

## Research Article

**The aquatic invader *Potamopyrgus antipodarum* (Gray, 1843) is a poorer food item for benthivorous fishes than native snails**Rokas Butkus<sup>1,\*</sup> and Giedrė Višinskienė<sup>2</sup><sup>1</sup>Marine Research Institute, Klaipėda University, H. Manto St. 84, Klaipėda, Lithuania<sup>2</sup>Nature Research Centre, Akademijos Str. 2, LT-08412 Vilnius, Lithuania

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**OPEN ACCESS****Abstract**

Laboratory experiments have indicated that tench (*Tinca tinca*) is an effective predator of *Potamopyrgus antipodarum*. However, few *P. antipodarum* have been found in the gastrointestinal tracts of wild caught benthivorous fishes, including tench. This had led to the assumption that the shell properties of the snail act against native predators. In general, it has been predicted that this is due to *P. antipodarum* possessing a thicker shell and a lower amount of soft tissues than native snails; the latter will thus be preferred by benthivorous fishes. In the current study, shell-crushing resistance and the soft tissue mass / shell mass ratio were compared between the non-native *P. antipodarum* and three native species. Results indicated a similar shell-crushing resistance for *P. antipodarum* relative to the native *Bithynia tentaculata*, the latter of which is a common food object in tench diet. However, the soft tissue mass / shell mass ratio of the invader was significantly lower than in most of the studied native snails, indicating a lower amount of soft tissues in *P. antipodarum*.

**Key words:** shell strength, portion of soft tissues, tench, feeding selectivity**Introduction**

Non-native species, colonizing ecosystems beyond their native range, encounter not only novel environmental conditions, but also new enemies (Maron and Vila 2001; Verhoeven et al. 2008; Levri et al. 2017). The ability of non-native species to escape natural enemies, such as predators and parasites, increases their probability of successful establishment in new environments (Keane and Crawley 2002; Torchin et al. 2003; Levri et al. 2017). Active escape from predators is limited in most aquatic gastropods and bivalves due to their low mobility. Snails can exhibit various behavioural (Alexander and Covich 1991; McCarthy and Fisher 2000; Levri and Clark 2015; Levri et al. 2017; DeWitt et al. 2018 and others) and morphological (Seed 1993; Zaranko et al. 1997; Cheung et al. 2004; Holomuzki and Biggs 2006 and others) traits, or even changes in life-history (Crowl and Covich 1990; Guo et al. 2017), which allow them to avoid enemies. Shells and their associated structures (e.g., spines, hairs,

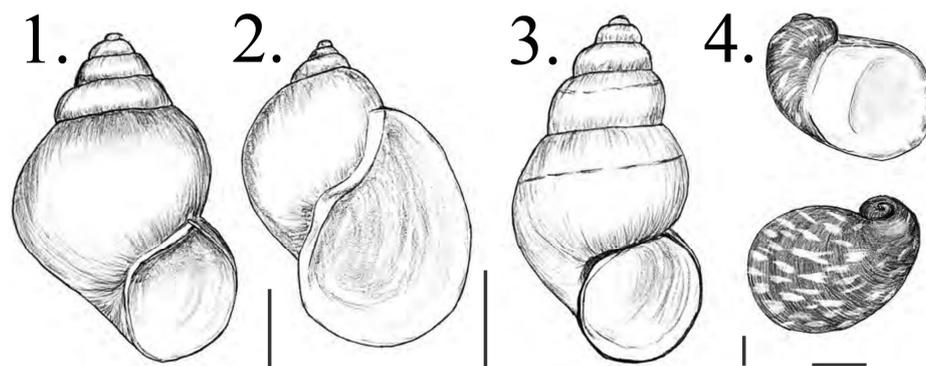
keel) are one of the structural traits that serve as a last line of defence (DeWitt et al. 2018). Molluscs are also widely demonstrated to exhibit various predator-induced shell form changes (Appleton and Palmer 1988; DeWitt 1998; Krist 2002; Bourdeau 2010; Sherker et al. 2017) or shell thickening (Auld and Relyea 2011; Bible et al. 2017; Zdelar et al. 2018). Nevertheless, most of these traits require time to be expressed, particularly in the case of non-native species that have not coevolved with native predators. However, some introduced species, even in the initial stages of invasion, are not consumed by native predators.

