Collaboration Outcomes and Future Research Plans with Swansea University

SUMMARY REPORT

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(OERA)

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INTRODUCTION

One of the biggest questions surrounding the development of tidal energy is how it will affect the local ecosystem and marine life. Efforts are being made by marine biologists to observe the movement patterns of marine life near the turbine sites, before and after the turbines are deployed. However, these observations are often expensive and sometimes possess a large degree of uncertainty. One solution involves using drifter buoys to infer where the tide will carry the animals. The issue with this method that the buoys are inert and do not swim as marine life does. There is another solution: using the speed and efficiency of computers, it is possible to predict marine life interaction with turbines using an Individual-Based Model (IBM) and compare the results to existing observations. Many different models exist, and no one model is perfect. However, there is much insight to be gained through their implementation.

TRIP DETAILS AND BACKGROUND INFORMATION

My trip to the UK and Ireland collectively lasted roughly two weeks, visiting two different sites and attending a conference. The primary purpose of the trip was to gain a strong understanding of the model used at Swansea University to simulate harbour porpoise movements near turbines. This model was developed by Thomas Lake, a PhD student under the supervision of Dr. Ian Masters. Their primary region of application was Ramsey Sound, where a 400 kW turbine was deployed by Tidal Energy Ltd. in late 2015. Thomas's code was run for several different test cases, showing general agreement to previous observations (see [1]). His thesis was submitted for review on my last day visiting Swansea University.

The model represents two key premises of marine life behaviour: noise and food, where food is an attracting field and noise is a repelling field generated by turbines. Both fields have an initial strength and both drop off radially according to a power law defined by the user. The marine life can be described by a number of parameters – mass, body shape, drag, swim speed, and depth preference can all be changed to accurately simulate the behaviour of a particular species. For the purposes of my research, the parameters for Striped Bass were used, as this fish is known to spend time near the berth sites in the Bay of Fundy (see [2]). A random motion is also added in the model to represent turbulence.

For the duration of my stay at Swansea University, Thomas showed great enthusiasm in showing the various aspects and operations of his code. A demonstration simulation was completed during my final week in Swansea, confirming that the FVCOM grid used to model tidal flow in the Bay of Fundy does work with the Swansea code. Figure 1 is an image generated through my work there, demonstrating how Striped Bass move past an arbitrary noise source in Minas Passage. 165 particles were used to model the fish (representing the number of tagged fish in [2]), and the parameters given were taken from various literature (the numbers used were taken from [2] and [3]).

Another useful aspect of Thomas's code was the capability for analysis. Apart from being able to generate basic statistics and time series plots, a probability map of the movement of marine life show how often the animals spend their time in a particular grid box. An example of this plot is shown in Figure 2. Variations can be made to the grid box resolution, etc. All plotting was done in Paraview, a program devoted to visualizing Computational Flow Dynamics (CFD).

