Proceedings of the 3rd Marine Energy Technology Symposium
METS2015
April 27-29, 2015, Washington, D.C.

ADVANCING A KEY CONSENTING RISK FOR TIDAL ENERGY: THE RISK OF MARINE MAMMAL COLLISION FOR IN-STREAM TIDAL ENERGY DEVICES

Cormac Booth
SMRU Consulting - Europe
St Andrews, United Kingdom

Carol Sparling
SMRU Consulting - Europe
St Andrews, United Kingdom

Jason Wood
SMRU Consulting – North America
Vancouver, Canada

Dom Tollitt
SMRU Consulting – North America
Vancouver, Canada

Lindesay Scott-Heyward
CREEM, University of St Andrews
St Andrews, United Kingdom

Eric Rexstad
CREEM, University of St Andrews
St Andrews, United Kingdom

Ylva Hultgren
Minesto AB
Västra Frölunda, Sweden

Martin Johnsson
Minesto AB
Västra Frölunda, Sweden

Eric Knutzen
Minesto AB
Västra Frölunda, Sweden

[1]Corresponding author: cgb@smrumarine.com

ABSTRACT

Collision risks between marine mammals and tidal energy devices are poorly understood and this perceived risk of collision remains a major issue for the in-stream tidal energy industry, regulators, and stakeholders. Without additional information on the level of risk there is a potential constraint on the scale of future tidal energy development. This paper presents the development of a new modelling approach to understand the risk posed by a novel tidal technology. Minesto has developed a tidal power plant named Deep Green. This technology comprises a kite/wing and a tether running to a single anchor point. The device leverages the tidal current to lift the hydrodynamic wing; the power plant essentially flies in the water column in a 'figure of 8' shaped pattern. Collision probabilities (CP) varied depending on the anchor point of the device, the current speed (tidal state) and swimming behaviour of animals. Overall CP estimates varied, with between 0.78 - 2.69% of animals that passed through the water column were predicted to collide with the device. Simulations where animals were actively swimming with the current had lower CP than when passively drifting with the current. Differences in CP were observed between anchor positions (surface: 1.1-1.5%; seabed 0.8-0.9%) for active animals. Animals were predicted to be more likely to collide with the tether than the kite (61-80% tether; 20-39% kite). It is difficult to directly compare with other tidal projects due to different methods and data used to estimate collision risk across projects. However, on average, the risk predicted here is lower than estimates for the same species at other sites for different devices. We will also present next steps for such assessments, including enhanced collision/strike risk models (incorporating animal movement), data gaps in model parameterization (and consequent risk levels), near-field monitoring tools presently being used to address these limitations and population-level modelling.

INTRODUCTION

Collision risks between marine mammals and tidal energy devices are poorly understood and this perceived risk of collision remains a major issue for the in-stream tidal energy industry, regulators, and stakeholders. Without additional information on the level of risk there is a potential constraint on the scale of future tidal energy development.

Minesto has developed a tidal power plant named Deep Green (DG). This works by allowing the tide to lift the hydrodynamic wing part into areas of peak tidal flow between 1.5-2.5 m/s. The power plant flies in the water column in a 'figure of 8' shaped pattern which accelerates the tidal velocity into the turbine (placed underneath the wing) with a factor of 10 to generate the most electricity (Figure 1). The kite has so far been deployed using both an anchor on the seabed (see Figure 1) and also been operational with the tether attached to surface barge. Under this 'surface' anchor, an inverted Figure 1 set-up exists (i.e. Figure 1 flipped vertically so the anchor point is at the surface) The tether runs from the kite to the surface barge but the shape of the kite movement remains similar to the seabed deployment (Minesto, pers comm.). The kite typically moves at between 3-8 m/s depending on the current speed at the site. They are currently testing a 1:4 power plant prototype at Strangford Lough, Northern Ireland.

