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REVIEW PAPER

Past, present, and future roles of small cladoceran *Bosmina longirostris* (O. F. Müller, 1785) in aquatic ecosystems

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Abstract *Bosmina longirostris* is a small-bodied, filter-feeding cladoceran. The species is widely distributed throughout the world in temperate and tropical climates, where it persists in all kinds of freshwater bodies regardless of their trophy, acidification, or salinity. Its wide distribution causes *B. longirostris* to be one of the most taxonomically recognizable Cladocera species all over the world, despite the fact that the species is a well-known example of a taxon with confused taxonomy. Although *B. longirostris* often displays high abundances in the world's freshwaters and sporadic studies on its feeding suggest that the species can have an important role in energy transfer throughout the food web, *B. longirostris* is still perceived by scientists as having a minor role in the classical food web structure. This perception of *B. longirostris* as a food web component could be altered in the near future due to global climatic changes, including increases in temperature which may cause cyanobacterial blooms that may be more harmful to *Daphnia* than *B. longirostris*. The response of *B. longirostris* to environmental, competitive, and predatory conditions has been repeatedly studied to search for application of that species as indicator in ecological, neolimnological, and paleolimnological research. Regardless of its common use as test species in ecological and limnological studies, *B. longirostris* still lacks appropriate study by researchers because of its problematic systematics. Research directed at this species seems to be hampered by the absence of an accurate taxonomical revision of *B. longirostris* or group of cryptic species called *B. longirostris*.

Keywords Bosminidae · Food web · Indicator · Cryptic species

Introduction

The Cladocera (commonly called water fleas) constitute an ancient clade of branchiopod crustaceans comprising 16 or 18 family lineages (Olesen, 1998; Stenderup et al., 2006). Most of these are herbivorous filter-feeders. They are known to switch between parthenogenetic and sexual reproduction when environmental conditions for growth and reproduction deteriorate (Taylor et al., 1999). They are relatively tolerant to environmental conditions, which would confirm their opportunistic and potentially invasive nature. As a result, Cladocera are distributed circumglobally and mostly occur in temporary or permanent freshwater pools, although a few species have colonized marine or brackish habitats (Richter et al.,

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2007). Cladocerans fulfill the pivotal role in aquatic food webs, for, through their grazing activities on picoplankton, nannoplankton, and microplankton populations, they function as intermediaries between lower trophic levels and fish. Currently, there are more than 600 known taxa of Cladocera (Korovchinsky, 1996). Among cladocerans, *Daphnia* genus is considered to be crucial for their ability to determine water quality due to its key role in biomass transfer between phytoplankton and planktivorous fish.

A small-bodied, filter-feeding cladoceran called *Bosmina longirostris* is one of the most recognizable species of Cladocera due to the round shape of its carapace, the easily distinguishable form of its postabdomen, and the distinctive shapes of its appendages, including chitinous anterior and posterior protuberances called antennules and mucrones, respectively. *B. longirostris* is widely distributed throughout the world in temperate and tropical climates including Holarctic, Nearctic, Palearctic, Neotropical, and Ethiopian regions. Although *B. longirostris* is a commonly distributed typical representative of branchiopod crustaceans, it is regarded to have a minor role in energy transfer through aquatic food webs due to its small body size resulting in their narrow food niche and minor role in the diets of fish. For a long period of time, *B. longirostris* constituted an interesting research subject for its defense mechanisms against predatory invertebrates that appear in the shape and longevity of its appendages. An interest in the ecology of *B. longirostris* has increased, since some studies have reported probable changes in food web components caused by current climate changes. Those changes may include the diminishment of *Daphnia* as a key herbivore and the increase of small-bodied cladocerans. Thereby, a number of studies have undertaken the challenge of testing how changes in the environment influence small herbivores represented mostly by *B. longirostris*. This has been done to predict future changes in aquatic ecosystems. These studies show that *B. longirostris* is more tolerant than other cladocerans to a large number of the stresses which may happen under natural conditions. Undoubtedly, this has increased scientific interest in this species.