*Potamopyrgus antipodarum* J. E. Gray, 1843 is a small (< 7 mm shell length) snail native to New Zealand. In recent decades, it has become one of the most widespread invasive species worldwide. Due to its high ecological plasticity, absence of natural enemies and obligate parthenogenesis, the snail has successfully established in various water bodies and has become highly abundant (in some ecosystems, the density reaching up to 500,000 ind. m<sup>-2</sup> (Hall et al. 2003). These high densities of *P. antipodarum* may be associated with a lack of natural enemies, particularly of effective predators. Previous studies have indicated that *Tinca tinca* (Linnaeus, 1758) is a most effective predator of this snail (able to crush the shell) under laboratory conditions (Rakauskas et al. 2016). The same tendency was expected in natural ecosystems, keeping in mind that the native snail *Bithynia tentaculata* (Linnaeus, 1758) is visually similar and is a common prey item for *T. tinca* (O'Maoileidigh and Bracken 1989; Brönmark 1994; Michel and Oberdorff 1995). However, field studies have indicated that *P. antipodarum* is not incorporated into the tench diet (Rakauskas et al. 2016), raising questions of how this abundant invader escapes one of its potential effective predators. To answer this, the snail's low proportion of soft tissues, and/or its small hard shell with an operculum, are traits that have been widely presented as an explanatory variables (Zaranko et al. 1997; Vinson and Baker 2008; Brenneis et al. 2011 and others), though these traits have to our knowledge never been analysed empirically.

It was assumed that *P. antipodarum* is an energetically poorer prey item for benthivorous fishes crushing their prey. As energetic values for molluscs are expected to be equivalent on a dry weight basis (Cummins and Wuychek 1971; Tucker et al. 1997), shell crushing resistance and the proportion of soft tissues to whole body weight of *P. antipodarum* versus three native snails were evaluated. The aim of this study was to estimate and compare shell properties such as crushing resistance and tissue to shell weight ratio in the invasive *P. antipodarum* and three species of native snails.

## Materials and methods

The non-native snail *P. antipodarum* and three native widespread and very common snails in majority of Lithuanian aquatic ecosystems – *Bithynia tentaculata*, *Radix* sp. and *Theodoxus fluviatilis* (Linnaeus, 1758) (Figure 1) –



**Figure 1.** Maximal shell size and shape of snail species used in the study. Numbers indicate *B. tentaculata* (1), *Radix* sp. (2), *P. antipodarum* (3) and *T. fluviatilis* (4) (modified from Rudzīte et al. 2010).

**Table 1.** The number of snails used in soft tissues to shell ratio (T/S), shell crushing resistance (SCR) analyses and snail shell length  $\pm$  SD.

Species	T/S	SCR	L, mm
<i>P. antipodarum</i>	35	25	4.2 $\pm$ 0.8
<i>B. tentaculata</i>	20	21	7.5 $\pm$ 1.2
<i>Radix</i> sp.	5	5	10.8 $\pm$ 0.6
<i>T. fluviatilis</i>	12	19	8.7 $\pm$ 0.9

were selected for performed analyses. *Bithynia tentaculata* and *Radix* sp. are common prey items for many benthivorous fish species, including tench. The samples were collected from the Elektrėnai water reservoir (Lithuania: 54.757160; 24.672924) using a hand net. The snails were transported to the laboratory and kept alive in lake water until further analysis. The number of analysed snails is presented in Table 1. A small number of *Radix* sp. was used in the analyses due to the low density of these snails in the sampling site.