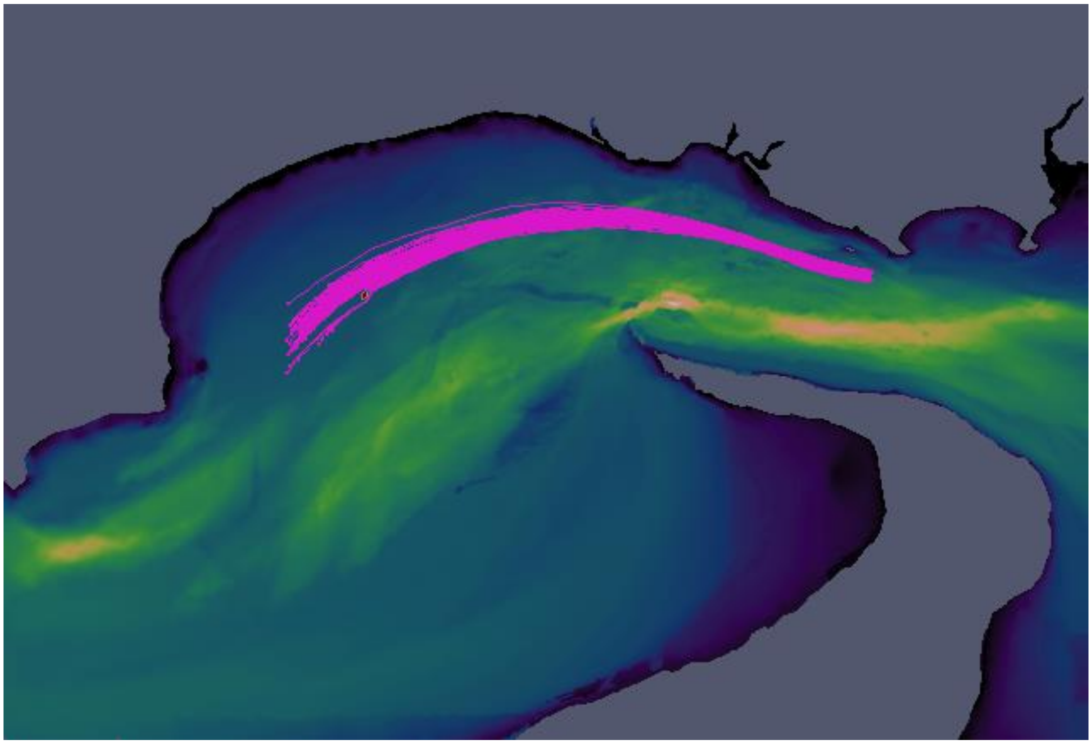

Figure 1: A clear wake is shown behind an arbitrary noise source in Minas Passage. The colors represent depth, and the pink trajectories are the particle (fish) path lines, starting from a point near Black Rock.

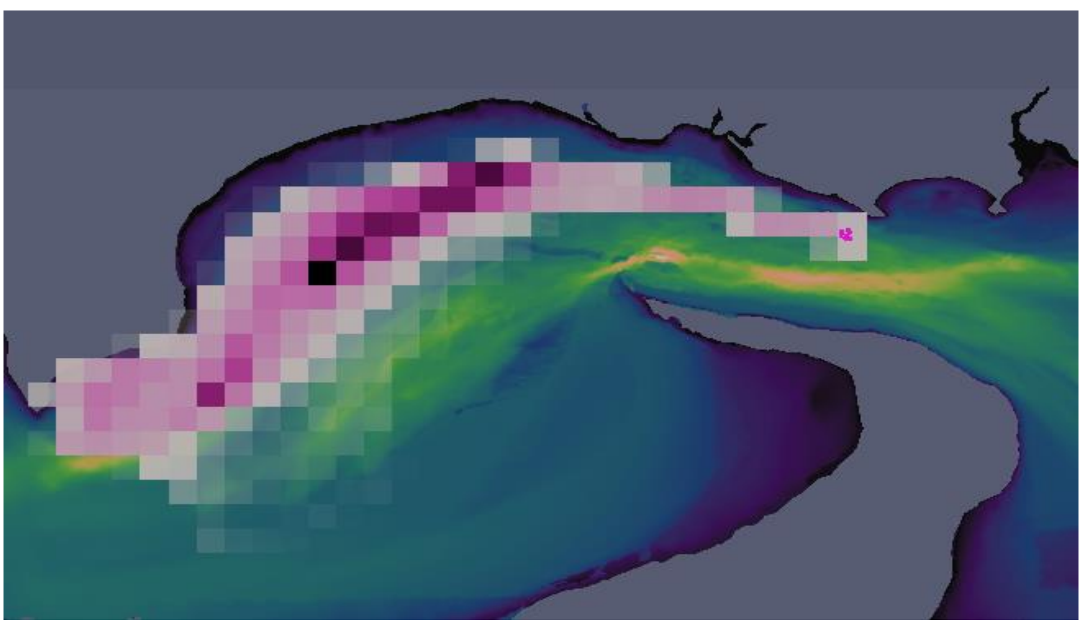

Figure 2: A demonstration run showing where fish spend most of their time over several tidal cycles – no noise or food is present in this run. The calculation allows the user to define a grid size, and each grid box is then colored depending on the frequency of fish transits. A darker color indicates many fish populate that region during the simulation. Once again, the particles were released near Black Rock.

During my visit to Swansea, I had the opportunity of visiting Tidal Energy Ltd.'s field office in Pembrokeshire, where I learned how the turbine was operated and maintained. I gave a presentation to the Marine Renewable Energy group during my stay as well.