In this paper, I discuss taxonomic problems of *B. longirostris*, summarize the growing body of literature on the applicable role of *B. longirostris* in paleolimnological, neolimnological, and ecological studies,

and highlight its potential role as a food web component on the grounds of its tolerance to unfavorable environmental conditions. I hope the review will encourage others and provide a firm foundation for future research on *B. longirostris*.

Confusing morphology

Despite some clear features identifying *B. longirostris* all over the world and its set phylogenetic status in Bosminidae family, the systematics of this species have notoriously caused confusion because *B. longirostris* shows clearly visible variance in the shape of its carapace, as well as the length and curvature of its appendages. Indeed, this confusion has existed for more than 200 years. *B. longirostris* was described for the first time by Otto Friedrich Müller in 1785. Afterward, other morphs of *B. longirostris* were described as distinct species; namely *B. curvirostris* Fisher, 1854, *B. cornuta* G. O. Sars, 1862, *B. brevicornis* Hellich, 1877, *B. similis* G. O. Sars 1870, and *B. pellucida* Stingelin, 1895. Finally, these were recognized as morphotypes of a single species, *B. longirostris*, the morphotype of which was described by O. F. Müller and called *typica* (Fig. 1). Nonetheless, biologists are still not sure of the systematic affiliation of those morphotypes. Besides *B. longirostris* forma *typica*, morphotypes of *cornuta*, *simillis*, and *pellucida* are the most often encountered in the world's freshwaters. They show distinct differences in the length and shape of their appendages: forma *typica* has quite a short and straight antennule and middle-sized mucrone; forma *similis* has a long, straight antennule and long crenate mucrone; forma *pellucida* has a slightly curved antennule and middle-sized mucrone; and forma *cornuta* has a hooked antennule and short mucrone (Margaritora, 1983; Lieder, 1996). Important diagnostic traits of *B. longirostris* include the head pores that are located on each side of the head in the region of the mandibular articulation (lateral head pores), on the median line above the compound eye (median head pores) (Goulden & Frey, 1963), and above the rostrum, between the two frontal setae (frontal head pores) (Kořinek, 1971). Studies on the distribution and shape of head pores show differences between the populations of *B. longirostris* from North America and Europe as well as differences among European

Fig. 1 Different morphotypes of *B. longirostris*: **a** *typica*, **b** *curvirostris*, **c** *cornuta*, **d** *brevicornis*, **e** *similis*, **f** *pellucida*
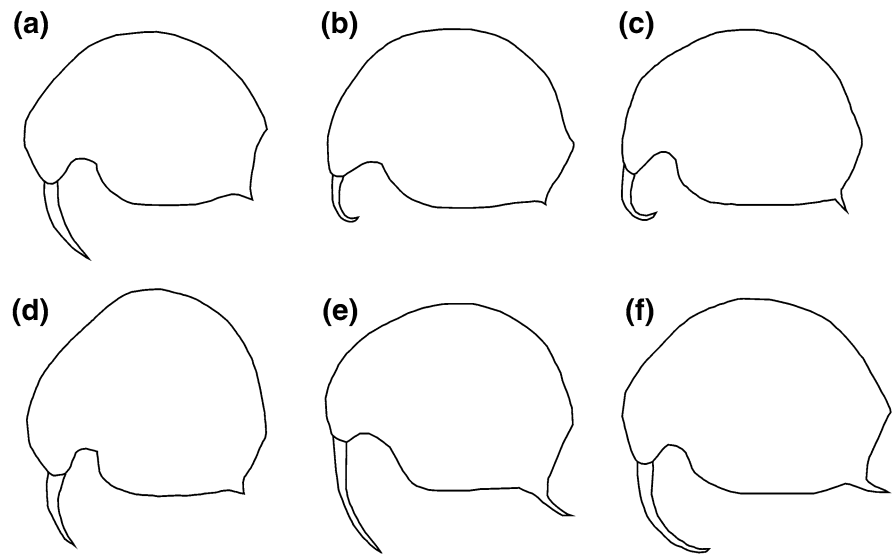
populations of the species. De Melo & Hebert (1994) found that the lateral head pores of North American *B. longirostris* are circular, and their lateral projection under the microscope produces an elongated shape as an apparent image. Goulden & Frey (1963), as well as Kořínek et al. (1997), established that the lateral head pores of European populations of *B. longirostris* are elongated, with a ventral margin which is nearly straight and a vaulted dorsal margin, and their lateral projection under the microscope produces an undistorted image. Hudec (1989) observed that differences in lateral head pores are morphotype specific, thus suggesting a species-specific derivation of the morphotypes in Slovakian populations of *B. longirostris*, whereas Kappes & Sinsch (2002) supported the hypothesis that differences in the position of the lateral head pores are not morphotype specific in populations of *B. longirostris* from German lakes.