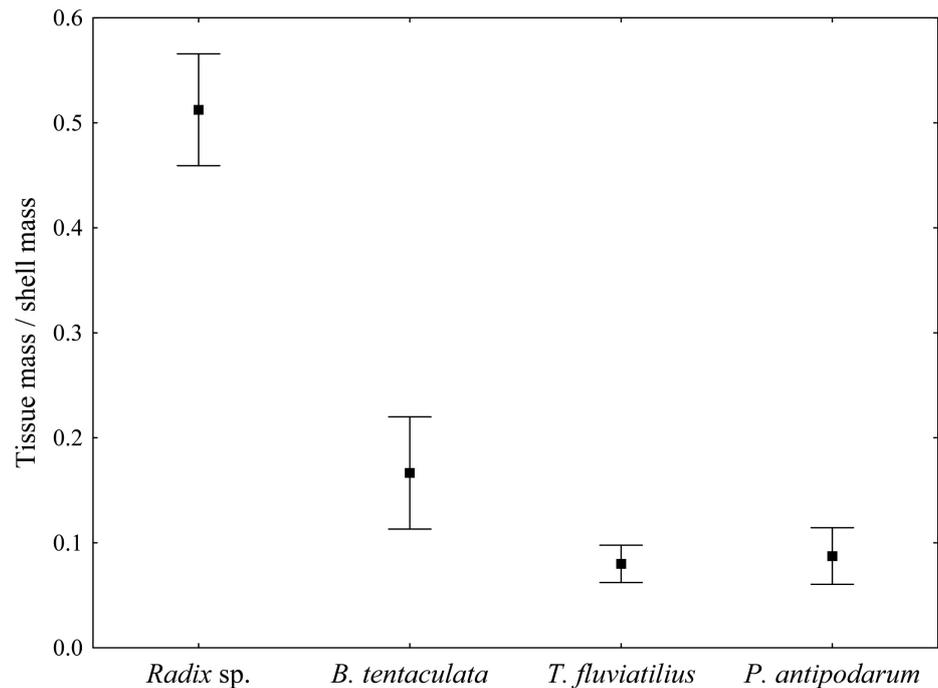
#### *Tissue to shell mass ratio*

The dry weight was estimated by dissecting the snails, separating the soft tissues (including the embryos in the case of *P. antipodarum*) from the shell and operculum, and drying them to a constant weight at 60 °C for 24 hours. The shell and soft tissues of each individual were weighted separately on calibrated SARTORIUS scales ( $d = 0.001$  mg).

Analysis of variance (ANOVA) followed by Unequal N HSD tests were applied to identify significant pairwise differences between species. Parametric tests were used as data met the normality assumption of parametric methods (Shapiro-Wilk's  $W$  tests,  $P < 0.05$ ). Calculations were performed using Statsoft Statistica 10.0 software.

#### *Shell-crushing resistance*

Prior to measurements of shell-crushing resistance (shell strength) among the studied snails, all specimens were pictured and shell length measured (to the nearest 0.1 mm) using ImageJ software. The force required to crush



