

Evaluation report of the doctoral dissertation entitled "Otolith microstructure, population dynamics and occurrence of *Pseudochaenichthys georgianus* Norman, 1937 (Channichthyidae) in Antarctic Sea" from Ryszard Traczyk submitted to the Faculty of Oceanography and Geography of the University of Gdansk under the supervision of Prof. Dr. Victor Mayer Rochow

1. General Evaluation

Mr. Ryszard Traczk presented as its PhD thesis a paper written document with 126 pages that included an extended abstract, four articles that constitutes the main body of its thesis, the co-author statements for each published international paper, some personal declarations and a short CV with the main scientific outputs of its academic career. I would have enjoyed to also see some additional sections, such as acknowledgements, general introduction, final discussion, major conclusions and final references, which is the common format in this kind of thesis in Europe, but I am not familiar with the rules of the hosting university in Poland.

In the four published papers, the PhD candidate was the first author and according with the co-author's statements, was also the leadership of the working plan, being responsible for the development of the research idea, selection of the methodological approaches, data collection and processing, statistical analyses, interpretation of the results, writing the original draft, and revising the original version of the manuscripts according with the reviewers and editor's comments and suggestions.

He also participated in a few Antarctic expeditions. Before being engaged in its doctoral working plan, he also published 3 international papers, 4 book chapters and 2 monographs. He also participated in some international congresses and research groups, where he presented some works, mainly in the area of fish & fisheries, some of them focused in the South Georgia icefish (*Pseudochaenichthys georgianus*).

The four articles have been published in international scientific journals and were previously subject to a double blind peer-review evaluation. They are original, relevant, methodologically solid, the conclusions are supported by the results and seem to have contributed significantly to the improvement of ecological knowledge about the age, growth and population structure of the South Georgia icefish. Although they are not exempt from criticisms of format and content, there seems to have been an evolution of the candidate's performance, assuming that the articles were worked and published according to the reported chronology. It is evident the commitment and work put on by the candidate in its execution, and I am of the opinion that it meets the minimum prerequisites of rigor and academic requirements necessary to award the degree of doctor.

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2. Specific Evaluation

a) Traczyk, R., & Meyer-Rochow, V. B. (2019). Age structure and biomass of the icefish *Pseudochaenichthys georgianus* (Channichthyidae) between 1976 and 2009: a Possible link to climate change. *Ocean and Polar Research*, 41(4), 233–250. <https://doi.org/10.4217/OPR.2019.41.4.233>

In this study, authors made a reassessment of the age structure and biomass of the population of the Antarctic ice fish, *Pseudochaenichthys georgianus*, based on the multimodal distributions of fish length frequency data obtained from historical commercial (1976 to 2009) and research (1989 and 1990) collections.

Age classes (I, II and III) were determined using appropriate and complex statistical methods. Moreover, the age (A50) and size (L50) at first maturity were also estimated, but need confirmation since gonadal histology (or even visual macroscopic evaluation) data is missing (as highlighted by authors). von Bertalanffy growth curve parameters (Linf, k and t0) were also obtained. A tendency of L50 reduction through time has observed and linked to natural variations of some abiotic and biotic factors, eventually related to the ongoing climate changes.

Biomass from two additional icefish species (*Chaenocephalus aceratus* and *Champscephalus gunnari*) were also estimated and non-overlapping temporal oscillations appears to be related with oceanographic harmonic periodicities.

The age data reported hereby is not new, but it is up-dated and improved compared with previous studies probably biased by limited datasets. This information is very useful to fisheries biology to take appropriate measures to make a rational and sustainable management of icefish species.

This study has been published in an international peer-review journal (CiteScore: Impact factor 0.5; Scimago Journal Ranking: Q4; Number of Citations: unknown).

b) Traczyk, R., Meyer-Rochow, V. B. & Hughes, R.M. (2020). Icefish adaptations to climate change on the South Georgia Island Shelf (Sub-Antartic). *Ocean Science Journal*, 55, 303–319. <https://doi.org/10.1007/s12601-020-0016-8>

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In this study, authors have been able to relate the biomass decreases in krill (*Euphausia superba*) and in some icefish populations (namely *Pseudochaenichthys georgianus* and *Chaenocephalus aceratus*) to predatory-prey interactions (such as competition for food availability and species growth) coupled with global changes (namely to ocean warming), although the habitat preferences of co-existent species (as previously suggested by Traczyk and Meyer-Rochow, 2019) give them some resilience skills to adapt to these environmental long-term changes.

Moreover, this study extrapolated their main findings to a future scenario (2100) of global warming, taking into consideration the long-term historical datasets of diverse Antarctic communities, weather conditions and oceanic currents.

Icefish and krill catch data were obtained from different research and commercial vessels between 1976 and 2017 during a narrow temporal season window (summer: December to February). These datasets jointly with seawater surface temperature (SST), ice cover extension and oceanographic sea currents were obtained from multiple reliable sources. Birds and mammal ecological data was also extracted from existent literature. Moreover, additional krill and icefish samples were also collected in the field by research vessels.

Age of adult fish was estimated from annual growth increments from otoliths and/or through the fish length frequency method. Biomass density and catch fluctuations were fitted against SST using appropriate mathematical approaches, including sinusoidal regressions which showed high determination coefficients.

Krill aggregations were distributed at different water depths and temperatures, oscillating at short temporal intervals due to SST, and with a long temporal interval resulting from annual cold and warm temperature cycles. The icefish biomass dataset also showed a cyclical variation related with the annual water temperatures, despite some regional discrepancies easily explained by oceanographic, weather or fishery variables. However, the resilience to warming is species specific due their habitat ranges and life histories, allowing the optimization of the habitat use and foraging resources in time and space. The breeding success of some seabirds and sea mammals was also inversely related with krill biomass, despite some time lags.