Why so many morphological differences?

Despite the unspecified phylogenetic status of the *B. longirostris* morphotypes, it has been observed that antennules and mucrones fulfill an important role in anti-predator defense behavior, and now it is widely accepted that morphotypes with elongated appendages are favored under conditions of high invertebrate predation. The role of appendages in anti-predator defense is such that individuals attacked by

invertebrate predators fold their single pair of swimming antennae into a groove behind the antennule and fall passively through the water column. During this motionless, dead-man behavior, fixed antennules protect the antennae, whereas mucrones protect against rotation toward the ventral groove region, through which feeding particles are filtered (Kerfoot, 1975a). When grasped by a predatory invertebrate, an individual with longer appendages is far more difficult to maneuver by a predator, and thus it has a greater probability of escaping from an encounter with a predator (Kerfoot, 1977, 1978; Post et al., 1995; Chang & Chanazato, 2003). The extreme morphological features of *B. longirostris* tend to diminish when individuals are taken from natural populations and reared in the absence of predator stimuli (Kerfoot & McNaught, 2010). Some studies have suggested that *B. longirostris* displays cyclomorphosis, i.e., seasonal polymorphism triggered by specific environmental variables (Hutchinson, 1967) which is an often observed phenomenon in cladocerans. The following patterns of life-history traits have been classified as cyclomorphosis in *B. longirostris*: (1) seasonal body size changes during spring and winter of large-sized, and during summer of small-sized individuals (Razak & Saisho, 1970); (2) egg size with small eggs in spring and summer, and bigger eggs in autumn (Razak & Saisho, 1970); (3) mucrone length with short mucrones during spring and summer and long mucrones during autumn (Kerfoot, 1975b); and (4)

antennule length with short antennules in spring and early summer, and long antennules in late summer and autumn (Kerfoot, 1975b). Kappes & Sinsch (2002) questioned the cyclomorphic changes in the length and shape of appendages, since they observed that cyclomorphosis in *B. longirostris* did not consist of a gradual change from one morphotype to another, but of a change in body shape within a morphotype. The phenomenon of the coexistence of different morphotypes within a population under laboratory conditions (Sakamoto et al., 2007) also weighs against the hypothesis of the seasonal occurrence of different morphotypes as the result of cyclomorphosis. To date, there have been no studies on the life history trade-offs of short- and long-appendaged *B. longirostris*, but it can be assumed that morphotypes of *B. longirostris* differ in life-history trade-offs, since reports on the costs of the phenotypic plasticity of other species of Cladocera have suggested that appendaged individuals have a lower intrinsic rate of population growth (Zaret, 1969; O'Brien & Vinyard, 1978; Hebert & Loaring, 1980), a lower rate of filtration (O'Brien & Vinyard, 1978), and produce fewer eggs with more yolk (Kerfoot, 1977) in comparison to non-appendaged individuals.

How does *Bosmina longirostris* grow?