METHODS

Collision Risk Modelling – DG and seal simulation

To assess the potential for collisions between harbour seals (*Phoca vitulina*) and the DG device a simulation-based model was constructed. The collision model is made of three parts:

1. Seal trajectory
2. Kite (DG) trajectory
3. Collision between trajectories through time

The seal trajectory models the movement of the seal in the horizontal plane ('x,y' dimensions); the starting point is randomised at the start of each simulation run. The size of the harbor seal was 1.6m in length and 0.2m in radius and was chosen to represent the size of an adult animal at the Strangford site. We considered that as collision probability is positively correlated with animal body length, that the collision probabilities presented here would therefore represent upper estimates (i.e. smaller animals would likely collide less than larger ones in the model). The DG trajectory is informed by raw kite movement data supplied by Minesto UK Ltd. Figure 2 shows a simplified diagram of the kite movement, indicating the current flow. Seal starting points were on the left wall of the figure (i.e. upstream) and animals moved left to right (moving downstream) in this figure (with the direction of flow). The start points of seal passages in the plane are non-uniformly distributed in the water column according to the known depth distribution of harbour seals in the Strangford Narrows from a telemetry study (Sparling & Lonergan, 2013).

The kite telemetry data provide the GPS location of the centre point of the kite at 20ms intervals. From this the kite and the tether positions are defined by a cloud of data points. The seals are sent on their trajectory from the start to end points also at 20ms intervals, while a portion of the kite telemetry trajectory (plus tether) is moved through time according to the kite movement data. The definition of contact is when the kite/tether data points are within 'gap' distance of the seal. The gap was set at 0 m – meaning direct contact.

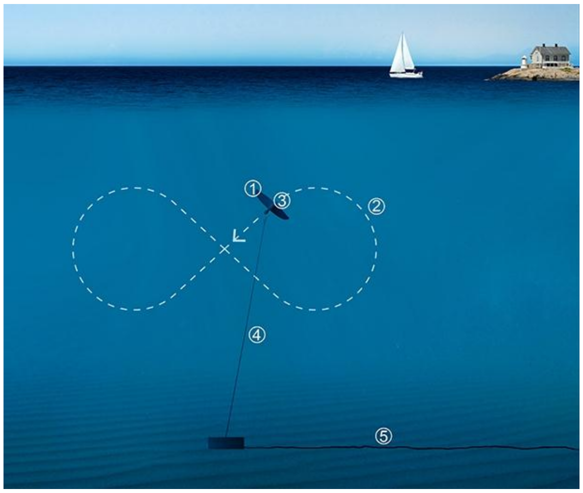

FIGURE 1. A SCHEMATIC SHOWING THE PRINCIPLE OF MINESTO'S DEEP GREEN DEVICE (© MINESTO UK LTD). "THE WATER CURRENT CREATES A HYDRODYNAMIC LIFT FORCE ON THE WING WHICH PUSHES THE KITE FORWARD (1). THE KITE IS STEERED IN AN 8-SHAPED TRAJECTORY BY A RUDDER AND REACHES A SPEED TEN TIMES THE WATER CURRENT SPEED (2). AS THE KITE MOVES, WATER FLOWS THROUGH THE TURBINE AND ELECTRICITY IS PRODUCED IN THE GEARLESS GENERATOR (3). THE ELECTRICITY IS TRANSMITTED THROUGH A CABLE IN THE TETHER ATTACHED TO THE WING (4). THE ELECTRICITY CONTINUES IN SUB-SEA CABLES ON THE SEABED TO THE SHORE (5)."

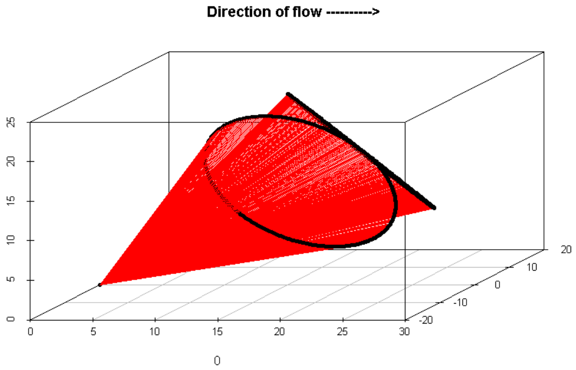

FIGURE 2. - SIMPLIFIED SCHEMATIC OF THE KITE (BLACK) AND TETHER (RED) MOVEMENT. THE DIRECTION OF MOVEMENT FOR SIMULATED SEAL PASSAGES IS FROM THE LEFT WALL TO THE RIGHT WALL. THE KITE IS ANCHORED TO THE SEABED IN THIS EXAMPLE.

