University of Prince Edward Island

Faculty of Veterinary Medicine
Summary of Dissertation

Submitted in Partial Fulfilment
of the Requirements for the

DEGREE OF DOCTOR OF PHILOSOPHY

Svenja Koepper
Department of Health Management

Supervisory Committee

Dr. J McClure, Chair
Dr. K. Thakur, Co-supervisor
Dr. C. Revie, Co-supervisor
Dr. H. Stryhn
Dr. F. Clark

Examination Committee

Dr. S. Saksida, Chair
Dr. J. Davidson
Dr. C. Revie, Co-supervisor
Dr. F. Clark
Dr. K. Lavalli, External Examiner

A comprehensive analysis of the shell microbiome of American lobsters in Atlantic Canada, supported by population dynamics modeling

Albeit being the most lucrative species in Atlantic Canada, the American lobster (*Homarus americanus*) fishery faces challenges, such as epizootic shell disease (ESD) outbreaks. While a shift in the lobster shell microbiome has been determined to be one of the key factors of ESD, the overall microbial community composition is still insufficiently researched. As ESD is also linked to lobster population dynamics, the first part of this thesis determined sex ratio patterns and size distributions in the two most important lobster fishing areas (LFAs) in southwestern Nova Scotia. The sex ratio differed by LFA and larger females were more likely to inhabit colder deeper waters. Showing that larger females prefer habitats where ESD prevalence is reportedly lower, contributes to the knowledge gap of how disease outbreaks could be linked to host and environmental factors. The second part of the thesis provides a novel, comprehensive description and analysis of the shell microbiome of apparently healthy lobsters from Atlantic Canada. *Gammaproteobacteria, Saprospiria,Verrucomicrobiae, Alphaproteobacteria, Flavobacteriia, Acidimicrobiia* and *Planctomycetia* were the most common bacterial classes, but differed in abundance by region, season, lobster sex and moult stage. Interestingly, the bacterial genus that is most commonly linked to ESD, *Aquimarina*, occurred to a higher degree in LFAs 37 and 25 but it has yet to be determined if differences in the frequency of this taxon stem from geographic variation alone if it could be linked to lobsters being more likely to develop ESD. Microbial alpha and beta diversity differed significantly by region, sampling month and moult stage but not by lobster sex or size. While larger females are more susceptible to ESD, no significant effect by lobster sex and size on the shell microbial diversity was detected in healthy lobsters. Overall, this thesis presents a comprehensive baseline for future work to deepen our understanding of the lobster shell microbiome and the data presented are highly relevant for future research on the American lobster pathobiome and bacteria-mediated diseases such as ESD.

Publications

Koepper S, Clark KF, McClure JT, Revie CW, Stryhn H, Thakur KK, 2023. Long-read sequencing reveals the shell microbiome of apparently healthy lobsters *Homarus americanus* from Atlantic Canada. Frontiers in Microbiology 14:1245818. https://doi: 10.3389/fmicb.2023.1245818

Koepper S, Kelley S, Thakur KK, Clark KF, 2023. Interspecies and spatial differences in the shell microbiome of Atlantic rock crab (*Cancer irrotatus*) and European green crab (*Carcinus m*aenas) from Atlantic Canada. Frontiers in Marine Science 10:1152544. https://doi.org/10.3389/fmars.2023.1152544

Kleinerz S, Yulianto I, Hennen C, **Koepper S**, Simeon BM, Theisen S, Palm HW, 2022. Elasmobranchs from Indonesian waters: feeding ecology and Trypanorhynch cestode fauna composition to support efforts in shark and ray conservation. Acta Parasitologica 2022. https://doi.org/10.1007/s11686-022-00593-7.

Koepper S, Nuryati S, Palm HW, Yulianto I, Wild C, Kleinertz S, 2022. Metazoan endoparasite fauna and feeding ecology of commercial fishes from Java, Indonesia. Parasitology Research, 121(2): 551-562. https://doi.org/10.1007/s00436-021-07377-4.

Koepper S, Scott-Tibbetts S, Lavallée J, Revie CW, Thakur KK, 2022. Fisheries dataset on moulting patterns and shell quality of American lobsters *H. americanus* in Atlantic Canada. Scientific Data, 9(1), 1-8. https://doi.org/10.1038/s41597-022-01503-2.

Heirina A, Krisanti M, Butet NA, Wardiatno Y, **Koepper S**, Hakim AA, Kleinertz S, 2021. Ectoparasites of blue swimming crabs (*Portunus pelagicus*) from Demak and East Lampung, Java Sea Indonesia. IOP Conference Series: Earth and Environmental Science, 774, 012026. https://:10.1088/1755-1315/744/1/012026.

Kleinertz S, Silva LMR, **Koepper S**, Hermosilla C, Ramp C, 2021. Endoparasitic insights off free-living fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*) and north Atlantic right whales (*Eubalaena glacialis*) from eastern Canadian waters. Acta Parasitologica, 66(2): 682-686. https://doi.org/10.1007/s11686-020-00298-9.

Koepper S, Revie C, Stryhn H, Clark FK, Scott-Tibbetts SH, Thakur KK, 2021. Spatial and temporal patterns in the sex ratio of American lobsters (*Homarus americanus*) in southwestern Nova Scotia, Canada. Scientific reports, Scientific Reports, 11(1):1-11. https://doi.org/10.1038/s41598-021-03233-8.

