Fakulta rybářství a ochrany vod
Faculty of Fisheries and Protection of Waters

Jihočeská univerzita v Českých Budějovicích
University of South Bohemia in České Budějovice
Czech Republic

Confidential

Review of USB FFPW PhD Thesis

First name(s), surname, titles of the PhD student: Radek Gebauer, Dipl.-Ing.	**First name(s), surname, titles of supervisor:** RNDr. Bořek Drozd, Ph.D.
Title of PhD thesis: Foraging behavior of non-indigenous gobiid fish species	

REVIEWER:

Surname: Grabowska	**Institution:** University of Lodz Faculty of Biology and Environmental Protection Department of Ecology and Vertebrate Zoology 90-237 Łódź, 12/16 Banacha Str., Building A
Name: Joanna	
Titles: Dr. hab.	**E-mail:** joko@biol.uni.lodz.pl
Please describe your professional relationship to the PhD student: none	**Please describe your field of expertise:** Biology and ecology of freshwater fish; invasive species

QUESTIONNAIRE

Originality, scientific importance, perspectives and impacts of results presented in the PhD thesis for basic and/or applied research

Evaluate competitiveness of the PhD thesis in the international context and compare its level with the current state of the art in the field **(extent ¼ – ½ page)**:

The thesis contributes to the knowledge upon the invasive ecology. Although there is a large body of literature considering this rapidly growing research area, there are still many problems to be solved and gaps in the knowledge to fill. Recently, classical ecological concept of functional response, characterizing the relationship between feeding rate and prey density, was adopted as a useful tool for assessing, comparing and predicting the impact of invasive species. The studies assembled as the PhD thesis of Radek Geubauer are an example of use of such a method to understand the dynamic of predator-prey interaction in different temperatures and substrate structure in case of two alien goby species and their potential impact on native biota. Considering that, I appreciate the thesis objectives as original and clearly stated. I would distinguish two main components of the thesis: 1) The identification of the factors important for explaining alien animal species richness in Czech Republic; 2) The quantification and comparison of the foraging behavior and the ecological impact of two alien gobiid species in the context of varying temperature and habitat structure. Both these components are of significant scientific importance and provide results of applicable value for management of invasive species. Especially component 1 has crucial importance for managers and policy makers. Although it is a local case study from Czech Republic, some of the conclusions may have universal significance and can be adopted to other neighboring countries. Considering the present wide and still extending

invasive distribution of Ponto-Caspian gobies, the identification of abiotic factor that may affect their impact on native biota through predator-prey interaction are of wide general interest.
Thus, I'm sure that the scientific content of the thesis will be broadly read and cited by other researchers.

Elaboration of the PhD thesis, objectives of the work and deliverables

Evaluate the overall level of elaboration of the PhD thesis (structuring of the main text, comprehensibility, logicality of the chapters and their ordering) and the originality of the selected approaches to solve the objectives; evaluate publications and whether the results described correspond to objectives of the PhD thesis **(extent ¼ – ½ page)**:

The dissertation is well composed, consists of five chapters preceded by a more general introduction, and topped off with a general discussion, that synthesises critically the threads of all the chapters. Two studies (Chapter 2 and 3) have already been published in the WoS Q2/Q3 journals: Ecology and Evolution as well as Aquatic Invasions. The remaining third study was presented as an unpublished manuscript (Chapter 4). It is certainly a good outcome for a PhD dissertation. Each of the study is focused on a separate and well-defined goal that, together, build a coherent and thorough scientific achievement. Although, the first publication (Chapter 2) included as a part of thesis, i.e. "Distribution of alien animal species richness in the Czech Republic" does not seem to be strictly relevant to the title of the thesis. It provides some general information and can be treated as a preliminary study to recognise the scale of the alien species problem in the case of Czech Republic, before focusing on particular detailed subject i.e. foraging and impact of non-indigenous gobies. Thus, in my opinion such approach is entirely acceptable and reasonable. The main subject of the thesis, i.e. foraging behaviour of the two fish species: *Neogobius melanostomus* and *Proterorhinus semilunaris* were compared using functional response in the context of environmental variables i.e. temperature and habitat complexity. Their potential impact on native biota was discussed. The methodology is in my opinion adequate for the objectives and the results of studies provides scientific value and lead to sound conclusions.

