Nickel concentration in gills is correlated with shell height in European freshwater duck mussels (Anodonta anatina)

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Research Article

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Abstract

The potential correlations between the concentrations of a number of elements in gills (mg/kg) and shell height (mm) were investigated in European freshwater duck mussels, *Anodonta anatina.* Our results showed that nickel (Ni) concentration in gills is moderately correlated with shell height in these animals, with correlation coefficient (r) of 0.698. Other elements (As, Cr, Zn, Fe, Pb, Cd, Ca, Mn, Na, K, Co, Hg and Cu) show low (0.3<r<0.5) or almost no correlation (r<0.3) with shell height, with the exception that Arsenic (As) in gills is moderately correlated with shell height (r = 0.532) in duck mussels.

1. Introduction

Mollusc shells show high diversity in size and shape as natural selection shapes morphology to respond to diverse ecological and functional demands (McDougall and Degnan 2018). Bivalve mollusks, as filter-feeding animals, can concentrate various contaminants from ambient water in their tissues using bioaccumulation process (Piwoni-Piórewicz et al. 2017; Zuykov et al. 2013). Elements or compounds present at low levels in their surroundings can be detected in bivalve tissues based on their high bioaccumulation ability. Multiple studies suggested that chemical compositions of mollusk shells are associated with certain external environmental characteristics (Piwoni-Piórewicz et al. 2017; Zuykov et al. 2013).

Bivalves such as mussels feed by capturing particles from the water using their gills (Gosling 2003). Particles are selected by size and density in these tissues, and selected particles are either ingested and then released as feces or rejected and expelled as pseudofeces (Gosling 2003; Beninger et al. 1999; Alexander et al. 2008). Since the concentration of elements in ambient water are highly correlated with their concentrations in gills of mussels, and these elements can accumulate in mussel shells and thus might effect shell size; in the present study, we aim to determine if concentrations of certain elements in gills are correlated with shell height and shell length in European freshwater duck mussels (*Anodonta anatina*).

2. Dataset And Data Analysis

The dataset we analyzed in the present study contains body size data (shell length (mm), shell height (mm) and wet weight (g)) for adult duck mussels (*Anodonta anatina*) (n=40) collected from Southern Sweden (56°06’45” N, 13°54’35” E) as described in the original paper (Ekelund Ugge et al. 2021a, b). Authors also analyzed total concentrations of a number of elements in gills or digestive glands of these animals by inductively coupled plasma sector field mass spectrometry (ICP-SFMS), inductively coupled plasma atomic emission spectrometry (ICP-AES) and atomic fluorescence spectrometry (AFS) (Ekelund Ugge et al. 2021a, b). The readers are referred to the paper by Ekelund Ugge et al. for more experimental detail (Ekelund Ugge et al. 2021a, b).

Data analysis and visualization was performed in R statistical programming environment in this study (R version 4.0.2 (2020-06-22)) (R Core Team 2021). Following R packages were used throughout the analysis: readxl (Wickham and Bryan 2019), tidyverse (a collection of R packages designed for data science, including ggplot2, dplyr, tidyr and tibble) (Wickham et al. 2019), ggpubr (Kassambara 2020), heatmaply (Galili et al. 2017), rmarkdown (Allaire et al. 2021) and knitr (Xie 2021). Correlation coefficients were computed using Pearson method.

R code written to analyze the data can be found in supplementary documents to make the study completely reproducible.

3. Results And Discussion

By analyzing data by Ekelund Ugge et al. (Ekelund Ugge et al. 2021a, b), we found that nickel (Ni) concentration (mg/kg) in gills is moderately correlated with shell height (mm) and wet weight (g) in European freshwater duck mussels (*Anodonta anatina*), with correlation coefficients (r) of 0.698 and 0.558, respectively (Figure 1, 2). We found that other elements (As, Cr, Zn, Fe, Pb, Cd, Ca, Mn, Na, K, Co, Hg and Cu) show low ($0.3<r<0.5$) or almost no correlation ($r<0.3$) with shell height and wet weight of duck mussels, with the exception that Arsenic (As) in gills (mg/kg) is moderately correlated with shell height ($r = 0.532$) (Figure 1).Furthermore, we found no correlation between shell length and the concentration of any of the elements in gills (data not shown). Thus, we proposed that nickel concentration in gills is only correlated with shell height, but not with shell length in duck mussels. Why nickel levels in gills are correlated only with shell height but not with shell length is currently unknown, and further research is needed. Similarly, no correlations were found between shell height, shell length or wet weight and element concentrations in digestive glands (data not shown). Thus, it can be speculated that nickel concentration only in gills, but not in digestive glands of duck mussels, is correlated with shell height. This tissue-specificity might be due to positions of these tissues with respect to outer environment and higher concentrations of Ni in gills (0.093 mg/kg) compared to digestive glands (0.067 mg/kg). Hannan et al. recently showed that mussel shells are efficient agents in immobilizing Ni (Hannan et al. 2021). Thus, it can be hypothesized that increased levels of Ni in gills might contribute to higher Ni immobilization in shells, leading to an increase in shell height. Considering that nickel in ambient water is first exposed to gills than digestive glands, and that gills are in closer contact with shells, nickel levels in gills might be expected to be better correlated with Ni immobilization in shells and thus with shell height.

