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RESEARCH ARTICLE

Potential causes for the stranding of *Macrohectopus branickii* (Dybowsky, 1874) specimens along the Angara River: strong currents, artificial lighting, or ice melting

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Abstract

Macrohectopus branickii (Dybowsky, 1874) is the world's only freshwater pelagic amphipod native to Lake Baikal. The habitat of this amphipod is limited to the pelagic zone of Lake Baikal (with periodic nocturnal migrations to the littoral part of the lake). Until now, this amphipod had never been recorded in the rivers flowing into Lake Baikal or in the Angara River flowing out of it. However, on 16 May 2022, near the Taltsy Museum, 20 km from the source of the Angara River, a massive accumulation of *Macrohectopus* individuals was washed ashore. The reasons for this phenomenon are still unknown. Considering the uniqueness of *M. branickii* within the world amphipod fauna and its importance for the Lake Baikal ecosystem, the determination of the factors contributing to this phenomenon is of great importance. In this paper we have presented some hypotheses that could explain the appearance of *Macrohectopus* on the shores of the Angara River. The first hypothesis is that the amphipods could not cope with the current at the source of the river and were carried down the river, and since they are negatively affected by natural light (at the beginning of the morning), they became trapped and died. The second hypothesis is that the *Macrohectopus* were attracted and disoriented by the artificial light emanating from the nearby villages, before being carried by the current. The third hypothesis relates

to the time frame in which this event was observed. This peculiar phenomenon was observed in mid-May, following the melting of the ice on Lake Baikal. Accordingly, *Macrohectopus* could have been feeding on the lower surface of the ice, or alternatively they could have been frozen in the ice as the ice floes were transported downstream. Each of the hypotheses we have presented does not necessarily exclude the others, but on the contrary may complement them. In this paper we do not exclude the possibility that there are other explanations for this phenomenon. However, if massive washing ashore of *Macrohectopus* occurs regularly, further research is needed, taking into account, among other things, the influence of washed ashore individuals on the food spectrum of aquatic organisms and waterfowl of the Angara River.

Keywords
Amphipods, ALAN, artificial light at night, daily vertical migrations, feeding under ice, Lake Baikal

Introduction

Lake Baikal is a unique natural complex that originated approximately 25–30 million years ago. Its formation was influenced by a blend of different factors, such as geography, geology and climate. These resulted in unique flora and fauna evolving in Baikal. The lake is recognised for its high level of biological diversity and endemism; two-thirds of its inhabitants are considered to be endemic. The amphipods (Crustacea) constitute the most abundant and entirely autochthonous group of macroinvertebrates in the lake, encompassing over 354 distinct species and subspecies (Takhteev et al. 2015). Amphipods exhibit a widespread distribution throughout the lake, being present in all depths and soil types, and occupying various ecological niches. For instance, the population comprises of both omnivorous littoral zone inhabitants and deep-sea scavengers (Takhteev and Didorenko 2015). Among the diverse range of amphipods inhabiting Baikal, *Macrohectopus branickii* (Dybowsky, 1874) is noteworthy. It is the singular freshwater pelagic amphipod known to the scientific community worldwide. In addition, this species occupies an ecological niche similar to mysids (in large European and North American lakes) and Antarctic krill (Rudstam et al. 1998; Jude et al. 2018, Holda et al. 2021). *M. branickii* plays an important role in the lake's ecosystem. It is one of the main components of the diet of pelagic fish (*Comephorus* spp., *Cottocomephorus* spp., *Coregonus migratorius* (Georgi, 1775)) (Rudstam et al. 1992). It is the dominant invertebrate zooplankton predator in the lake, feeding mainly on the copepod species *Epischura baikalensis* (Sars, 1900). During the day, *M. branickii* lives at a depth of 200-700 m; with the onset of night, it makes vertical migrations to the upper water layers to feed (Rudstam et al. 1992). *Macrohectopus* individuals typically exhibit a sociable behaviour during vertical migrations and daytime hours (Naumova et al. 2020). The formation of groups is influenced by the mobility of individuals which is determined by their size. It is worth mentioning that this species displays sexual dimorphism, with females reaching a maximum size of 38 mm and males not exceeding 6 mm (Timoshkin et al. 1995).