**Figure 2.** Mean ( $\pm$  SD) ratio of soft tissue mass to shell mass for study snails.

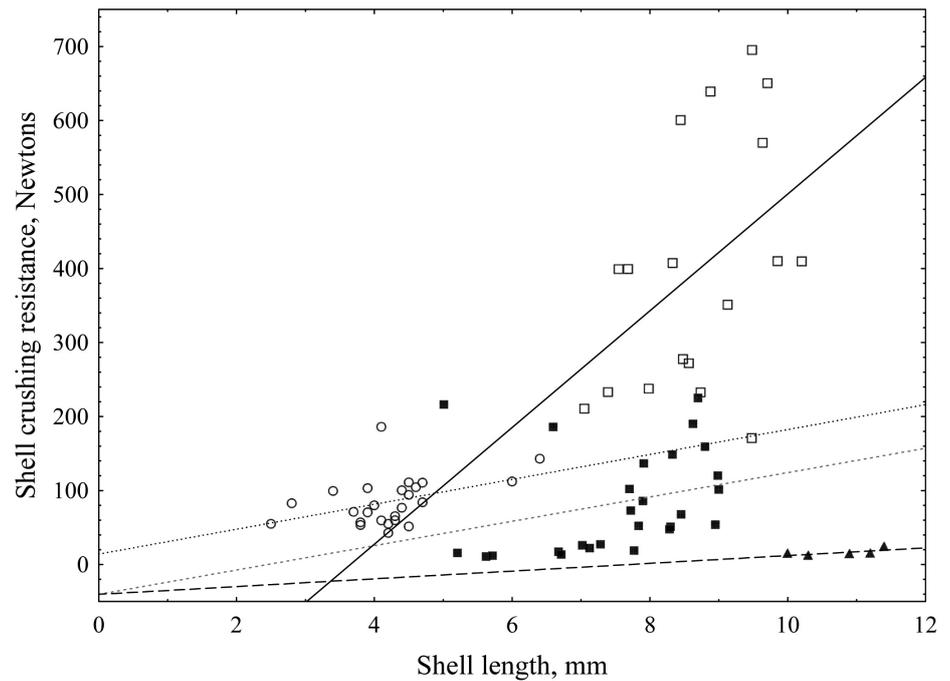
the shells was estimated with a modified drill press, by applying compressive force directly to live snails with the aperture facing down, placed on calibrated scales ( $d = 1$  g), which were filmed. Increasing downward force was applied until shell failure. The force at shell failure was defined as the maximum crushing force. The obtained data was expressed as a pressure weight (KgF), which was converted to Newtons (N). The shell-crushing resistance values of the studied snails were  $\log_{10}$  transformed and compared using ANCOVA with shell length as covariate, followed by Unequal N HSD pairwise comparisons. All statistical analyses were performed in statsoft STATISTICA 10.0 software.

## Results

### *Tissue to shell mass ratio and shell-crushing resistance*

The analysis of tissue to shell mass ratio of the studied snails indicated significant (ANOVA:  $F_{3,71} = 146.636$ ,  $P < 0.001$ ) variation between the studied species (Figure 2). Applied pairwise comparison tests indicated no significant differences in the ratio only between *P. antipodarum* and *T. fluviatilis* specimens ( $P = 0.95$ ). Both of these snails had significantly lower tissue to shell mass ratios than *B. tentaculata* and *Radix* sp. ( $P < 0.001$ ). The highest ratio was estimated for *Radix* sp. specimens. The average tissue to shell mass ratios in *Radix* sp. and *B. tentaculata* were 5.9 and 1.9 times higher, respectively, than that evaluated in *P. antipodarum*.

ANCOVA revealed significant differences in shell-crushing resistance ( $F_{3,69} = 43.81$ ,  $P < 0.001$ ) among the studied snails (Figure 3). Applied post hoc unequal N HSD tests indicated that the native snail *T. fluviatilis* had



**Figure 3.** Shell-crushing resistance of *Radix* sp. (black triangles), *B. tentaculata* (black squares), *P. antipodarum* (white circles) and *T. fluviatilis* (white squares) in relation to shell length.

the highest shell resistance, while *Radix* sp. required the lowest amount of force to crush the shell. There were no statistically significant ( $p = 0.18$ ) differences in force required to crush the shells of *P. antipodarum* and *B. tentaculata*.

### Discussion

In general, the obtained results confirm the assumption that *P. antipodarum* is a poor food item for benthivorous fishes that crush their prey. The relatively high resistance of the shell to crushing and their small individual size, combined with the low amount of digestible soft tissues and the large brood pouch consisting of embryos, some of which are shelled, make this species an energetically less valuable prey item than most of native snails.

Foraging theory suggests that if obtained energy is lower than the sum of searching and processing costs, predators will unlikely include a given prey in the diet (Pyke 1984). One of most important findings of the current study was that the resistance of the shell to crushing in *P. antipodarum* is very similar to some of the native snails, though it contains a lower amount of soft tissues than the latter. As the energy required to process the shell of *P. antipodarum* is relatively high, but the amount of digestible tissues is relatively low, the poorer energetic value of *P. antipodarum* in comparison to most of the studied native snails can be assumed. It was found that *P. antipodarum* and *B. tentaculata* require a similar amount of power for their shells to be crushed. The lowest resistance to crushing was observed in *Radix* sp. specimens, which have thin and very fragile shells. The thick-shelled *T. fluviatilis* specimens required the greatest amount of power to crush

