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Shell repair in the freshwater gastropod *Bithynia tentaculata* (Linnaeus, 1758)

Gerhard C. CADÉE
Royal Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, NL-1790 AB Den Burg, The Netherlands
email: gerhard.cadee@nioz.nl

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ABSTRACT

A large sample rich in empty *Bithynia tentaculata* (Linnaeus, 1758) was collected in a drift-line along Lake IJssel, The Netherlands. Of 400 adult *Bithynia* shells 62 (15.5%) showed repair of a damaged outer lip, most probably due to failed attacks by predators. The roach *Rutilus rutilus* (Linnaeus, 1758) was probably its main shell-crushing predator here. However, repair after physical damage by waves breaking on the stones of the dike cannot be excluded completely.

INTRODUCTION

Shells are not only objects to classify, but also functional structures that *inter alia* help to protect the animal against predators (Vermeij, 2015). Shells may show marks of predation or repair scars indicating failed predation. It was in particular Vermeij who stressed to study shell repair in fossil and recent shells. On the changes in geologic time of failed predation attacks he based his hypothesis of selection favoring the evolution of breakage resistant shells and the coevolution of mollusks and their predators (Vermeij, 1987; Alexander & Dietl, 2003). Shell repair is better studied in marine than in terrestrial and freshwater gastropods (see review by Vermeij, 2015). To add some quantitative data on repaired shells in the latter group, I collected a large sample of *Bithynia tentaculata* (Linnaeus, 1758) in a drift line along Lake IJssel years ago (2 October, 1997). A note I started to write in 1998 on these data remained unfinished. As there are still few quantitative data on freshwater gastropod shell repair, I finished this note now, being well aware that it certainly asks for more research.

Bithynia tentaculata is a palearctic species and one of the most common aquatic gastropods in the Netherlands. It occurs widespread with some tolerance for brackish water (up to 12‰ S, Benthem Jutting, 1922). Temperatures below -4 to -5 °C are lethal and thus it prefers deeper waters, where water will remain warmer and it can survive in winter (Gittenberger et al., 1998); hence also its Dutch name 'diepwaterslak'. It produces a stronger shell than most other freshwater gastropods in the Netherlands. It has a calcareous operculum and the outer lip is thickened, sometimes strengthened by a white, rather strong, internal rib (Jeffreys, 1862: 60). The shells are therefore less easily penetrated or crushed by predators than other Dutch common freshwater gastropods belonging to the planorbids and lymnaeids.

Lake IJssel was formerly brackish, connected to the North Sea and named 'Zuiderzee'. In 1932 it was closed by the famous 'Afsluitdijk' and gradually changed to a freshwater lake. The changes in the flora and fauna were studied extensively. The changes in the molluscan fauna after the closure were dealt with by Benthem Jutting (1954). Within two years after the closure all marine species were extinct. Immigration of freshwater mollusks was very slow. From two to four years after the closure living mollusks were entirely absent. Species with pelagic larvae like *Dreissena polymorpha* (Pallas, 1771) or with larvae parasitic on fish (the Najades) dispersed more rapidly all over the lake. The others with no free-swimming larvae, including *B. tentaculata*, invaded the lake more gradually from the margins.

MATERIAL AND METHODS

A sample of drift, rich in empty freshwater gastropod shells, was collected along the Houtribdijk (East-side), about 10 km North of Lelystad (RD coörd. 516.6-156.70) (Fig. 1). This dike connects Enkhuizen and Lelystad and was built to enclose another polder in the lake, the Markerwaard. Later it was decided not to reclaim this part of the lake, but to keep it as a freshwater reservoir.

Of this sample 400 adult shells of *Bithynia tentaculata* were studied under a stereomicroscope (Wild M5) using 12x magnification (and sometimes 25x). The number of shells showing repairs of a fractured aperture in their last two whorls were counted.

RESULTS

The sample consisted of dry plant material, >1000 mostly empty adult *Bythinia* shells and much smaller numbers of other freshwater species (*Dreissena*, *Valvata*, *Lymnaea*, *Viviparus*, but no planorbids). Also some brackish water shells, such as *Cerastoderma*, *Macoma* and *Mya*, dating from before the closure in 1932, were present.