Macrohectopus is not present in the rivers that flow into Baikal or in the Angara, which flows from it, due to ecological factors. Nonetheless, in the Taltsy Museum region, located approximately 20 km away from the source of the Angara River, a significant number of *M. branickii* individuals were found stranded on May 16, 2022. The strand of discarded individuals spanned several tens of meters. This phenomenon is new and its causes are yet to be determined. Our study attempts to put forth a number of hypotheses that provide potential explanations for this phenomenon.

Materials and methods

On May 16, 2022, *Macrohectopus* individuals washed up on the shore in the vicinity of Taltsy Museum (51°59'28.2"N 104°39'54.1"E). Photographs were captured to scale, employing a ruler for reference. These images were subsequently processed in the ImageJ program, utilizing the Cell Counter plugin to determine the count of individuals in each photograph.

The section of shore (where *Macrohectopus* was found) is a bottleneck between two wider areas. The width of the river at this location is 1.017 km, the width upstream is 1.84 km, and the width downstream is 2.37 km. A shallow sandy littoral with a depth of up to 4 m adjoins the shore (at the place where *Macrohectopus* was found). This sandy area extends 70 m from the shore. In addition, it is worth noting that the maximum depth (in the area from the source of the river to the city of Irkutsk) is 35 m, and the average depth is 13.6 m.

Results

Objectively, only sexually mature female individuals of large size were observed in this region. After accurately counting and recalculating discarded individuals per meter of coastline, the average number recorded was 1769 individuals/meter of coastline. Mature female *Macrohectopus* individuals have a minimum size of 15 mm. The discarded Macrohectopus individuals' biomass along the coastline was estimated at a minimum of 54.824 g/meter, applying the methodological manual (weight of individuals of this size is 31 mg) as indicated by Arov et al. (2000). As previously noted, a substantial wash ashore of *Macrohectopus* individuals on the Angara River was observed for the first time. Therefore, this paper presents several hypotheses to explain this phenomenon comprehensively and objectively.

First hypothesis. It is known that Lake Baikal features circular underwater currents that allow schools of *Macrohectopus* to move through the water column. Additionally, individuals of *M. branickii* may be absent for extended periods (ranging from months to years) in specific local areas of the lake's pelagic zone (Karnaukhov et al. 2023). Thus, a flock of *Macrohectopus* individuals, after undergoing ver-

tical migration to the water's surface during the night, could find themselves in a particular section of the pelagic zone near the source of Angara, which could lead them further down the river. Due to the negative impact of natural light on *Macrohectopus*, removed individuals become trapped and perish at dawn. Nevertheless, this theory is contested by data indicating that female specimens of *M. branickii* (specifically, large females that washed up ashore) exhibit a considerable speed of 4 m/s (Koryakov 1977; Sherstyankin and Kaplin 1973). This velocity could provide adequate resistance for *Macrohectopus* individuals against the flow at the Angara River's origin (Fig. 1).