their shell. Such results imply that the small hard shell of *P. antipodarum* does not give any benefit in the avoidance of benthivorous predators that exhibit shell-crushing behaviour. Such results are interesting as, despite their similar size, the non-native snails exhibit thicker shells than the natives, which are known to provide benefit in native predator avoidance (Appleton et al. 2009; Miranda et al. 2016). For example, shell thickening is well documented in molluscs as one of the frequent traits associated with predator avoidance (Leonard et al. 1999; Smith and Jennings 2000; Reimer and Harms-Ringdahl 2001; Brookes and Rochette 2007; Weigand and Plath 2014; Miranda et al. 2016 and others).

However, although the power needed to crush the shells of *B. tentaculata* and *P. antipodarum* was found to be very similar, the proportions of soft tissues in the bodies of the snails were different. It was found that native species, particularly *Radix* sp. and *B. tentaculata*, contained a higher percentage of soft tissues than *P. antipodarum*. Only *T. fluviatilis* with its typically thick shell contained relatively less soft tissues than the invader. A lower amount of flesh in the prey indicates a lower amount of assimilated energy in the predator. In general, the obtained results coincide with the results of field studies that have indicated that *B. tentaculata* and *Radix* sp. are preferred food objects in the tench diet (O'Maoileidigh and Bracken 1989; Brönmark 1994; Michel and Oberdorff 1995). The ability of the tench to crush the shells, and the relatively large amount of soft tissues, make these snails a preferable food object.

As studied morphological properties of *P. antipodarum* can not solely account for low numbers of the snail in the *T. tinca* diet, some other predator avoidance traits can be suspected. The invader *P. antipodarum* and *T. tinca* exhibit different preferences for microhabitat – the invasive snails prefer sand or gravel substrate in lakes (Zaranko et al. 1997; Butkus *personal obs.*), while tench prefer muddy substrates with macrophyte communities (Rendón et al. 2003). Thus, different preferences could allow the snail to escape the tench by spatial segregation. If such an assumption is correct, there would be a trivial amount of *P. antipodarum* in the tench diet, as indicated by Rakauskas et al. (2016). Additionally, the distribution of the non-indigenous snail is limited to particular areas in the ecosystem during the initial stages of invasion, while the tench are present across the entire lake; thus, despite active foraging, the probability of the fish to consume the invader is lower than that for native snails. Though such an assumption is reasonable, other explanations are also possible. Some behavioural and morphological traits associated with predator avoidance have already been documented for *P. antipodarum* (Holomuzki and Biggs 2006; Liess and Lange 2011; Levri et al. 2019 and others). Previous study has indicated that *P. antipodarum* is not incorporated into not only tench, but also in other benthivorous fish diet (Rakauskas et al. 2016). Despite high density of the snail in studied ecosystems, only trivial numbers were

found in the gastrointestinal tracts of *Abramis brama* (Linnaeus, 1758), *Gymnocephalus cernua* (Linnaeus, 1758), *Perca fluviatilis* (Linnaeus, 1758) and *Rutilus rutilus* (Linnaeus, 1758), (Rakauskas et al. 2016). In general, it is already well documented that benthivorous fishes avoid consuming *P. antipodarum* in nature, but the main biological mechanisms of predator escape are still questionable.

Overall, the results of current study agree with the widely accepted assumption that *P. antipodarum* is poorer than native prey items for benthivorous fish species that crush their prey. However, as *P. antipodarum* is abundant, spatially aggregated and easily accessible in lake ecosystems, the lower energetic value relative to native snails (high shell resistance and low amount of digestible tissues) cannot solely explain the trivial quantities of *P. antipodarum* in the diet of *T. tinca*. Further studies on traits associated with predator escape, particularly spatial segregation between *P. antipodarum* and *T. tinca*, may provide useful insights in this native predator – invasive prey interaction.