400 adult *Bithynia* shells were studied. They ranged in size from 7.4 to 10.7 mm (average 9.1 mm). The scars (Fig. 2) were easiest visible in the last whorl, some were seen in the penultimate whorl (Fig. 2, right specimen), other whorls were not studied as they are largely hidden in the other whorls. No shells with more than one repair were found. In 62 (15.5%) of the 400 shells a repair scar was observed. All repairs were related to fractures of the outer lip. Fractures or holes made elsewhere in shells are probably always lethal.

DISCUSSION

Are the repaired damages observed in *Bithynia tentaculata* traces of failed predation? We can only hypothesize about their cause. Moreover, as few comparable repair studies exist for freshwater gastropods elsewhere, it is difficult to judge whether the 15.5% observed is high or low. Interesting studies exist on the role of predators on the shape freshwater snails (*Physa* sp., DeWitt et al., 2000). Covich (2010) studied the arms race of freshwater gastropods and predators. Vermeij & Covich (1978) came to the conclusion that coevolution of freshwater gastropods and their predators cannot play an important role in temporary waters but is best developed in ancient lakes and rivers. An adequate concentration of calcium carbonate and time is needed to evolve less vulnerable shell sizes, spines and thicker shells (Covich, 2010). However, quantitative data on repair frequency in freshwater gastropods are scarce.

For Recent marine gastropods more shell-repair data are available and predators are an important cause of sometimes high levels of shell-repair (summaries in Vermeij, 1987; Alexander & Dietl, 2003). However, in littoral environments, and in particular the surf zone with rolling stones or ice-blocks, mechanical damage and subsequent repair is also possible (Shanks & Wright, 1986). Such damage was described in e.g. littorinids (Ankel, 1941: p. 201; Raffaelli, 1978) and patelliform shells. For the latter group repair of mechanical damages is described in *Acmaea* (Bulkley, 1968), *Patella* (Cadée et al., 2000) and *Nacella polaris* (Hombron & Jacquinot) (Cadée, 1999 as *Nacella concinna* (Strebel, 1908)). As many as 75% of *Nacella* living in the surf zone on King George island (Antarctica) showed usually more than one repair per shell, which I related to mechanical damage in the surf zone by stones and ice blocks. Stafford et al. (2014) compared repair scars in the gastropod *Chlorostoma funebrale* (= *Tegula funebralis* (A. Adams, 1855)) in high and low energy environments and found the highest number of repair scars in the low energy environment and a strong relationship with predator abundance. This indicates repair frequency in their study as a valid tool assessing predation intensity.

Still other causes not related to predators are reported to result in shell repair marks: Checa (1993) observed non-predatory repaired damages in the deep-borrowing infaunal bivalves *Panopea glycymeris* (Born, 1778), *Lutraria lutraria* (Linnaeus, 1758), *L. magna* (= *L. oblonga* (Gmelin, 1791)), *Solecurtus strigilatus* (Linnaeus, 1758) caused by burrowing. Also the up to 40 cm deep burrowing bivalve *Mya arenaria* Linnaeus, 1758 in the Wadden Sea often show comparable repaired damages (own observations). These are not due to predators, as these cannot reach this deep-burrowing bivalve. Up to now, repaired damage due to burrowing is as far as I know not described for gastropods. Nielsen (1975) pictures *Buccinum undatum* (Linnaeus, 1758) shells with repairs caused by its feeding method: inserting its shell lip between the valves of bivalves. There is a large number of papers on damage in mollusks by bottom disturbing fishery gear, also producing repaired scars. Witbaard & Klein (1994) studied this effect on the long living bivalve *Arctica islandica* (Linnaeus, 1767). Iceberg scour may have a similar effect in infaunal bivalves (Harper et al., 2012).