OVERALL COMMENTARY ON THE PhD THESIS

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Please write comments in extent of 1-2 pages:

Radek Geubauer has presented a mature, well planned and elaborated thesis on a subject that required not only a lot of meticulous work but also skills in various areas. His thesis has been partly published in JCR journals and thus, his work has already passed successfully through reviewing process what confirmed its quality.
In my opinion, the first paper of the dissertation provides information of applicable value about location deserving control efforts as particularly prone to future invasion, based on a very clever usage of available variable data sets as well as literature review. The other two studies are experimental and applied statistical modelling to predict the impact of invasive and potential invasive fish species. The results were concise yet informative. The discussion in all cases was led in a professional manner, the results were critically discussed against a broad and well-chosen literature. Also the conclusions were well rooted in the obtained data.
Among the main achievements of the thesis are:

- Identification of factors important for explaining alien species richness and based on that mapping the invasion hotspots in the Czech Republic.
- Applicable value of obtained results that can be used in alien species management and control politics.
- Comparison of foraging behavior of *Neogobius melanostomus* and *Proterorhinus semilunaris* under different temperature, which can predict the impact of these species in the light of global warming problem.
- Underline the differences in habitat preferences between species revealed by their foraging performance on varied substrate type. It exposed possible thread of currently not invasive *P. semilunari* in particular type of habitat, i.e. rich in submerged macrophytes or not invaded by *N. melanostomus.*

To summarize, I believe that Radek Geubauer may be recognized already as a mature and devoted scientist. I recognise his PhD thesis as a very valuable scientific achievement. Its results will certainly be widely discussed and cited in the scientific literature dealing with alien species problems and biological invasions ecology.

FINAL RECOMMENDATION

- ☒ **PhD Thesis can be recommended for defence**
- ☐ **PhD Thesis can be recommended with reservations for defence**
- ☐ **PhD Thesis can not be recommended for defence**

Łódź 30. 06. 2018

.....
Date and place

J Grabowska
.....
Name and signature

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Title of PhD thesis: Foraging behavior of non-indigenous gobiid fish species	

REVIEWER:

Surname: Worischka	**Institution:** Technische Universität Dresden, Institut für Hydrobiologie
Name: Susanne	
Titles: Dr.	**E-mail**: susanne.worischka@tu-dresden.de
Please describe your professional relationship to the PhD student: Supervised a 4-week internship in Dresden during a joint project with B. Drozd	**Please describe your field of expertise:** stream ecology, fish and macroinvertebrate ecology, aquatic invasive species, behaviour, food webs

QUESTIONNAIRE

Originality, scientific importance, perspectives and impacts of results presented in the PhD thesis for basic and/or applied research

Evaluate competitiveness of the PhD thesis in the international context and compare its level with the current state of the art in the field **(extent ¼ – ½ page)**:

In his thesis, Radek Gebauer approaches a global problem of rising importance, the spread and effects of alien invasive species. The large-scale spatial analysis of invasion hotspots and main geographical, climatic and anthropogenic factors facilitating biological invasions (chapter 2) is an original approach including terrestrial and aquatic of invasive animal species, its results being very interesting and readily applicable for stakeholders in management-related decision finding. Two aquatic invasive species, the Ponto-Caspian round goby and western tubenose goby, are then analysed with regard to their feeding behaviour. The former is classified as a high-impact species on two continents already, illustrating the need for detailed knowledge of its functional ecology; the latter, although not commonly regarded as very invasive, poses a similar risk and should therefore be studied as well. For both, the thesis provides novel data that are valuable for basic and applied research. Overall, the thesis presents a good mix of (field) data-based and (laboratory) experimental studies and two of the chapters have been published in reputable journals, Ecology & Evolution and Aquatic Invasions. Mr Gebauer has proven with his thesis that he is able to propose relevant scientific questions and solve them autonomously with

appropriate methods and in a creative manner.