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### References

- Alexander JE, Covich A (1991) Predator avoidance by the freshwater snail *Physella virgata* in response to the crayfish *Procambarus simulans*. *Oecologia* 87: 435–442, <https://doi.org/10.1007/BF00634603>
- Appleton RD, Palmer AR (1988) Water-borne stimuli released by predatory crabs and damaged prey induce more predator-resistant shells in a marine gastropod. *PNAS* 85: 4387–4391, <https://doi.org/10.1073/pnas.85.12.4387>
- Appleton CC, Forbes AT, Demetriades NT (2009) The occurrence, bionomics and potential impacts of the invasive freshwater snail *Tarebia granifera* (Lamarck, 1822) (Gastropoda: Thiaridae) in South Africa. *Zoologische Mededelingen* 83: 525–536
- Auld JR, Relyea RA. (2011) Adaptive plasticity in predator-induced defenses in a common freshwater snail: altered selection and mode of predation due to prey phenotype. *Evolutionary Ecology* 25: 189–202, <https://doi.org/10.1007/s10682-010-9394-1>
- Bible JM, Griffith KR, Sanford E (2017) Inducible defenses in *Olympia* oysters in response to an invasive predator. *Oecologia* 183: 809–819, <https://doi.org/10.1007/s00442-017-3811-x>
- Bourdeau PE (2010) Cue reliability, risk sensitivity and inducible morphological defense in a marine snail. *Oecologia* 162: 987, <https://doi.org/10.1007/s00442-009-1488-5>
- Brenneis VE, Sih A, de Rivera CE (2011) Integration of an invasive consumer into an estuarine food web: direct and indirect effects of the New Zealand mud snail. *Oecologia* 167: 169–179, <https://doi.org/10.1007/s00442-011-1962-8>
- Brookes JI, Rochette R (2007) Mechanism of a plastic phenotypic response: predator-induced shell thickening in the intertidal gastropod *Littorina obtusata*. *Journal of Evolutionary Biology* 20: 1015–1027, <https://doi.org/10.1111/j.1420-9101.2007.01299.x>
- Brönmark C (1994) Effects of Tench and Perch on Interactions in a Freshwater, Benthic Food chain. *Ecology* 75: 1818–1828, <https://doi.org/10.2307/1939640>
- Cheung SG, Lam S, Gao QF, Mak KK, Shin PKS (2004) Induced anti-predator responses of the green mussel, *Perna viridis* (L.) on exposure to the predatory gastropod, *Thais clavigera* Kutser, and the swimming crab, *Thalamita danae* Stimpson. *Marine Biology* 144: 675–684, <https://doi.org/10.1007/s00227-003-1233-2>