Kappes & Sinsch (2002), who studied phenotypic differentiation among *typica*, *pellucida*, and *cornuta* morphotypes, found no gradual changes from one morph to another during ontogenic development. Concurrently, they concluded that only adult individuals showed morphological traits characteristic to distinct morphs, whereas juveniles mainly resembled the morph *pellucida*, and only a few *cornuta*, which is in slight contradiction to their former statement. Sakamoto & Hanazato (2009), when studying the relations between the invertebrate predation and morphologic plasticity of *B. longirostris*, found that, although adults were *pellucida* or *cornuta* morphotypes, all juvenile individuals presented *pellucida* morphotypes. Sakamoto et al. (2007) cultured separately three monoclonal populations of *B. longirostris* descending from three distinct clones under conditions of optimal food and without predatory pressure. They found that in each of the monoclonal populations, *cornuta*: *typica* and *pellucida* morphotypes occurred,

and the ratio of *cornuta*: *typica/pellucida* was 65.8:34.2 in the first population, and respectively, 43:57 in the second population, 92.6:7.4 in the third population. Thus, contrary to Kappes & Sinsch (2002) who concluded that antennule shapes are invariable phenotypes, Sakamoto et al.'s studies showed that morphotypes of *typica*, *pellucida* and *cornuta* are not hereditarily rigid phenotypes within a species. Those findings could suggest strong spontaneous epigenetic regulation of phenotypes in *B. longirostris*. Sakamoto & Hanazato (2009) compared the length of antennules and mucrones and body size between different treatments (laboratory *versus* field and predator *versus* no predator conditions) concluding that the smallest (thus, probably the youngest) individuals had significantly longer antennules and mucrones than larger *ergo* older individuals. This could be explained by their atypical growth consisting of a progressive reduction in the lengths of antennules and mucrones during the ontogenic development of *B. longirostris*. This could also suggest that anti-predator defense mechanisms mainly appear in juvenile individuals and disappear steadily during maturation. If atypical growth of antennules and mucrones is possible, this can suggest steady shifts from the *pellucida* morph to *cornuta* or *typica* morphotypes, despite the fact that some authors have rejected such a possibility. Thus, the hypothesis that different morphotypes are not genetically distinct forms, but are only developmental stages in the ontogenic development of *B. longirostris* is highly possible.

Bosmina longirostris as a food web component

Despite the common occurrence and often high abundances of *B. longirostris* in the world's freshwaters, the species is perceived as having a minor role in classical food web structure. The assignment to *B. longirostris* of such low importance in aquatic food webs results from its relatively small body size. It is assumed in mechanistic models that the body sizes of herbivorous zooplankton determine their grazing selectivity patterns and the size range of the grazed algae. Thus, according to that assumption small herbivores (e.g., *B. longirostris*) mainly feed upon small phytoplankton, and large herbivores (e.g., *Daphnia* species) feed on a wider size range of phytoplankton (Hansson et al., 1998). Contrary to that

assumption, experimental studies have displayed shifts to small algae in the presence of small grazers and shifts to larger algae as grazer size increased (Carpenter & Kitchell, 1984; Berquist et al., 1985). Despite the fact that the role of *B. longirostris* in the classical food web is not clear, its role in the microbial food web is truly unquestionable. The abilities of *Daphnia* and *B. longirostris* to depress the densities of ciliata and heterotrophic nanoflagellates are similar (Burns & Schallenberg, 1996; Jürgens et al., 1996), but *B. longirostris* is more effective than *Daphnia* in feeding bacteria (De Mott, 1982). Thus, since *B. longirostris* affects each level of the microbial loop, the species can have a key role in transferring energy, carbon cycling, and nutrient remineralization throughout the microbial and classical food web. The role of *B. longirostris* in the food web is also enhanced by its ubiquitous behavior in lakes. Just as the *Daphnia* avoidance of littoral habitats is well known (Lauridsen & Lodge, 1996; Bergstrőm et al., 2000), *B. longirostris* shows quite even horizontal and vertical distributions (Adamczuk, 2012a) suggesting its similar trophic role in both littoral and pelagic food webs.

