studied fauna of Ohrid Lake during many years of past century.

The studied material of Amphipoda was collected by the plankton hand-net along the coast of the Ohrid Lake, on the stone- and gravel beaches, 1-4 meters far from the water, under the rocks, gravel and sand. Numerous samples were collected in the shallow coastal sea-water up to 20 m depth, in vari-

ous types of bottoms: bottom covered by vegetations (*Chara* spp. etc.), gravel, sand and sediments.

Various samples of amphipods were collected also in the coastal springs and torrents [springs Biljanini Izvori (=Studentčište), several springs near Monastery St. Jovan; springs near Struga (Šum springs), springs near Monastery St. Naum; springs and coastal torrents in Pogradec (Albanian coast), etc.].

The collected material was preserved in the 70% ethanol. The specimens were dissected using a WILD M20 microscope and drawn using camera lucida attachment. All appendages were temporarily submersed in the mixture of glycerine and water for study and drawing. Later all appendages have been transferred to the permanent slides with Liquid of Faure.

## Investigation area

Ohrid Lake is 30.4 km long, and 24.8 km wide, with maximum depth of 288 m. The lake covers area of 358 km<sup>2</sup>, and the shoreline is 87.5 km long. Ohrid Lake is one ancient Tertiary lake originated from the geotectonic depression during the Pliocene epoch, created over 4 million years ago.

Very complex geological history of the basin of Ohrid Lake, the karstic oligotrophy of the lake itself, with favorable atmospheric conditions, and zoogeographical and ecological history and situation, was the base for developing and preservation of highly endemic fauna of Amphipoda in the Lake.

## Results

Based on our study of the Amphipoda fauna from Ohrid Lake basin and the Lake itself during over 40 years, as well as the studied material from other sources, we can recognize among all known species of this region, two species as invaders in Ohrid Lake, *Orchestia cavimana* Heller, 1865 and *Gammarus roeselii* Gervais, 1835.

### FAMILY GAMMARIDAE

#### *Gammarus roeselii* Gervais, 1835 (sensu auct.)

*Carinogammarus roeselii* Spandl 1924: 454; Karaman, S., 1931: 57 (map);

*Carinogammarus roeselii meridionalis* Karaman, S., 1929b: 89 [loc. typ. Ohrid Lake, coastal zone till 20 m depth];

*Carinogammarus triacanthus* Schäferna, 1922: 35, pl. I, fig. 1; text figs. 14, 15 [loc. typ.: N. part of Skadar Lake]; Spandl, 1924: 454; Karaman, S., 1929b: 89, figs. 4a, 5a; Karaman, S., 1931: 56;

*Gammarus (Rivulogammarus) roeselii* f. *triacantha*

Schellenberg, 1943: 100, fig. 2b;  
*Gammarus (Rivulogammarus) triacanthus* Karaman, G., 1966: 125;  
*Gammarus (Rivulogammarus) roeselii* Schellenberg, 1937: 511;  
*Gammarus roeselii* Karaman, G. & Pinkster, 1977: 170, figs. 1-3; Karaman, G., 1997: 24; Karaman, G., 2003: 55;  
*Gammarus roeselii* f. *triacanthus* Karaman, G., 1981: 249.

**Locus typicus:** River Yonne near Coulanges-sur-Yonne, France.

**Material examined:**

- Ohrid Lake, Monastery St. Naum, spring of Crni Drim river, 7 exp., 18. 7. 2011 [mixed with *G. parechiniformis* Kar. G., 1977 [leg. M. Komnenov];
- Sateska reka-River, influent of Ohrid Lake, Macedonia, 3 exp., 1957 [leg. Institute Ohrid];
- Ohrid Lake, several springs E. of Monastery St. Naum, 17. 10. 2012, many exp. [leg. Karaman, G. & Karaman, B.);
- Ohrid Lake, in *Chara* sp., depth 13-15 m, Macedonia, 4. 9. 1934, 8 exp. (leg. T. Wolski);
- Biljanini izvori- springs at coast of Ohrid Lake in town Ohrid, 21. 7. 1969, many exp. mixed with *Gamm. ochridensis* Schäf., 1926 (leg. G. Karaman);
- Ohrid Lake, coast on road Ohrid- Struga, 0.20-0.90m depth along coast in the *Scirpus* plants, 19.7. 1985, many exp. (leg. Karaman, G. & Karaman, B.).