These results also suggest that nickel levels in aquatic environments might have an impact on mussel shell height or more generally on mussel morphology. How these changes in animal morphology due to Ni concentrations might effect animal health and fitness remains to be identified.

4. Conclusions

We showed that nickel concentration in gills is positively correlated with shell height (but not with shell length) in duck mussels. How these two parameters are correlated needs further research. Also, the

directionality of the effect (whether higher nickel concentration in gills increases shell height or higher shell height leads to increased Ni accumulation in gills) remains to be determined with controlled experiments. Since this data points out that Ni levels in gills might possibly contribute to increased shell height in mussels, levels of nickel in aquatic environments must be monitored closely considering its potential impact on morphology and ion homeostasis in mussels (Brix et al. 2017; Gauthier et al. 2021). Furthermore, temperature rise in aquatic environments due to climate change might change the availability and toxicity of certain metals for the aquatic biota; thus, might indirectly influence animal morphology and fitness (Nin and Rodgher 2021).

Declarations

Conflict of interest: The authors declare that there are no conflicts of interest.

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Authors contributions:

CB: Conceptualization; Formal analysis; Investigation; Visualization; Roles/Writing - original draft

EC: Funding acquisition; Project administration; Resources; Supervision; Writing - review & editing.

Data availability: We used datasets by Ekelund Ugge et al. (2021a, b).

Ethical Approval: Not applicable.

Consent to Participate: Not applicable.

Consent to Publish: Not applicable.