In conclusion, this is an original, innovative and methodologically sound work, particularly important to show the Antarctic biota adaptations, particularly of the icefish species, to the ongoing climate changes. Moreover, acquired knowledge about co-existent icefish species assemblages is crucial for the fisheries management and conservation in this particular geographic area.

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This study has been published in an international peer-review journal (JCR: Impact factor 1.042; Scimago Journal Ranking: Q3, Number of Citations: 2).

c) Traczyk, R., Meyer-Rochow, V. B. & Hughes, R.M. (2021). Age determination in the icefish *Pseudochaenichthys georgianus* Norman (Channichthyidae) based on multiple methods using otoliths. *Aquatic Biology*, 30, 1–18. <https://doi.org/10.3354/ab00736>

In this study authors describe a method to age *Pseudochaenichthys georgianus* individuals by reading the primary increments in their sagittal otoliths mainly through transmitted and reflected light microscopy, and confirmed in some sub-samples by scanning electron microscopy after EDTA etching and platinum-palladium coating. A huge number of individuals, ranging from 6 to 56 cm of total length, annually collected between 1977 and 1992 by summer research vessels were used in this study.

The daily increments and growth patterns were counted/analysed visually by naked eye and using a microdensitometer coupled with a spectro analyser software. Particular attention was given to subdaily microincrements and secondary accessory primordia, that could bias the daily rings count. The daily deposition of microincrements was validated through complex and indirect methods. Some otolith shape variables (e.g. area, perimeter, radius and others) were also recorded. Otolith mass frequencies were also checked for congruency among sampling dates and geographic locations.

A good relationship was found between otolith mass and fish age (days after-hatching). All data was explored using complex statistical analyses. A relationship between the ice fish feeding regime and deposition of the daily micro-increments is suggested. Moreover, changes in the appearance and width of the daily increments allowed the authors to track several life history events, such as hatching, shift from pelagic to benthic habitat and spawning.

Finally, the hereby results (namely the unimodal individual variability of the otolith mass) suggest the existence of a single panmictic population of *P. georgianus* in the Southern Ocean between the Antarctic Peninsula and sub-Antarctic South Georgia, a crucial information to the rational and sustainable management of the fisheries.

This MS has been published in an international peer-review journal (JCR: Impact factor 2.125; Scimago Journal Ranking: Q2; Number of Citations: 1).

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d) Traczyk, R., & Meyer-Rochow, V. B. (2022). Otolith microstructural organization in the South Georgia icefish *Pseudochaenichthys georgianus* (Channichthyidae) and cautious considerations on how otoliths can provide clues on a species' distribution and migration in Antarctic waters. *Ocean and Polar Research*, 44(1), 39–59. <https://doi.org/10.4217/OPR.2022003>

In this study a detailed microstructural study was done using 3736 sagittal otoliths of *Pseudochaenichthys georgianus* individuals collected in South Georgia and South Shetland between 1976 and 1991 from research cruises. The three-dimensional morphology of these otoliths has been analysed in terms of collagen and calcium carbonate deposition during the otolith aragonite growth accretion that takes place during the ontogenetic development of the icefish coincidental with changes in their habitat. The otolith microstructural properties were observed using light microscopy, and thereafter embedded, grounded, polished and coated otoliths were viewed under scanning electron microscopy at several magnifications.

Microincrements showed to be a bipartite structure, made off a narrow collagen layer, and a wide aragonite layer. The predominant mineral form of the calcium carbonate polymorphs of the otolith matrix (e.g. aragonite, vaterite or calcite) was inferred following EDTA etching and LM and SEM observations.

This study suggests that otolith microstructural transitional changes that occur through the fish life history, namely from larvae to juveniles/adults, are due to physical effects related to swimming abilities related to a better adaptation to a particular water depth and habitat. Some differences were also recorded between sexes, with the females having lighter otoliths, which are probably related with reproductive migration and aggregation purposes.

Because of the physiological particularities of icefish, and due to the difficulty of performing laboratorial experimental designs for these species, further studies, with other fish species and using alternative approaches, are however need to validate this hypothesis.

This study has been published in an international peer-review journal (CiteScore: Impact factor 0.5; Scimago Journal Ranking: Q4; Number of Citations: unknown).

3. Final Remarks

After a careful and detailed reading of this thesis, in particular of the published articles that constitute its main body, it is evident the considerable amount of work done by the candidate, some of them particularly time-consuming such as the otolith microstructural studies, the excellence of the mathematical and statistical analyses approaches, the careful interpretation of the obtained results and the importance of the main conclusions obtained for the rational and sustainable fisheries management of the icefish species. Equally important, is the fact that the articles are strictly interconnected, and have been constructed temporally in a logical sequence, which is to be desired in a doctoral thesis.

However, there are some aspects that the candidate should try to improve in the future regarding the scientific style writing, although his progression in performance should be highlighted: i) you should put extra care in the English writing, as some basic typos errors are still common even after the articles been copy-edited and published; ii) do not forget the need to always support scientific statements with appropriate citations, sometimes forgotten in some sentences and/or paragraphs in the published papers; and iii) the need to clarify in the M&M section the reader to the material used in each paper, using complementary detailed tables.

Finally, and as a corollary of the thesis, I suggest to the candidate the use of alternative approaches to validate or refute some working hypotheses, namely the use of otolith shape (EFD and WD) and chemical (elemental and isotopic composition) signatures for the study of the population structure, migration patterns and habitat connectivity in fish.

I want to finish my evaluation by congratulating the candidate for having completed this important stage of his academic life.

Porto, 8 January 2023



Prof. Dr. Alberto Teodorico Correia (BSc, PhD and PD in Aquatic Sciences)