Bosmina longirostris as an indicator of the past

Bosmina longirostris and other Bosminidae constitute an important group of indicators in paleolimnological studies. The successful use of bosminids in that field of science stems from their cosmopolitanism, excellent preservation of body parts in sediments (Jeppesen et al., 2001), and the ease of discerning Bosmina species from head shields (Szeroczyńska & Sarmaja-Korjonen, 2007). The shape of *B. longirostris* shields provides us with important information about past predatory pressure (Korosi et al., 2013). Paleoecological studies conducted by Kerfoot (1981) revealed progressive shifts from late-glacial long-appendaged morphotypes to the recent dominance of short-appendaged morphotypes, suggesting long-term changes in dominant predatory types. These results were later supported by Sanford (1993) who showed the extended dominance of forma *cornuta* as a response to the diminishment of invertebrate predation in favor of predation by planktivorous fish. Currently, the proportion of *cornuta* to morphotypes with long attennules is commonly used in paleolimnology as an indicator of fish predation (Sanford, 1993; Salo

et al., 1994). It remains to be suggested that the dominance of *B. longirostris* is also useful for quantitative reconstruction of the eutrophication process, as the domination of *B. longirostris* along with elevated nutrient status has been observed in many paleolimnological studies of European lakes (Nevalainen & Luoto, 2012; Jensen et al., 2013; Nevalainen et al., 2013). The replacement of *E. coregoni* and *E. longispina* by *B. longirostris* is regarded as a classical case of eutrophication-induced species succession in the past millennia (Goulden, 1964; Crisman & Whitehead, 1978). Nonetheless, studies in Arctic lakes did not support the role of *B. longirostris* as an indicator of eutrophication processes and have proposed this species as an indicator of deep and clear water, since Frolova et al. (2014) found that *B. longirostris* was associated with deep, clear Siberian lakes, and Davidson et al. (2011) linked the occurrence of *B. longirostris* to deeper sites and the presence of fish in lakes in Greenland.

Bosmina longirostris in an unpredictable world

The world's freshwaters are considered to be subject to intense climate changes with prospective climate-induced alterations in the structure and function of aquatic ecosystems, including further eutrophication of already eutrophic lakes (Moss et al., 2011), an increase in salinity in coastal lakes (Zehrer et al., 2015), higher proportions of cyanobacteria in summer (Wagner & Adrian, 2009; Kosten et al., 2012), changes in physiological processes (Hawkins, 1995), and changes in response to predation regimes resulting in significant changes in community composition and energy transfer through food web structures (Emmerson et al., 2005; Jeppesen et al., 2010; Adamczuk et al., 2015a). Temperature elevation and ongoing cultural eutrophication could create favorable conditions for *B. longirostris*. Paleolimnological studies have shown that *B. longirostris* has invaded warming waters, including originally coldwater high Alpine lakes where *B. longirostris* had previously been absent or rare. However, once these waters started to warm up, *B. longirostris* invaded them and quickly became the dominant species of Cladocera (Nevalainen & Luoto, 2012; Nevalainen et al., 2014). Correlations between increased temperatures and the abundance of *B. longirostris* have also been noted in long-term

neolimnological research (Adamczuk et al., 2015b). The preferences of *B. longirostris* for eutrophic conditions were described above; thus, it is predicted that the species will be dominant in an increasing number of eutrophying lakes. *B. longirostris* also tolerates salinity (Aladin, 1991; Jeppesen et al., 1994; Deasley et al., 2012) and shows higher resistance to acidification than bigger cladocerans. Its dominance in saline and acid environments results from its ability to cope with changing chemical conditions, decreased competition for food, and decreased predation pressure from invertebrates. In their experiment with controlled pH reduction, Havens & DeCosta (1985) found that compared with the control treatment, acidification resulted in a decreased abundance of planktonic invertebrates, except for *B. longirostris*, the abundance, biomass, and mean body size of which even increased during the acid treatment (Havens et al., 1993; Locke & Sprules, 2000). As *B. longirostris* is able to grow and reproduce under rapidly changing pH levels and highly acidic conditions, it is, thus, often the single dominant species in acidified lakes (Yan & Strus, 1980).