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Supplementary Documents

The supplementary documents are not available with this version

Figures

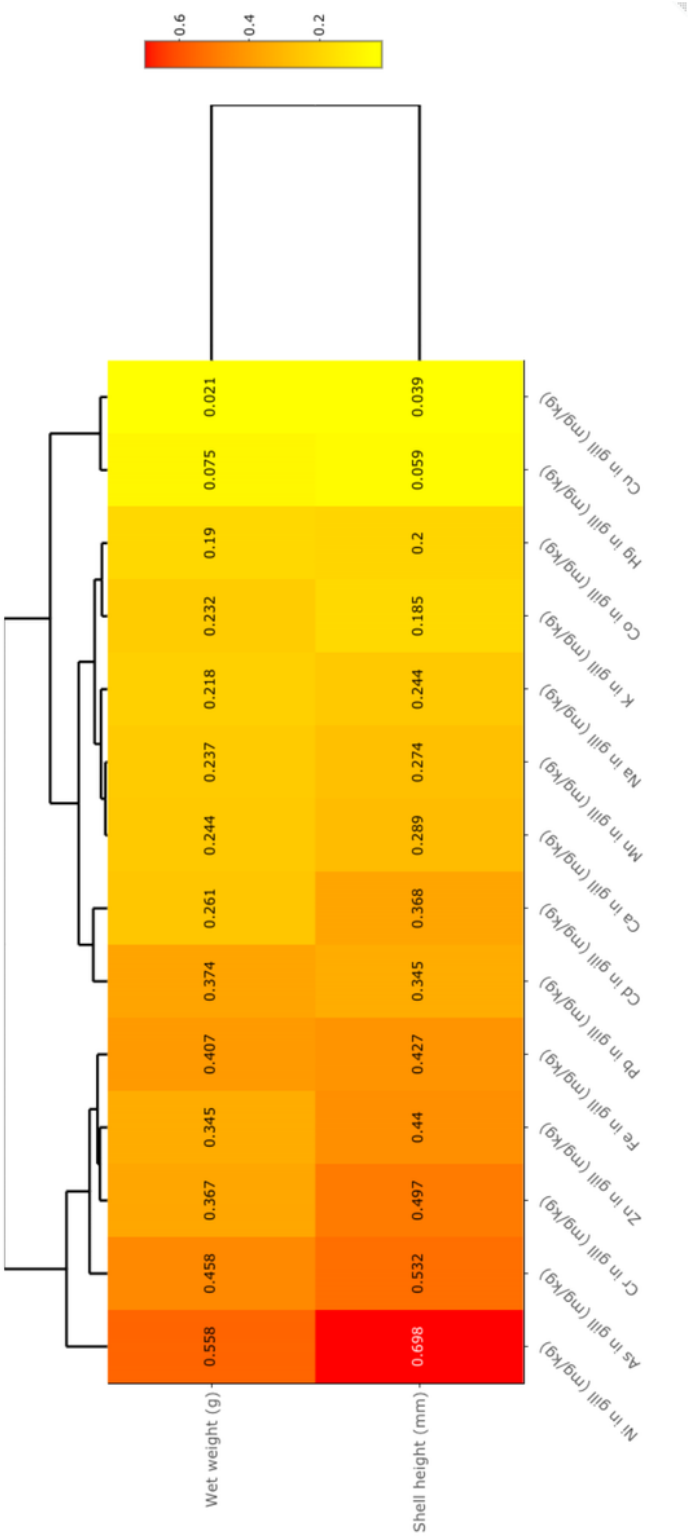

Figure 1

Heatmap showing correlation between element concentrations in gills and wet weight (top row) or shell height (bottom row) in European freshwater duck mussels (*Anodonta anatina*). red: the highest correlation yellow: the lowest correlation. Pearson correlation coefficients (r) were given in each cell. Data from Ekelund Ugge et al. (2021a, b).

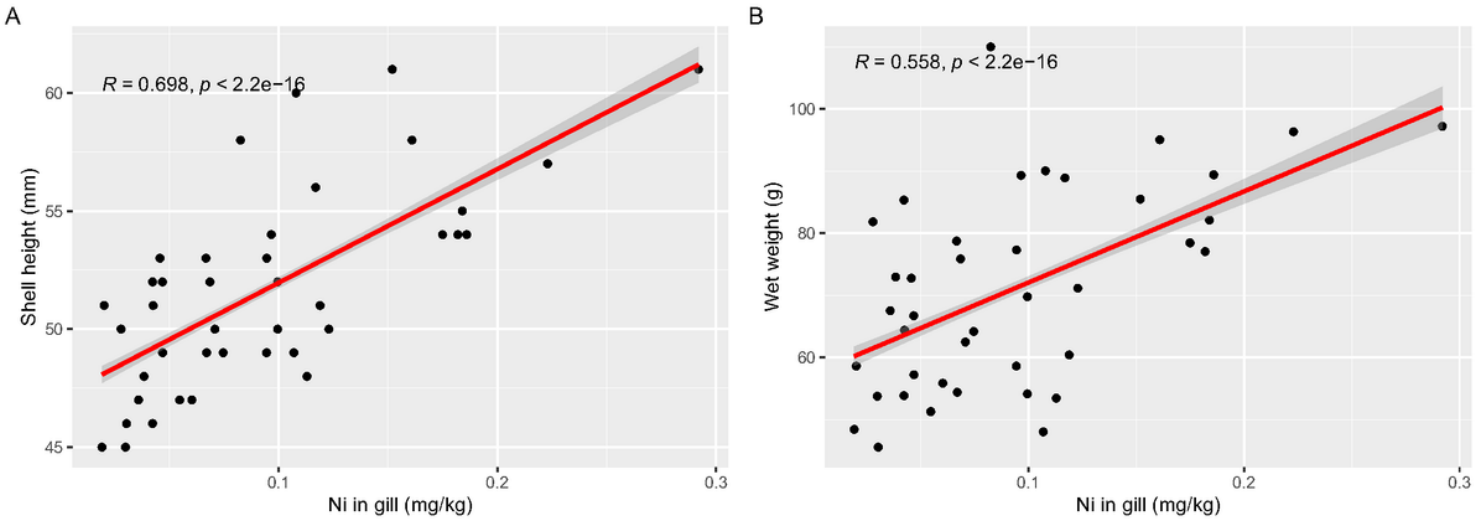

Figure 2

Plots showing correlations between nickel concentration in gill and shell height (A) or wet weight (B) in duck mussels. n=40. *R: Pearson correlation coefficient*. Data from Ekelund Ugge et al. (2021a, b).