Elaboration of the PhD thesis, objectives of the work and deliverables

The thesis is well-structured and the sequence of the chapters is logical. Mr Gebauer chose original and reasonable approaches for solving the objectives of his thesis and the results of the three presented studies correspond fully to the objectives.

The main text is well comprehensible with only few minor exceptions (see comments to introduction). The clarity and readability could be still improved by inserting page numbers, correcting some minor linguistic/ grammar errors in chapters 1, 4, and (partly) 5, and rectifying the numbering of chapter 5 (General discussion) in the text body.

All chapters fulfil the requirements for a PhD thesis. However, the scientific value of the general discussion would be even higher with an added short synthesis (see comments on chapter 5) which might be integrated in the conclusions. The whole thesis is well underpinned by references from literature, citing the fundamental conceptual papers as well as current research.

OVERALL COMMENTARY ON THE PhD THESIS

Please write comments in extent of 1-2 pages:

The first chapter briefly describes the global problem of alien species invasions, introduces the terminology used in this thesis, and explicates the single stages of the invasion process. A short paragraph on the management of biological invasions closes the general part, followed by a comprehensive introduction of the focal species. From this second part, the objectives 3 and 4 of the thesis derive in a very logical and coherent way. The motivation for the objectives 1 and 2, however, becomes not quite as clear, which is only partly caused by the necessary sequence of the introduction parts. A more detailed presentation of the ecological impacts of invasive alien species in the introduction would surely help. Some concrete examples, preferably from aquatic ecosystems (even a goby example would not hurt in this place), would make the problematic even clearer and the need for management more understandable. In addition, they would provide the "bridge" between the chapter 2 and chapters 3+4. A respective paragraph would fit very well between 1.1.2 (stages) and 1.1.3 (management) and could even be taken from the beginning of chapter 5. I miss also the important factor "biotic resistance" in the introduction, which should be mentioned, for instance, in the middle of paragraph 1.1.2.2 (Establishment) as a feature of the receiving community. In paragraph 1.2.1.1 the description of the pelvic fins of *N. melanostomus* should be

generalized because these are fused to form a suctorial disc in all gobies, otherwise it would be misleading even with the description being given also for *P. semilunaris* below. In the paragraph on functional response (1.3.), the part explaining the integral parameters of FR should be placed above the description of the curve types, making the concept easier to understand for readers. As the comparative FR approach is a central part of the thesis objectives, it should also be mentioned that recently, there was a controversial discussion about the proper use of this approach in evaluation and comparison of invaders' potential impacts (Dick *et al.*, 2017b, Vonesh *et al.*, 2017a, Dick *et al.*, 2017a, Vonesh *et al.*, 2017b). Although FR is clearly an important and useful tool, the cautions connected with the interpretation of its parameter values in invasion ecology should be recognized at least in the general discussion of this thesis, preferably also in chapter 4.

Chapter 2 is formed by a paper identifying invasion hotspots in Czech Republic and main factors facilitating invasions. The study is based on a rich database and a sound statistical analysis. Its special merit, however, is in my opinion the high practical usefulness. The graphical presentation using grid maps is intuitive and the most important enhancing factors are clearly named, both aiding stakeholders with finding efficient management decisions, e.g. prioritizing risks. The factor annual precipitation might have been excluded from analysis a priori because the correlations with other climatic and geographical factors are obvious and its effect is probably an apparent/ indirect one, which is supported by the difficulties to find a convincing explanation. However, since these correlations are acknowledged in the discussion, it is not wrong to present the results for this factor.