**Localities cited for Ohrid lake basin:**

Spandl (1924) cited *G. roeselii* for Ohrid Lake and springs near Ohrid.

Stanko Karaman (1929A) cited this species from Ohrid Lake (on depth till 20 m) (*Carinogammarus roeselii meridionalis*) and from the springs in the vicinity of Ohrid (*triacanthus*).

Stanko Karaman (1937) mentioned this species for the springs at the coast of Ohrid Lake (*triacanthus*) and the coastal zone of the Ohrid Lake (*roeselii meridionalis*).

Schellenberg (1943) cited this species for Kalište and Ohrid Lake off Ohrid (12 m) (*roeselii*); Bej Bunar spring; Šum spring; spring near St Naum (mixed populations);

Karaman, S. & Karaman, G. (1959): Šum springs near Struga (*triacanthus*); Ohrid Lake (*triacanthus* and *roeselii*);

Karaman, G. (2003) cited it for Pogradec, Albania.

Smiljkov et al. (2005): Ohrid Lake (Radožđa; Livadište; Kališta; Struga; As).

**Discussion**

*Gammarus roeselii* Gervais, 1835 is widely distributed species in rivers and springs over Central and SE Europe, often collected mixed with some other native *Gammarus* species. This very variable species is characterized by presence of 4 dorsocentral body-teeth.

Schäferna (1922) discovered and described similar species *Carinogammarus triacanthus* from Skadar Lake (Crna Gora), species with only 3 dorsal body-teeth. Later there were found often mixed populations with specimens having 3 or 4 teeth, as well as specimens with transitive this character, and Schellenberg (1943) removed *G. triacanthus* to the species *G. roeselii* as a distinct form only (*R. roeselii* f. *triacanthus*).

Because of very large variability of populations of *G. roeselii* in various localities, several distinct subspecies and forms were created by various authors (*Carinogammarus roeselii meridionalis* S. Karaman 1929b from Ohrid Lake; *Carinogammarus vardarensis vardarensis* S. Karaman 1929b from Vardar river, *Rivulogammarus (Fluviogammarus) triacanthus strumicae* Karaman, S. & Karaman, G. 1959 from Strumica river, etc. On the other hands, various authors cited single taxa under different names, as subspecies, species, forms or synonyms (Karaman & Pinkster 1977).

The present taxonomical status of all taxa of *Gammarus roeselii*-complex is not clear. As the morphological characters seems to be not sufficient to recognize separate distinct taxa within this complex, it is necessary to revise all taxa based on morphological and genetic characters. It is evident that within the *G. roeselii*-complex exist various distinct taxa, but for the moment we mentioned here all populations under the name *Gammarus roeselii* Gervais, 1835 and his forma *triacanthus* Schäferna, 1922. In this work we took in consideration only data regarding Ohrid Lake basin.

We collected *G. roeselii* in many springs and small torrents around the Ohrid Lake: Biljanini Izvori springs (=Studenčište), several springs near Monastery St. Naum, spring and torrents in Pogradec (Albanian coast of Ohrid Lake), springs near Struga, etc. But, in the shallow coastal waters of the Lake (0-20 m), between Struga and Ohrid Town, and shallow waters near Pogradec, numerous specimens of *G. roeselli* were collected mixed with specimens of f. *triacanthus*, as well as intermediate specimens. These samples support conclusion that the number of dorsal body spines is not enough distinct character to recognize the different taxa within *G. roeselii* - complex.

*Gammarus roeselii* (sensu auct.) began his invasion from the SE Europe and Asia Minor towards the West probably after the last glacial period, and

his invasion is still in the progress. Twenty years ago it was collected at the first time in NE Italy (Padova) (Karaman G. 1993).

In the Ohrid Lake, *G. roeselii* have not penetrated deeply in the Lake because of the strong biological resistance and competition with the native *Gammarus*-species existing already there. It remains in some shallow part of the Lake often covered by plant *Chara* or in the lower part of the small tributaries and springs near the lake, often in the mixed populations with native species.