After my trip to Wales was completed, I was privileged to spend two nights in London to attend the NERC (Natural Environment Research Council) Challenges and Opportunities of Renewable Energy conference at the QEII Conference Center. Here, I met researchers in academia and industry pursuing interests in many fields of renewable energy, including tidal energy, wave energy and offshore wind farms. I was exposed to the different ways these unique problems are approached, and just how multi-faceted they can become: everything from the economy to the local infrastructure and working population has an impact on the decisions made.

The second group I visited was the OpenHydro Technical Centre in Greenore, Ireland. OpenHydro is slated to deploy two 2 MW demonstration turbines in Minas Passage in 2016, so this trip proved invaluable in terms of acquiring a more qualitative response to tidal energy. During my visit, I was able to talk to many different researchers about their input to the project and how they felt about upcoming deployments. I met with researchers who were specifically focused on marine life and their interactions with the turbines, as well as various project engineers who dealt with the day-to-day operations of the turbines.

Although my trip to Greenore was shorter than Wales, I was exposed to the people involved in the entire process, from CFD modeling to stress analysis to biological monitoring. It was in many ways similar to my visit to the turbine in Pembrokeshire; however, Tidal Energy Ltd.'s turbine is much smaller than OpenHydro's, and OpenHydro did not have any operating turbines on-site. They did have a machine that simulated tidal currents through a model turbine instead, thus generating electricity that was sent through the entirety of the turbine control center (TCC). Thus, the power systems could be tested as if they were operating in a tidal flow. Jamie Ross was the Research and Development Engineer who showed me around the site. He answered many questions I had on the performance of the turbine, specifically what kind of noise they create in the water (to be used in the Swansea code).

BENEFITS OF TRAVEL

Because Thomas was busy with his research and his thesis, he was unable to write up a formal set of instructions for using his code. The biggest benefit of traveling to see him, then, was to learn how to use his code in conjunction with FVCOM, learn the basics of Paraview, generate plots, and conduct statistical analyses on the results.

Much discussion occurred surrounding how the code could possibly be improved and where we could see it going in the future. Various suggestions have been taken into consideration by Thomas, who will continue to work on his code after his thesis is finished review. Among the suggestions, a few that stood out were:

1. Easily turning off 'swimming' and other fish parameters in order to model inert drifters, which is another aspect of my research. This was completed by Thomas recently. This would allow an additional method of validation for FVCOM through comparison to Greg Trowse's OERA-funded research.
2. Currently, the model simulates turbines as a noise source with a strength and a decay. There is no vertical variation in the strength of the turbine. In order to do so, a good model for noise transmission through vertical columns of water would be needed. Furthermore, the low frequency noise emitted by the turbines would travel a far distance before it attenuates

significantly, and it is computationally easier in the model to consider the turbine as a 2D structure.

3. Allowing movements on the surface. Once again, this would help with simulating drifters. However, dealing with boundaries in CFD models is difficult, and dealing with boundaries in IBM models is also difficult, so for now, an easy fix for this is to just model the drifters within the top 10% of the water column.
4. Easily implementing flow-variant noise for the turbines. Currently, noise and food can be time-dependent, but to make the noise flow-dependent is a difficult problem. Moreover, the signal-to-noise ratio for a turbine in the water is not known with certainty, so implementing a method to calculate the noise perceived by fish at slack tide versus peak tide speed is problematic.

Another benefit of the trip was to bring back some advice for the improvement of PyTracker. Mitchell O'Flaherty, at the Bedford Institute of Oceanography, has developed a primitive, Python-based particle-tracking code to model inert objects. It would be a good investment of time to study the tools used by Thomas in his code and adapt them for use in the Python model. As of yet, Mitchell's code is incomplete, so input from other projects is appreciated. The comparison between the two codes is also of value: I had previously used Mitchell's code to model inert drifters, and Thomas's code to model swimming marine life - it would be worth understanding how the two compare in terms of performance and accuracy for similar tasks.

The trip was also beneficial to the researchers at Swansea University. With the application in Minas Passage, Ian and Thomas both get an additional venue to see their project in action. Previously, the model had been used only in the North Sea and Ramsey Sound. At least now, the group can see how well their model works in a completely different environment using completely different animals.