Chapter 3 compares FR of *N. melanostomus* and *P. semilunaris* feeding on fish larvae with temperature as an influencing factor. The results indicated only marginal difference between the two species and no significant effects of temperature. The latter fact might be partly due to the moderate temperature range studied (20 and 25°C). However, the transferability to natural field conditions should not be affected too much because these temperatures often prevail during larval development of fish in larger rivers. Such experimental studies form the knowledge base of risk assessment for invasive species. The particular contribution of this study is the finding of similarly severe potential impacts of *P. semilunaris*, compared to the more "notorious" *N. melanostomus*.

Chapter 4 is a manuscript presenting a study of FR of the gobies with focus on habitat complexity as an influencing factor. Like in the previous chapter, the results show a high similarity between the two species. Interestingly, the efficiency of both predators seems to be lowest in habitats with medium complexity (cobbles) compared to low (sand) and high complexity (cobbles with plant surrogate) – which at first glance suggests slightly disturbing implications for the impacts in natural vs. moderately regulated river stretches. Perhaps the conclusion by the authors concerning this should be drawn in a more differentiated way, as the experimental conditions were necessarily rather on the artificial side and thus cannot reflect prey behaviour in larger habitats, for instance.

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Nevertheless, the results give a valuable insight into feeding behaviour and potential impacts of two potentially harmful aquatic invaders. The manuscript would profit from following minor revisions: providing the full model selection table to make the conclusions traceable for readers (especially effect of predator species – as a justification for pooling them in the calculation of Cmax); citing Murdoch (1969) as an original reference for switching and prey population stability; re-formatting Figs. 1, 2 and 3 (visibility also in b/w prints, axis label size, letters denoting the plots instead of "up" and "down"); checking citations' formatting.

The general discussion corresponds closely with the contents of the previous three chapters, presenting the most important results. The value of this chapter and the whole thesis would be even improved by adding a short synthesis and perspectives beyond the pure results. Possible questions could be for example: How can the geographical analysis be linked with the ecological impacts of the gobies? Which concrete measures are conceivable to protect native competing or prey species, based on the results? And others. In the paragraph "Foraging behaviour", I recommend mentioning the debate on FR (see above) at least briefly, replacing "all temperatures" by "two temperatures". After the general discussion, a list of concise conclusions follows. With regard to a synthesis, the last conclusion (complexity of management actions) is very interesting, for instance, and deserves a more detailed elaboration. The summary is clear and concise. The sentence about annual precipitation and alien vertebrates should be omitted, as no true explanation for this (probably pseudo-) correlation was given in chapter 2. The temperature tolerance of the two gobiids should perhaps not be described as "broad" when only two temperatures near the optimum have been analysed.

Dick, J.T.A., Alexander, M.E., Ricciardi, A., Laverty, C., Downey, P.O., Xu, M., Jeschke, J.M., Saul, W.C., Hill, M.P., Wasserman, R., Barrios-O'neill, D., Weyl, O.L.F. & Shaw, R.H. (2017a) Fictional responses from Vonesh et al. RESPONSE. *Biological Invasions,* **19,** 1677.

Dick, J.T.A., Alexander, M.E., Ricciardi, A., Laverty, C., Downey, P.O., Xu, M., Jeschke, J.M., Saul, W.C., Hill, M.P., Wasserman, R., Barrios-O'neill, D., Weyl, O.L.F. & Shaw, R.H. (2017b) Functional responses can unify invasion ecology. *Biological Invasions,* **19,** 1667-1672.

Murdoch, W.W. (1969) Switching in general predators. Experiments on predator specificity and stability of prey populations. *Ecological Monographs,* **39,** 335-&.

Vonesh, J., Mccoy, M., Altwegg, R., Landi, P. & Measey, J. (2017a) Functional responses can't unify invasion ecology. *Biological Invasions,* **19,** 1673-1676.

Vonesh, J., Mccoy, M., Altwegg, R., Landi, P. & Measey, J. (2017b) Rather than unifying invasion biology, Dick et al.'s approach rests on subjective foundations RESPONSE. *Biological Invasions,* **19,** 1679-1680.

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Dresden, 29.06.18
Date and place

Name and signature