The most probable predators on *B. tentaculata* in Lake IJssel are freshwater fishes of which only the roach, *Rutilus rutilus* (Linnaeus, 1758)) is known to feed regularly on this gastropod (E. Lammens, pers comm. e-mail 15-9-1998). This fish sucks in the entire gastropod and has pharyngeal teeth strong enough to crush the shells. However, Lammens regularly observed entire shells in the stomach contents. He did not study whether these snails were still alive and might eventually leave the roach alive, albeit somewhat damaged. Such a passage of the digestive tract of a predator and subsequent repair of shell damage was observed in the Wadden Sea tidal flat gastropod *Peringia ulvae* (Pennant, 1777), with shelducks as their predator (Cadée, 2011). Shell breaking predators also feed in Lake IJssel, e.g. diving ducks, but they feed mainly on the common bivalves *Dreissena* (de Leeuw, 1999). Crustaceans were, at least at the time of collecting in 1998, not common in Lake IJssel. At the moment the American freshwater crayfish *Orconectes limosus* (Rafinesque, 1817) and a number of other exotic crayfish species are increasing in numbers in the Netherlands and might also feed on *Bithynia*.

CONCLUSION

Shell repair observed in the *B. tentaculata* shells was most probably related to failed predation. However, mechanical damage to the living gastropods cannot be excluded completely. The empty shells were collected in a drift line on the dike. This dike has a base of stones and, depending on wind strength and direction, waves will break on this dike. In winter, ice blocks may accumulate on the dike. *Bithynia* living on vegetation near the dike may become damaged. This preliminary study needs to be repeated on samples collected from other locations where comparable mechanical damages can be excluded.

Fig 1. Part of the sample of measured *Bithynia tentaculata* (Linnaeus, 1758) shells from lake IJssel. Scale bar = 1 cm.

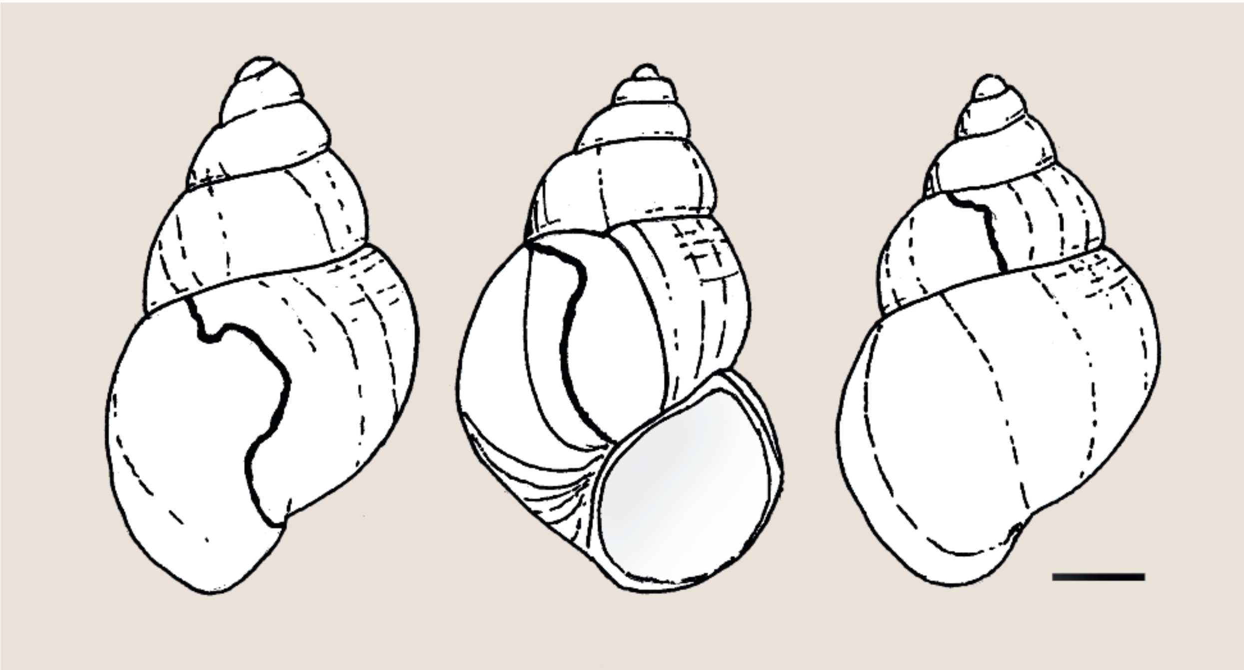

Fig 2. Repaired *Bithynia tentaculata* (Linnaeus, 1758) from Lake IJssel. Scale bar = 1 mm.

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