Simulation scenarios

Six seabed tethered DG movement datasets were provided by Minesto UK Ltd at six tidal states: one hour before peak flow, during peak flow, one hour after peak flow for both spring and neap tides. It was assumed that the kite will function on both the ebb and flood tide. For each of these six tidal states two categories of seal movement were modelled: passive seals that moved downstream through the simulated space at the current speed and active seals that actively swam downstream at a speed of 1.5m/s more than the current speed as they moved through the simulated space.

For each simulation, 10,000 seals were moved through the simulated space. Each simulation was then run ten times for each tidal state to allow an assessment of the variation in probability of collision (this variability is driven by the randomised starting position of seals in each simulation run). Each simulation also estimated whether the collision between the seal and the DG device occurred with the kite or the tether.

Prediction of harbor seal collision rates

To assess the number of animals likely to collide with the device per lunar tidal cycle (28 day period- henceforth described as a 'tidal cycle'), we used the unfiltered passage rates for harbour seals from Sparling & Lonergan (2013). We calculated the number of seals predicted to collide over the whole tidal cycle by assigning one of the 'tidal states' to each hourly block and approximating across 24 hours. In each hour we calculated the number of animals passing through and weighted this by the mean collision probabilities. We then summed this over each day and then over the tidal cycle for each of the models (passive, active, summer, winter). We used the summer and winter at-risk passage values for six months in each calculation. In predicting the number of seals to collide, we made the assumption of 50% evasion. This is a precautionary step in the face of uncertainty about how seals behave around such devices (the full range of potential values range from negative avoidance values (i.e. attraction) through to 100% evasion/avoidance). In addition, there is a precedent from previous tidal deployments in Strangford Lough and discussions with the Department of Energy Northern Ireland – Marine Division – regarding a suitable level of evasion to consider in CRMs.

RESULTS

Simulated probability of collision with DG device

Collision probabilities varied depending on the anchor point of the device, the current speed (tidal state) and the swimming behaviour of the seals (Figure 3). Across all simulations, collision probabilities ranged between 0.0078 – 0.0269 (i.e. 0.78 - 2.69% of animals passing are predicted to collide with either the kite or the tether) – under the assumption that animals did not exhibit any evasion behavior in response to encountering the kite/tether. Simulations where animals were actively swimming with the current had lower collision probabilities than when passively drifting the current. Average collisions were similar for surface and seabed deployments for passive seals but higher when the DG device was anchored at the surface barge (0.0114 – 0.0151) than the seabed (0.0078 – 0.0093) for active animals.

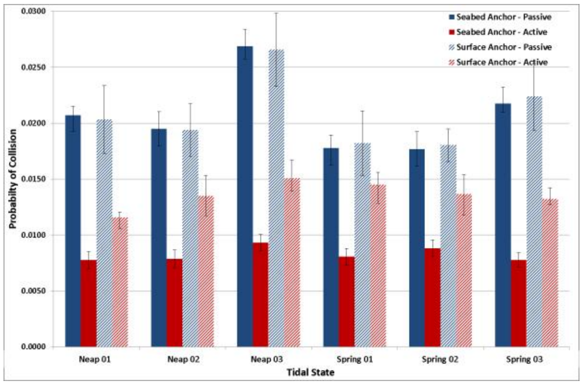

FIGURE 3. THE AVERAGE COLLISION RISK FOR PASSIVE AND ACTIVE SEALS ACROSS THE SIX TIDAL STATE SIMULATIONS.

Animals were predicted to be more likely to collide with the tether than the kite (61-80% of collisions with tether; 20-39% of collisions with the kite). There was no clear linear relationship between tidal current speed and collision probability. Similarly the state of tide did not correlate well with the probability of collision. On average, across all simulations, seals were approximately twice as likely to collide with the tether as with the kite itself.