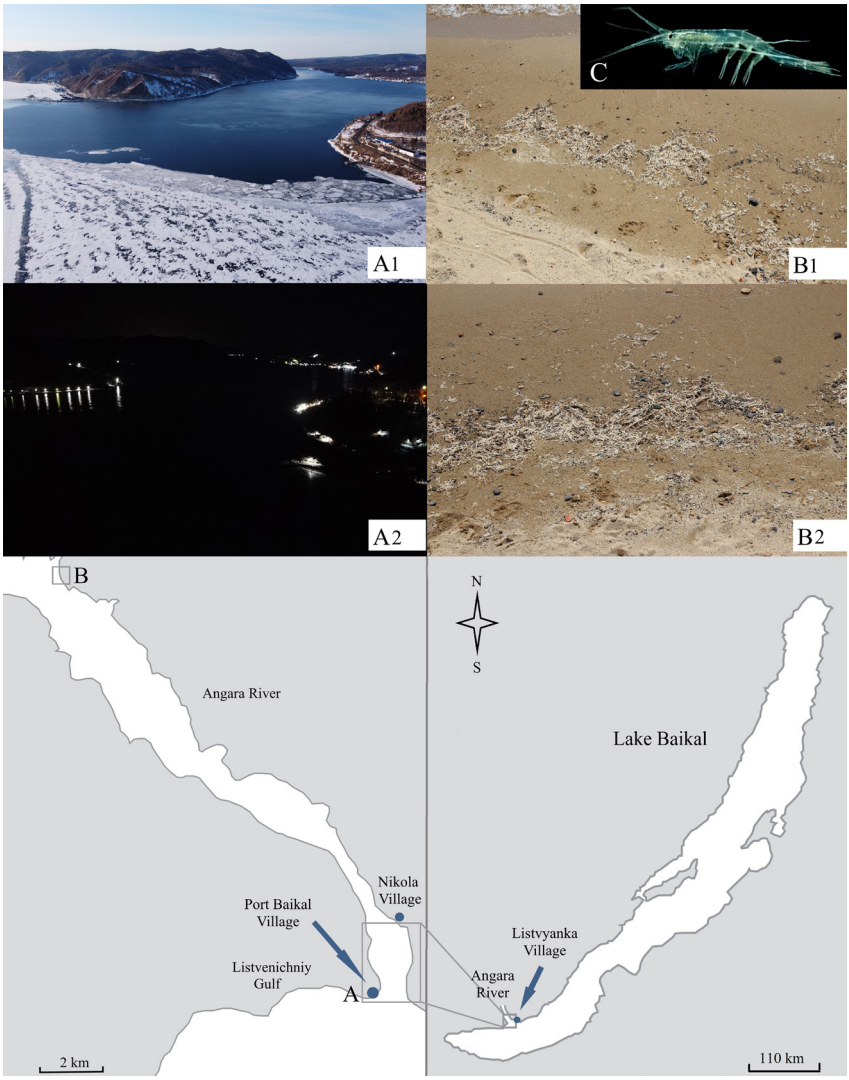

Figure 1. Scheme illustrating the position of the Angara River source during day and night (**A**) and the coastline location in the Taltsy Museum area (**B**), as well as an adult female Macrohectopus (Photo by Drozdova P.) (**C**).

Second hypothesis. It is hypothesised that certain species of amphipods have an attraction to artificial light (Czarnecka et al. 2022). Furthermore, artificial lighting attracts some Baikal amphipod species (Takhteev et al. 2019). The *Macrohectopus* has not escaped this phenomenon, and according to some research, it responds differently to artificial lighting with varying spectral characteristics (Karnaukhov et al. 2019b). It is plausible that a group of *Macrohectopus*, which had ascended to the surface near the origin, were drawn to the artificial illumination (Fig. 1), and subsequently transported downstream by the flow. This occurrence may not have been detected previously for two reasons. Firstly, as we already mentioned, *Macrohectopus* individuals could be absent from specific regions within the lake's pelagic zone for prolonged periods or may not exist in significant numbers. Furthermore, it is established that diverse forms of man-made illumination can influence the conduct of *Macrohectopus* differently. In recent years, there has been a considerable shift from one source to another for artificial lighting. According to the literature, it is known that these light sources vary in spectral characteristics and their effects on organisms. There are light sources, specifically LEDs, which possess a broad spectrum with a peak in the blue section of the wavelength range (400-480 nm). In addition, narrowband light sources like low and high pressure sodium lamps have peaks shifted towards yellow-red (560-750 nm) and infrared light (800-850 nm) (Davies and Smyth 2018; Elvidge et al. 2010), the same is true for a standard incandescent lamp. Thus, the population's transition from one light source to another could have affected the attraction of *Macrohectopus* individuals.

