FILAMO Grant — Connecting field work and laboratory experiments to numerical modelling in a changing marine environment

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Report on my experience

I have spent the last few months working with Professor Magnus Wahlberg at the University of Southern Denmark's (SDU) Marine Biological Research Center in Kerteminde, Denmark. The research center is located next to the Fjord and Belt Center which houses captive harbour porpoises and seals. My time spent working with Prof. Wahlberg has been a priceless asset to my future career path in marine bioacoustics. I cannot begin to describe how much I have learned during my short time in Denmark funded by the FILAMO award. The marine lab through SDU has been a perfect fit for my research purposes as well as supervision during my time spent in Denmark.

Upon returning from Denmark, I will dedicate time toward applying for post-doctoral grant funding in order to return to Denmark for a post-doc position under the supervision of Prof. Wahlberg. We have a great working relationship and would like to continue to work together. My future career has already been positively affected by the FILAMO study program in that I have been able to successfully build a relationship with Prof. Wahlberg and SDU. I have been given the opportunity to travel to Argentina for seven weeks during December - January to participate in a fieldwork expedition to record an understudied species of dolphin off Patagonia. Prof. Wahlberg is funding this trip and I am extremely excited for the opportunity to implement what I have learned and to continue to work together in this aspect. We plan to publish papers based on the data collected during my upcoming trip to Argentina.

Background of my PhD research

My doctoral research is dedicated to understanding the acoustic behaviour and distribution of odontocetes (toothed whales), with a focus on Heaviside's dolphins (*Cephalorhynchus heavisidii*). Heaviside’s dolphins are small (< 1.7 m) and endemic to the Benguela ecosystem along the western coast of southern Africa. Previous literature reports Heaviside’s dolphins exclusively produce narrowband high-frequency (NBHF) echolocation clicks with no energy below 100 kHz, identical to harbour porpoises (Morisaka et al., 2011). My doctoral research has shown that Heaviside’s dolphins can produce lower-frequency broadband clicks (BBCs) in addition to NBHF clicks (Martin et al., 2018). My PhD is novel in documenting this acoustic behaviour in Heaviside's dolphins and in doing so questions the current understanding of sound production in odontocetes, as there have been no animals recorded that can produce both types of biosonar signals. Interestingly, the recorded BBCs generally were produced in rapid succession in the form of ‘burst-pulses’ which are believed to be communication signals used by other odontocete species. We hypothesise that Heaviside’s dolphins produce lower-frequency broadband burst-pulse signals to extend their communication range. In contrast, NBHF clicks are highly directional and cannot travel more than 1 km underwater.

My research considered the question: Do lower-frequency broadband burst-pulses extend Heaviside’s dolphin acoustic transmission space; thereby, increasing the likelihood of being heard at greater distances and facilitating longer range group cohesion? To address this, I collaborated with Prof. Magnus Wahlberg, a pioneer scientist of odontocete sound analysis and director of a research lab within the Sound Communication and Behaviour Group at SDU. Dr Wahlberg is an internationally renowned leader in the field of biosonar and we collaborated on an acoustic propagation modelling study of sounds recorded from Heaviside's dolphins.

What I learned in Denmark
I received training in acoustic propagation modelling beginning in March 2019. Training took place at the campus Fjord and Baelt Centre, which specialises in harbour porpoise biosonar research and houses porpoises in an outdoor enclosure connected to the ocean. The tide and fish pass freely through the enclosure making it an ideal natural environment to conduct sound experiments. There are very few research centres capable of providing such bioacoustic expertise and the prerequisite equipment, making this a unique learning opportunity. Prof. Wahlberg's training has allowed me to conduct a thorough analysis of this research question and will be invaluable to my professional development as an acoustic scientist.

My research considered the question: Do lower-frequency broadband burst-pulses extend Heaviside's dolphin acoustic transmission space, thereby increasing communication range? My first PhD paper (Martin et al., 2018) addressed this question with a numerical modelling approach conducted solely by Danish co-author, Dr Frants Jensen. Dr Jensen modelled the detection range for NBHF clicks and for burst-pulses. He used a piston model to estimate changes in transmission beam and used empirical measurements of hearing sensitivity of a harbour porpoise to estimate changes in directional hearing. He modelled the detection range for a noise-limited scenario with Wenz Sea State 2 noise levels and accounted for changes in transmission loss due to lower frequency-specific absorption. A separate sensitivity analysis was conducted across a 25-dB variation in wind-generated ambient noise and a 25-dB variation in signal source levels to examine how varying noise conditions and output levels affect the relative change in active space between the two signal types. Dr Jensen concluded that while detection range depends on the modelled noise levels as well as source and receiver geometry, the estimated detection range was consistently greater for burst-pulse signals at all estimated source and receiver angle combinations. The resulting potential gain in active space of a burst-pulse signal would be around 2.5 to 5 times greater than the active space of a NBHF click, depending on noise level.

While this approach provided significant insight into the proposed question, it was never tested in the field. Further, I received no training in this numerical modelling approach. Prof. Wahlberg taught me how to conduct the range of aforementioned modelling approaches that Dr Jensen used so that I can autonomously conduct similar analyses in the future. Numerical modelling was conducted using MATLAB (The Mathworks Inc., USA). Also, we tested Dr Jensen's model results via acoustic playback experiments in the field. Prof. Wahlberg has the acoustic modelling experience as well as the necessary equipment and space to conduct playback experiments. We played back previously recorded Heaviside's dolphin NBHF clicks and burst-pulses underwater inside the Fjord and Belt Center at a range of amplitudes and with a series of calibrated hydrophone recorders located at increasing distances and angles from the playback speaker. We measured how both sound types propagated underwater (depending on ambient noise) by calculating the received source level at each hydrophone. The estimated detection range was indeed consistently greater for burst-pulse signals at all distances and receiver angle combinations. This exercise helped to establish confidence in our hypothesis that Heaviside's dolphins use lower-frequency broadband burst-pulses to extend the acoustic transmission space, thereby increasing communication range.