Estimating harbour seal collision rates over a tidal cycle

Using the estimated passage rates (summer and winter) from Sparling & Lonergan (2013) (80 per month in summer; 30 per month in winter) to estimate collision rates and assuming no evasion behaviour, predicted collision rates were approximately 0.59 – 1.63 collisions per tidal cycle (28 days) (passive animals) or 0.23 – 1.02 collisions per tidal cycle) (active seals)(Table 1).

Assuming 50% evasion and/or 95% evasion these estimates decrease to 0.3 – 0.81 collisions per tidal and 0.03 – 0.08 collisions per tidal cycle for passive seals and lower for active seals (50% evasion: 0.11 – 0.51; 95% evasion: 0.01 – 0.05).

TABLE 1. PREDICTION COLLISIONS PER TIDAL CYCLE (FULL SPRING-NEAP TIDAL CYCLE) IN SUMMER AND WINTER AND UNDER DIFFERENT SWIMMING AND EVASION SCENARIOS.

			Predicted Collisions per tidal cycle		
Anchor	**Season**	**Swim?**	**No evas.**	**50% evas.**	**95% evas.**
Seabed	Summer	Passive	1.63	0.81	0.08
	Summer	Active	0.61	0.30	0.03
	Winter	Passive	0.61	0.31	0.03
	Winter	Active	0.23	0.11	0.01
Surface	Summer	Passive	1.58	0.79	0.08
	Summer	Active	1.02	0.51	0.05
	Winter	Passive	0.59	0.30	0.03
	Winter	Active	0.38	0.19	0.02

CONCLUSIONS

This assessment made use of a simulation framework to assess the potential for collisions between the DG device (including the anchor tether) and harbour seals at the DG test deployment site in Strangford Lough. As part of the simulations, the sensitivity of collision rates to swim speed, current speed, avoidance rates were considered.

Collision risk was highest when seals were passive and when current speeds were low because of the maximum potential for contact between the seal and the DG device. But broadly, collision probabilities were low – indicating that a relatively low number of collisions are predicted to occur.

A ‘best estimate’ based on current knowledge and previous experience can be made using the following assumptions. Assuming the summer and winter at-risk passage rates above are valid for the DG device site, that the device is attached to the seabed, that seals are swimming actively and detecting and evading the device 50% of the time gives a total estimate of 2.5 collisions per year. If the device is attached at the surface, the estimate (with the other assumptions remaining the same) is 4.2 collisions per year.

It is difficult to directly compare with other tidal projects due to differences in the approaches and data used to estimate collision risk across projects. However, the risk predicted here is generally lower than estimates at other sites for different devices.

The above results demonstrate that the physical properties of the turbine and the environment (e.g. current speed), as well as seal behaviour affect collision probabilities. Turbine properties are well defined by the turbine developers and parameters like current speed are generally well measured and modelled in sites where tidal developments are proposed as this is required to estimate the resource value. However, little is known about how marine mammals utilize tidal inlets at the spatial and temporal scales needed to calculate collision probabilities. The needed marine mammal information includes dive and movement behaviour within tidal inlets and in relation to tidal cycles, as well as potential avoidance, attraction or evasion that marine mammals may exhibit due to tidal energy devices.

For some species, these marine mammal parameters can be informed by tagging individual animals, but this is unlikely to be possible for multiple species and multiple sites. Therefore, ongoing work is developing animal movement/behaviour (animat) computer models that will be informed by the available tag data. This work has two objectives: to determine collision probability sensitivities to different marine mammal behaviour input parameters to help prioritize future tagging and data collection and; develop a tool that could be used by tidal energy developers to use in assessing collision probabilities in the tidal inlet they are proposing to install tidal energy devices.

ACKNOWLEDGEMENTS

We are grateful for the comments of two anonymous reviewers who helped improve this extended abstract.

REFERENCES

Sparling, C.E. and Lonergan, M.E. 2013. Collision risk modelling: Harbour seals and SeaGen at Strangford Lough. SMRU Ltd Report SMRUL-MCT-2013-010. February 2013 (unpublished).