For many years, the dogma of *Daphnia* as a superior competitor over *B. longirostris* has been repeated (Goulden et al., 1982; Vanni, 1986). However, recent studies suggest that expected climate changes may favor *B. longirostris* at the cost of *Daphnia*. The conditions of elevated water temperature in conjunction with the occurrence of blooms of toxic blue–green alga enhance the exclusion of *Daphnia* and dominance of *B. longirostris* (Figueroa-Sanchez et al., 2014; Jiang et al., 2014). *B. longirostris* is resistant to strains of *Microcysits aeruginosa* and *Anabaena flosaquae* that have lethal toxic effects on other cladocerans (Fulton, 1988); thus, this species can potentially coexist with toxic blue-green alga blooms (Jiang et al., 2013). Some studies report that *B. longirostris* is even able to consume them (Fulton, 1988). Changes in food web structure, primarily warmth-induced changes in fish communities, can be to the detriment of *Daphnia* and benefit *B. longirostris*. Fish communities in warm waters have fever strictly piscivorous fish but more of omnivores (Meerhoff et al., 2007; Texeira de Mello et al., 2009; Moss, 2010), including small, rapidly reproducing fish (Jeppesen et al., 2010) which can remove virtually all effective grazers, including *Daphnia*. Since Wells (1970) observed that the successful invasion of

alewife, *Alosa psudoharengus*, into Lake Michigan was associated with depressed densities of large-bodied cladoceran taxa and with increased densities of smaller taxa, mainly *B. longirostris*, we have noted evidence of *Daphnia* loss in favor of *B. longirostris* under conditions of high pressure of planktivorous fish (Nilsson & Pejler, 1973; Chappaz et al., 1999; Lampert et al., 2014).

So, what can limit the successful spread of *B. longirostris*? Despite the high level of ability of *B. longirostris* to tolerate conditions that seem to be highly unfavorable for other cladocerans, *B. longirostris* turns out to be sensitive to metal contamination. The sensitivity of *B. longirostris* to metal contamination has been supported both under laboratory and field conditions suggesting that *B. longirostris* is more sensitive to metal contamination than *Daphnia* (Koivisto et al., 1992; Koivisto & Ketola, 1995 Labaj et al., 2015). The differences in sensitivity result from size differences between the species, for large cladocerans accumulate lower amount of metals than smaller cladocerans (Rainbow & Moore, 1986; Lasenby & Van Duyn, 1992). Given that metal contamination of lakes is caused by anthropogenic activity, this factor can effectively limit the current and future density and dominance of this species. Another threat for *B. longirostris* is connected to the projected dominance of invertebrate predators in food webs. It has been experimentally showed that the activity of invertebrate predators increases under warmer conditions (Beisner et al., 1996). *B. longirostris* is highly vulnerable to carnivorous invertebrates (Von Ende & Dempsey, 1981; Branstrator & Lehman, 1991; Adamczuk, 2012b), and climate-induced changes in aquatic ecosystems can result in domination of small invertebrate predators (Daufresne et al., 2009; Rice et al., 2014) that are primarily damaging for small prey, including *B. longirostris*.

Bosmina longirostris responses to environmental disturbances

Performance of *B. longirostris* across all environments and high fitness levels over a range of environmental conditions suggest that *B. longirostris* has a generalist genotype. Moreover, conditions of rapid changes seem to even favor *B. longirostris*. Hart (2004) found that *B.*

longirostris is quite numerous in periods of annual overturn in an environment. On the basis of that discovery, he classified *B. longirostris* as a 'disturbance-tolerant' species. That term seems to be the most adequate when taking into consideration the high adaptive ability of *B. longirostris* to changing environmental conditions. Studies on competition between *B. longirostris* and *Daphnia* in experimentally manipulated habitats have revealed the ability of *B. longirostris* to rapid adaptation to a changing environment that has resulted in its outcompeting *Daphnia* (Goulden et al., 1982; Kurmayer, 2001; Jiang et al., 2014) An advantage of *B. longirostris* over *Daphnia* under disturbed conditions can result from some differences between these two taxa. Primarily, *B. longirostris* is more efficient than *Daphnia* in carbon production, especially at low food conditions (Urabe, 1991). *B. longirostris* also has lower phosphorus content in comparison to *Daphnia* (Reissig et al., 2015). As a result, *Daphnia*, although larger, cannot outcompete *B. longirostris* under decreased food conditions (Goulden et al., 1982).