- Cummins KW, Wuycheck JC (1971) Caloric equivalents for investigations in ecological energetics. *Mitteilungen - Internationale Vereinigung fuer Theoretische und Angewandte Limnologie* 18: 1–158, <https://doi.org/10.1080/05384680.1971.11903918>
- DeWitt TJ (1998) Costs and limits of phenotypic plasticity: testswith predator-induced morphology and life history in a fresh-water snail. *Journal of Evolutionary Biology* 11: 465–480, <https://doi.org/10.1007/s000360050100>
- DeWitt TJ, McCarthy TM, Washick DL, Clark AB, Langerhans RB (2018) Predator avoidance behaviour in response to turtles and its adaptive value in the freshwater snail *Planorbella campanulata*. *Journal of Molluscan Studies* 84: 266–274, <https://doi.org/10.1093/mollus/eyy025>
- Crowl T, Covich A (1990) Predator-Induced Life-History Shifts in a Freshwater Snail. *Science* 247: 949–951, <https://doi.org/10.1126/science.247.4945.949>
- Guo J, Martín PR, Zhang C, Zhang J-e (2017) Predation risk affects growth and reproduction of an invasive snail and its lethal effect depends on prey size. *PLoS ONE* 12: e0187747, <https://doi.org/10.1371/journal.pone.0187747>
- Hall RO, Tank JL, Dybdahl MF (2003) Exotic snails dominate nitrogen and carbon cycling in a highly productive stream. *Frontiers in Ecology and the Environment* 1: 407–411, [https://doi.org/10.1890/1540-9295\(2003\)001\[0407:ESDNAC\]2.0.CO;2](https://doi.org/10.1890/1540-9295(2003)001[0407:ESDNAC]2.0.CO;2)
- Holomuzki JR, Biggs BJF (2006) Habitat-specific variation and performance trade-offs in shell armature of New Zealand mud snails. *Ecology* 87: 1038–1047, [https://doi.org/10.1890/0012-9658\(2006\)87\[1038:HVAPTI\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2006)87[1038:HVAPTI]2.0.CO;2)
- Keane RM, Crawley MJ (2002) Exotic plant invasions and the enemy release hypothesis. *Trends in Ecology and Evolution* 17: 164–170, [https://doi.org/10.1016/S0169-5347\(02\)02499-0](https://doi.org/10.1016/S0169-5347(02)02499-0)
- Krist AC (2002) Crayfish induce a defensive shell shape in a freshwater snail. *Invertebrate Biology* 121: 235–242, <https://doi.org/10.1111/j.1744-7410.2002.tb00063.x>
- Leonard GH, Bertness MD, Yund PO (1999) Crab predation, waterborne cues, and inducible defenses in the blue mussel, *Mytilus edulis*. *Ecology* 80: 1–14, [https://doi.org/10.1890/0012-9658\(1999\)080\[0001:CPWCAI\]2.0.CO;2](https://doi.org/10.1890/0012-9658(1999)080[0001:CPWCAI]2.0.CO;2)
- Levri EP, Clark TJ (2015) Behavior in the invasive New Zealand mud snail (*Potamopyrgus antipodarum*) is related to source population. *Biological Invasions* 17: 497–506, <https://doi.org/10.1007/s10530-014-0746-6>
- Levri EP, Landis S, Smith B, Colledge E, Metz E, Li XS (2017) Variation in predator-induced behavioral changes in introduced and native populations of the invasive New Zealand mud snail (*Potamopyrgus antipodarum*, Gray, 1843). *Aquatic Invasions* 12: 499–508, <https://doi.org/10.3391/ai.2017.12.4.07>
- Levri EP, Luft R, Li X (2019) Predator detection and a possible dispersal behavior of the invasive New Zealand mud snail, *Potamopyrgus antipodarum* (Gray, 1843). *Aquatic Invasions* 14: 417–432, <https://doi.org/10.3391/ai.2019.14.3.02>
- Liess A, Lange K (2011) The snail *Potamopyrgus antipodarum* grows faster and is more active in the shade, independent of food quality. *Oecologia* 167: 85–96, <https://doi.org/10.1007/s00442-011-1963-7>
- Maron JL, Vila M (2001) When do herbivores affect plant invasion? Evidence for the natural enemies and biotic resistance hypotheses. *Oikos* 95: 361–373, <https://doi.org/10.1034/j.1600-0706.2001.950301.x>
- McCarthy TM, Fisher WA (2000) Multiple predator-avoidance behaviours of the freshwater snail *Physella heterostropha pomila*: responses vary with risk. *Freshwater Biology* 44: 387–397, <https://doi.org/10.1046/j.1365-2427.2000.00576.x>
- Michel P, Oberdorff T (1995) Feeding habits of fourteen European freshwater fish species. *Cybiurn* 19(1): 5–46
- Miranda NAF, Measey GJ, Peer N, Raw JL, Perissinotto R, Appleton CC (2016) Shell-crushing resistance of alien and native thiarid gastropods to predatory crabs in South Africa. *Aquatic Invasions* 11: 303–311, <https://doi.org/10.3391/ai.2016.11.3.08>
- O'Maoileidigh N, Bracken JJ (1989) Biology of the tench, *Tinca tinca* (L.), in an Irish lake. *Aquaculture Research* 20: 199–210, <https://doi.org/10.1111/j.1365-2109.1989.tb00345.x>
- Pyke GH (1984) Optimal foraging theory: a critical review. *The Annual Review of Ecology, Evolution, and Systematics* 15: 523–575, <https://doi.org/10.1146/annurev.es.15.110184.002515>
- Rakauskas V, Butkus R, Merkytė E (2016) Consumption of the invasive New Zealand mud snail (*Potamopyrgus antipodarum*) by benthivorous predators in temperate lakes: a case study from Lithuania. *Hydrobiologia* 775: 213–230, <https://doi.org/10.1007/s10750-016-2733-7>
- Reimer O, Harms-Ringdahl S (2001) Predator-inducible changes in blue mussels from the predator-free Baltic Sea. *Marine Biology* 139: 959–965, <https://doi.org/10.1007/s002270100606>
- Rendón PM, Gallardo JM, Ceballos EG, Regadera JJ, García JC (2003) Determination of substrate preferences of tench, *Tinca tinca* (L.), under controlled experimental conditions. *Journal of Applied Ichthyology* 19: 138–141, <https://doi.org/10.1046/j.1439-0426.2003.00469.x>
- Rudzīte M, Dreijers E, Ozoliņa-Moll L, Parele E, Pilāte D, Rudzītis M, Stalažs A (2010) Latvijas gliemji: Sugu noteicējs. A guide to the molluscs of Latvia. University of Latvia press, Riga, 252 pp
- Seed R (1993) Invertebrate predators and their role in structuring coastal and estuarine populations of filter feeding bivalves. In: Dame RF (ed), *Bivalve filter feeders in estuarine*