Koepper S, Nuryati S, Palm HW, Yulianto I, Theisen S, Wild C, Kleinertz S, 2021. Parasite fauna of the white-streaked grouper (*Epinephelus ongus*) from the Thousand Islands, Java, Indonesia. Acta Parasitologica,66(2): 543-552. https://doi.org/10.1007/s11686-020-00312-0.

Papkou A, Schalkowski R, Barg MC, **Koepper S**, Schulenburg H, 2021. Population size impacts host-pathogen coevolution. Proceedings of the Royal Society B, 288(1965): 20212269. https://doi.org/10.1098/rspb.2021.2269.

Papkou A, Guzella T, Yang W, **Koepper S**, Pees B, Schalkowski R, Barg MC, Rosenstiel PC, Teotónio H, Schulenburg H, 2019. The genomic basis of Red Queen dynamics during rapid reciprocal host–pathogen coevolution. Proceedings of the National Academy of Sciences,116(3):923-928. https://doi.org/10.1073/pnas.1810402116.

Submitted:
Koepper S, Revie CW, Stryhn H, Thakur KK. Observed size distribution changes in American lobster over a 12-year period in southwestern Nova Scotia, Canada. PloS ONE (Manuscript submitted).

Koepper S, Clark KF, McClure JT, Revie CW, Stryhn H, Thakur KK. Differences in diversity and community composition of the shell microbiome of apparently healthy lobsters *Homarus americanus* in Atlantic Canada. Frontiers in Microbiology (Manuscript submitted).

Presentations

Thakur KK, Clark KF, McClure JT, Revie CW, Stryhn H, **Koepper S.** Bacterial interactions and diversity patterns in the shell microbiome of American lobster (*H. americanus*) in Atlantic Canada. Canadian Association for Veterinary Epidemiology and Preventive Medicine (CAVEPM) (2023). Oral presentation.

Koepper S, Clark KF, McClure JT, Revie CW, Stryhn H, Thakur KK. The healthy lobster shell microbiome: A diversity and community assessment. 30th Annual conference: Fishermen and Scientists Research Society (2023). Oral presentation.

Koepper S, Clark KF, McClure JT, Revie CW, Stryhn H, Thakur KK. Diversity and community composition of the American lobster (*Homarus americanus*) in Atlantic Canada. Conference of Research Workers in Animal Diseases (CRWAD), 2023. Oral presentation.

Koepper S, Clark KF, McClure JT, Revie CW, Stryhn H, Thakur KK. The shell microbiome of American lobster *Homarus americanus* in Atlantic Canada. 9th International Symposium on Aquatic Animal Health (ISAAH), 2022. Oral presentation (virtual).

Koepper S, Clark KF, McClure JT, Revie CW, Stryhn H, Thakur KK. Characterizing the shell microbiome of American lobster *Homarus americanus* from Atlantic Canada. Aquaculture Canada and WAS North America, 2022. Poster presentation.

Koepper S, Clark KF, McClure JT, Revie CW, Stryhn H, Thakur KK. The shell microbiome of American lobster *Homarus americanus* in Atlantic Canada. 16th International Symposium of Veterinary Epidemiology and Economics (ISVEE), 2022. Oral presentation

Koepper S, Clark KF, Scott-Tibbetts S, Revie CW, Stryhn H, Thakur KK. Spatial and temporal patterns in the sex ratio of American lobster in southwestern Nova Scotia. Ocean Frontiers Institute, Climate Action Conference, 2022. Poster presentation.

Koepper S, Clark KF, Revie CW, Stryhn H, Thakur KK. Methods and their importance for describing the shell microbiome of American lobsters (*H. americanus*). 29th Annual conference: Fishermen and Scientists Research Society, Halifax, Canada, 2022. Oral presentation (virtual)

Koepper S, Clark KF, Scott-Tibbetts S, Revie CW, Stryhn H, Thakur KK. Sex ratio patterns and shell microbiome community of American lobsters in Atlantic Canada. UPEI Graduate Studies and Research Conference, 2021. Oral presentation.

Awards

2022 - Dr. Ian Dohoo Award for conference travels, University of Prince Edward Island (CA$2,500)

2022 - Funding: Student Research Travel Fund for conference travel, University of Prince Edward Island (CA$500)

2021 - Award: Fish Health Graduate Student Award, Atlantic Veterinary College, University of Prince Edward Island (CA$167)

2021 - Scholarship: One Health Summer Institute: Introduction to Bioinformatics, University of Calgary (CA$500)

2021 - Scholarship: 11th Summer Institute in Statistics and Modelling in Infectious Diseases (SISMID); Microbiome Data Analysis, University of Washington (US$300)

Biographical Data

My name is Svenja Koepper and I am originally form Germany, where I received both my Bachelor's and Master's degree. I have a background in marine biology and my past work focused on host-parasite relationships, fish parasitology and aquatic animal health. I am a PhD candidate in aquatic epidemiology (Department of Health Management). My project investigates population dynamics of American lobsters and the role of the lobster shell microbiome on epizootic shell disease, an infectious disease that is a concern to the local lobster fishery. Working towards sustainable and healthy fisheries is one of my strongest research interests.

Born in Hanover, Germany.