*Gammarus roeselii* pushed often the other native torrent- species towards the spring, sometimes eliminating completely the native species (*G. balcanicus* or *G. ochridensis*). Our laboratory experiments show that *G. roeselii* support much larger ecological variability than native species *G. balcanicus* Schäf., 1922, especially regarding the water temperature, oxygen consumption, variety of the food, etc. (Karaman G. 1966). We believe that the biological resistance of native *Gammarus* fauna in the Lake Ohrid is strong enough to prevent invasion of this invasive species into deeper parts of Ohrid Lake.

#### Family TALITRIDAE

##### *Orchestia cavimana* Heller, 1865 (sensu auct.)

*Orchestia cavimana* Heller, 1865: 979, pl. 17, fig. 1; Karaman, G., 1965: 27P, fig. 1-5; Karaman, G., 1998a: 38; Karaman, G., 1998b: 28; Karaman, G., 2003: 53.

LOCUS TYPICUS: Olympus Mt., Cyprus island.

##### Material examined:

- Coast of Ohrid Lake between Struga and Pogradec, Albania, 11. 10., 2012, 5 exp. [leg. Karaman, G. & Karaman, B.];
- Coast of Ohrid Lake near Peštani, Macedonia, 16. 10. 2012, 4 exp. [leg. Karaman, G. & Karaman, B.];
- Coast of Ohrid Lake near Ohrid town, 15. 10. 2012 (leg. Karaman, G. & Karaman, B.).

##### Localities cited from Ohrid Lake basin:

Karaman, G. (1998b): Coast of Ohrid Lake near Monastery St. Naum; mouth of the springs near this monastery.

Karaman, G. (2003): Coast and springs near Pogradec [Albania, Ohrid Lake].

#### Discussion

*Orchestia cavimana* is marine element settled sea coast over Europe, Mediterranean coast and Asia Minor, but always the places with slightly or pure freshwaters. This species penetrated often deeply into the European continent through the mouth of the rivers, and settled some freshwater lakes far from the sea also [Lago di Garda in N. Italy, etc.] (Karaman G. 1993).

This species has been discovered at the first time in Macedonia (Dojran Lake) in 1965 (Karaman G. 1965) and later along the coast of Ohrid Lake in Macedonia and Albania (Karaman G. 1998b, 2003). At the same time, we discovered it also in Serbia [Danube river in Karataš and Kladovo (Karaman G. 1998a)].

*Orchestia cavimana* invaded recently Ohrid Lake coast, because during our numerous studies of Amphipoda fauna of Ohrid Lake provided during last 50 years, this species was never found before 1998. The ecological consequences of this invasion to the native fauna are still unknown.

Because of very large distribution of this species in very different ecological niches, the new molecular and genetic studies provided by some authors, indicated the possible existence of more distinct taxa within *Orchestia cavimana* (sensu auctorum)-Complex.

#### Conclusion

The present fauna of Amphipoda in Ohrid Lake is consisting of over 12 endemic species belonging to 3 genera: *Synurella* Wrzesniowski, 1877, *Gammarus* Fabricius, 1775 and *Niphargus* Schiödte, 1849. But, in Ohrid Lake are discovered 2 invaders belonging to 2 different families and genera: *Orchestia cavimana* Heller, 1865 (sensu auct.), invasive species of marine origin, and *Gammarus roeselii* Gervais, 1835, freshwater invader coming from the SE Europe and Asia Minor.

*Gammarus roeselii* invaded Ohrid Lake probably after the last Glacial period, and *Orchestia cavimana* (sensu auct.) invaded Ohrid Lake recently, because it was discovered at the first time along Ohrid Lake shore in 1998, despite intensive previous studies of Ohrid fauna during last 80 years by various authors.

The recent molecular and genetic studies of *G. roeselii* and *O. cavimana* suggested the existence of possible more distinct taxa within the present *G. roeselii* (sensu auct.) and *O. cavimana* (sensu auct.).

It is necessary to study the steps of these invasions of the Lake and the eventual consequences on the native Amphipoda fauna in Ohrid Lake.

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