For the latter part of the NERC conference, I was lucky enough to sit in on a discussion with Dr. Masters , researchers, and investors from the Scottish Oceans Institute and other organizations focused on understanding the collision risk of marine life with renewable technology. Because my background is in mathematics, I never really understood the vast level of difficulty that exists in trying to quantify avoidance and evasion rates for different species of fish and birds. Different devices may be used to monitor, but none capture the entire situation – how does the animal behave near the structure(s)? What are the conditions affecting the animal's perception? What are the impacts on migration or breeding behavior? If an animal strikes a turbine's blade, is it damaging to either animal or blade? Large uncertainties exist concerning marine renewables and the environment.

OUTCOMES OF TRAVEL

The trip was a success. I was exposed to the world of renewable energy from an academic and industrial standpoint. I was able to put my problem into a global context and better appreciate the multi-disciplinary nature of tidal energy. More technically, I was able to understand Thomas's code much more efficiently than if I had spent a summer writing my own code. Upon my return to Canada, I immediately developed a plan moving forward: the rest of my summer is to be spent adjusting the code parameters until a sufficient model for Minas Passage is developed. This includes a comprehensive literature review on the various feeding behaviors, noise detection, and physical parameters of Striped Bass in both the summer and the winter (two separate runs for Minas Passage will be completed for both seasons), and an understanding of the noise signal generated by the turbines, as well as the impact the background noise has on the signal. Initially, a small number of particles will be used for computational ease and efficiency.

With these two models, we hope to show that we can predict, in qualitative terms, the movement of Striped Bass in the passage. If this is successful, more work will be done to ensure statistical robustness and allow for a more quantitative analysis. It can then be seen how the presence of a turbine in the model affects the movement of the Striped Bass – the environmental impacts of the in-stream devices may be assessed. Furthermore, now that Thomas has added the ability to model inert objects, we may compare the particle tracking code to Mitchell O'Flaherty's results in Minas Passage.

The work will lead to an undergraduate thesis, expected in the spring of 2017, as well as a joint publication with the Swansea group in a journal highlighting the application of Thomas Lake's code to Ramsey Sound and Minas Passage, submitted by the end of the summer. In both cases, regions of high marine life activity may be identified. Moreover, I plan on attending various undergraduate conferences that are approaching this upcoming school year if I have time, namely, the Atlantic Undergraduate Physics and Astronomy Conference at UPEI, the Computer Science, Mathematics and Statistics Conference in Cape Breton, the Canadian Undergraduate Physics Conference in Halifax and the Marine Renewables Canada Annual Conference in Halifax.

SIGNIFICANCE TO NOVA SCOTIA

Several significant deliverables come from this collaboration. Firstly, the project is important for understanding the marine life-turbine interactions for Minas Passage developments. The project will allow researchers at Acadia understand how Striped Bass behave in the presence of a turbine, which has recently been a point of contention among locals (see [4], [5]).

Another significant outcome of this collaboration: it opens the door for future work with Swansea University and other connected institutions in the UK. The UK is a world leader in renewable power generation, and has one of the strongest marine renewables research program, with world-renowned academics all over the nation studying off-shore wind energy, tidal energy, and wave energy. The European Marine Energy Centre (EMEC) itself has alone supported the deployment of more wave and tidal energy devices than any other site on the planet (see [6] for more information). With the impending separation from the European Union, the funding status of many of these projects, including Ian's, remains under question. It is quite possible that a new world leader in marine power emerges to take the stage. If Nova Scotia is to accept this role and truly stand for tidal energy, with all its benefits and challenges, it must first lean upon the years of work and development from more experienced projects such as those developed by EMEC and other institutions.

ACKNOWLEDGEMENTS

I would first and foremost like to extend my deep-hearted gratitude to my supervisor, Dr. Richard Karsten, whose boundless devotion to his students and their enrichment has elevated him to god-like status in my eyes. I would like to thank Greg Trowse, without whom my honours project would not even exist. Also, diolch yn fawr to my Welsh collaborators at Swansea University, who have devoted much time to answer my unending questions during and after my trip (especially Tom Lake, whose thesis deadline was at the end of my two week stay!). Thanks to OERA for funding this trip – it has developed me as a student, a researcher, and a human being. Finally, if it weren't for my good friend Jon Smith, I would still be in my office banging my head against a desk for lack of working code.

Slán go fóill / Hwyl fawr am nawr / Good bye for now.

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