Future challenges

The common use of *B. longirostris* as indicator of environmental conditions in paleolimnology and neolimnology conflicts with its underestimated role as a food web component. Sporadic studies on the feeding of *B. longirostris* suggest that the species could have a more important role in energy transfer throughout the food web than is currently recognized. This role could increase due to global climate changes, including increases in temperature enhancing blue–green alga blooms which are destructive for *Daphnia* and tolerable for *B. longirostris*. The role of *B. longirostris* in aquatic ecosystems is difficult to study without prior explanation of the morphotypic derivation and distribution of genetic variants of *B. longirostris*. Currently, there is a tendency to perceive *B. longirostris* as a cosmopolitan species. Nevertheless, the existence of cryptic species (i.e., distinct species that are classified as one due to morphological similarity) in the group of *B. longirostris* is also highly possible. Taylor et al. (2002) concluded his studies on phylogeny of Bosminidae with the suggestion that all subgenera within bosminids may contain cryptic species that may account for the seemingly widespread distribution of that family across environmental gradients. The possibility of this phenomenon can be supported by the subtle morphological differences observed in *B. longirostris*, including inter- (Europe *versus* North America) (Goulden & Frey, 1963; De Melo & Hebert, 1994; Kořinek et al., 1997) and intracontinental (Slovakia *versus* Germany) (Hudec, 1989; Kappes & Sinsch, 2002) differences in the shape and position of head pores described in this review, as well as contradictory premises of *B. longirostris* preferences for shallow and eutrophic European lakes *versus* the deep and clear lakes of Greenland. In this case, the cryptic diversity of *B. longirostris* may bias results of ecological studies if cryptic species possess different ecological characteristics. Phenotypic observations on morphotypes of *B. longirostris* provide strong evidence of their environmentally induced (Razak & Saisho, 1970; Kerfoot, 1975b; Sakamoto & Hanazato, 2009), spontaneously phenotypic (Sakamoto et al., 2007), genotypic, and rigidly hereditary (Kappes & Sinsch, 2002) or maybe ontogenic (Sakamoto & Hanazato, 2009) derivation. Simultaneous environmental, spontaneous, ontogenic, and genotypic bases of some traits in single species do not occur in biology; however, since each of these derivations of morphotypes is supported, it is hard to logically exclude any of them. Yet, if we predict the existence of cryptic species within the group of *B. longirostris*, all derivations of morphotypes are possible. Describing cryptic species could lead us to conclude that *B. longirostris* is not such a genotypic generalist as it is regarded currently. Understanding how genetic and phenotypic variability determines the plasticity of *B. longirostris* is crucial for predicting the species' rate of adaptation to environmental changes. As presented in this review, *B. longirostris* can persist under an amount of unfavorable conditions and shows a significant ability to adapt to rapid environmental changes. Although we understand the phenomenon of the dominance of *B. longirostris* under disturbed environmental conditions as a result of decreased competition for food and decreased predation pressure of invertebrates, we still do not know the genetic and physiological mechanisms of the resistance of *B. longirostris* to physical and chemical changes in the environment. Some responses of *B. longirostris* to varying conditions, including positive responses to eutrophication and temperature regimes, are transferred mainly as the outcome of paleolimnological

studies. However, paleoreconstructions seem to have most of their limitations stemming from the selective preservation of taxa that causes problems in the recapture of complete food webs, and increasing anthropogenic influences that create difficulties in finding contemporary systems comparable with those reconstructed from ancient fossil remains. Thus, the short- and long-term responses of *B. longirostris* to elevated nutrients and increased water temperature should be reinvestigated in neolimnological studies. The tolerance levels of *B. longirostris* to salinity, acidification, toxins of blue–green algae, and resistance to rapid changes in environmental conditions need in-depth analyses on the basis of reliable and current field observations using modern techniques such as molecular biology. Nonetheless, only resolution of taxonomic problems will presume us to understand the ground of thorough-paced resistance of *B. longirostris* to unfavorable environmental conditions and its further use as a test species to study the role of genetic variation on stress tolerance and the mechanisms of adaptation of aquatic invertebrates on genetic, organismal, and population levels.

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