Third hypothesis. The described phenomenon was observed relatively immediately (in mid-May) after the ice cover on Lake Baikal melted. Accordingly, it can be assumed that either *Macrohectopus* individuals could have been frozen into the ice (Fig. 2), or they could have fed on the underside of the ice at night, when these ice floes were carried with the current into the Angara (Fig. 1). Freezing of *Macrohectopus* into ice has been repeatedly noted previously (Karnaukhov et al. 2019a). In turn, the feeding process of *Macrohectopus* individuals near the lower side of the ice has not yet been recorded, however, this process is characteristic of Antarctic krill (a species that occupies a similar ecological niche with *Macrohectopus*) (Rudstam et al. 1998).

Irrespective of the cause, this occurrence can impact ongoing trophic relationships. It is possible that certain fish or birds can partially or entirely alter their feeding habits to include *Macrohectopus* during its wash ashore of the Angara River. Consequently, this may result in a surge in the population of organisms that are normally preyed upon by fish and birds. Examples of one-time, short-lived population bursts that can affect the trophic balance of an ecosystem for multiple years are already observable within the animal kingdom (Getman-Pickering et al. 2023). Significantly, the incorporation of *Macrohectopus* in further trophic connections necessitates comprehensive and specialised investigation. Since phenomena discovered in recent years, for example, this phenomenon, or the feeding of bats with

Macrohectopus (Botvinkin et al. 2021, Didorenko et al. 2021, 2022), introduce additional questions into establishing the abundance of this amphipod important for the lake ecosystem (Afanasyeva et al. 1984; Timoshkin et al. 1995).

Conclusion

In this paper we have presented a number of hypotheses (random removal by a strong current, attraction by artificial lighting, removal by ice floes) that we believe can explain the phenomenon observed in May 2022. It should be noted that some of these hypotheses are by no means mutually exclusive and may overlap. Given that this is the first time that this phenomenon has been observed, we do not exclude the possibility that there are other causes that we have not described in this paper. If this phenomenon occurs with high frequency, it will require detailed study.

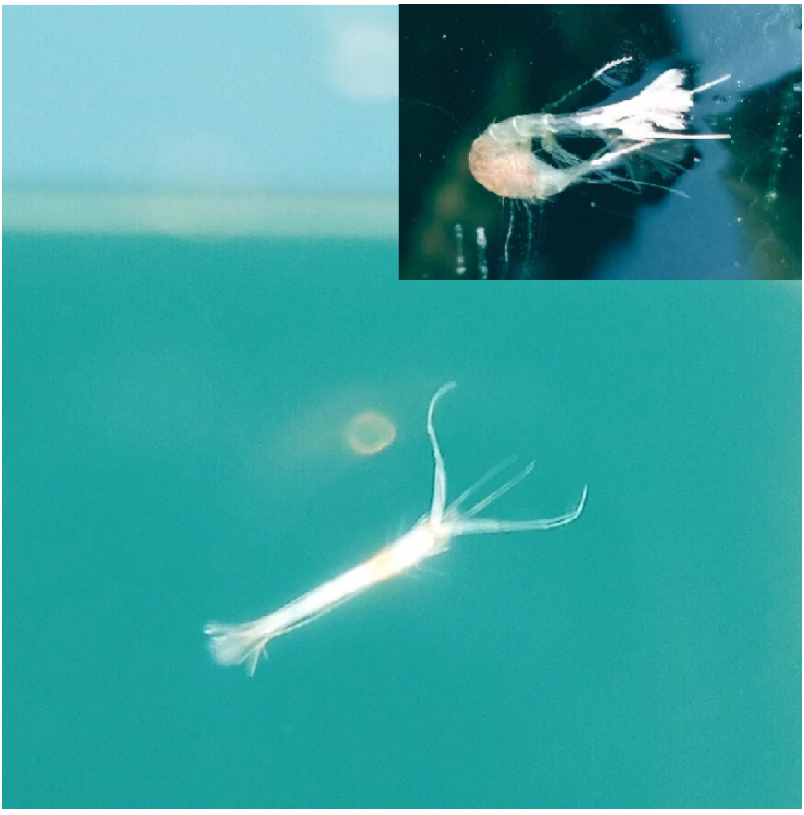

Figure 2. Individuals of *M. branickii* frozen in ice (Photo by Shipitsin A.).

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