- and coastal ecosystem processes. Springer-Verlag, Berlin, pp 149–195, [https://doi.org/10.1007/978-3-642-78353-1\\_5](https://doi.org/10.1007/978-3-642-78353-1_5)
- Sherker T, Ellrich JA, Scrosati RA (2017) Predator-induced shell plasticity in mussels hinders predation by drilling snails. *Marine Ecology Progress Series* 573: 167–175, <https://doi.org/10.3354/meps12194>
- Smith LD, Jennings JA (2000) Induced defensive responses by the bivalve *Mytilus edulis* to predators with different attack modes. *Marine Biology* 136: 461–469, <https://doi.org/10.1007/s002270050705>
- Verhoeven KJF, Biere A, Harvey JA, Van Der Putten WH (2008) Plant invaders and their novel natural enemies: who is naïve? *Ecology Letters* 12: 107–117, <https://doi.org/10.1111/j.1461-0248.2008.01248.x>
- Vinson MR, Baker MA (2008) Poor Growth of Rainbow Trout Fed New Zealand Mud Snails *Potamopyrgus antipodarum*. *North American Journal of Fisheries Management* 28: 701–709, <https://doi.org/10.1577/M06-039.1>
- Torchin ME, Lafferty KD, Dobson AP, McKenzie VJ, Kuris AM (2003) Introduced species and their missing parasites. *Nature* 421: 628–630, <https://doi.org/10.1038/nature01346>
- Tucker A, Yeomans S, Gibbons J (1997) Shell Strength of Mud Snails (*Ilyanassa obsoleta*) May Deter Foraging by Diamondback Terrapins (*Malaclemys terrapin*). *The American Midland Naturalist* 138: 224–229, <https://doi.org/10.2307/2426670>
- Weigand AM, Plath M (2014) Prey preferences in captivity of the freshwater crab *Potamonautes lirrangensis* from Lake Malawi with special emphasis on molluscivory. *Hydrobiologia* 739: 145–153, <https://doi.org/10.1007/s10750-013-1705-4>
- Zaranko DT, Farara DG, Thompson FG (1997) Another exotic mollusk in the Laurentian Great Lakes: the New Zealand native *Potamopyrgus antipodarum* (Gray 1843) (Gastropoda, Hydrobiidae). *Canadian Journal of Fisheries and Aquatic Sciences* 54: 809–814, <https://doi.org/10.1139/f96-343>
- Zdelar M, Mullin F, Cheung C, Yousif M, Baltaretu B, Stone JR (2018) Pollution-, temperature- and predator-induced responses in phenotypically plastic gastropod shell traits. *Molluscan Research* 38: 34–40, <https://doi.org/10.1080/13235818.2017.1358587>