Improving predictions of collision risk for marine mammals and tidal turbines – understanding the most critical factors

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Collision risk predictions revisited with empirical data in the presence of a tidal turbine – Joy et al (in review)
Marine Scotland’s Strategic approach to reducing knowledge gaps and enabling tidal energy
<table>
<thead>
<tr>
<th>ID</th>
<th>Knowledge Gap</th>
<th>Target Species/Group</th>
<th>Target Regions</th>
<th>Renewables Sector</th>
<th>Themes</th>
<th>Reasoning</th>
<th>Prioritisation</th>
<th>Potential activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM.01</td>
<td>Fine scale behavioural responses of marine mammals around tidal turbines</td>
<td>Harbour seal</td>
<td>North Scotland; West Scotland; Northern Isles</td>
<td>Tidal</td>
<td>x, x</td>
<td>To increase evidence base for use in estimation of collision rates in collision risk modelling</td>
<td>3, 0, 1, 1, 1, Y, 6</td>
<td>Using active acoustic tags in 3D around tidal turbines</td>
</tr>
<tr>
<td>MM.02</td>
<td>Fine scale behavioural responses of marine mammals around tidal turbines</td>
<td>Harbour porpoise</td>
<td>North Scotland; Northern Isles</td>
<td>Tidal</td>
<td>x, x</td>
<td>To increase evidence base for use in estimation of collision rates in collision risk modelling</td>
<td>3, 0, 1, 1, 1, Y, 2</td>
<td>Using passive acoustic tags in 3D around tidal turbines</td>
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<tr>
<td>MM.03</td>
<td>Fine scale behavioural responses of marine mammals around tidal turbines</td>
<td>Grey seal</td>
<td>North Scotland; Northern Isles</td>
<td>Tidal</td>
<td>x, x</td>
<td>To increase evidence base for use in estimation of collision rates in collision risk modelling</td>
<td>3, 0, 1, 1, 1, Y, 0</td>
<td>Using active acoustic tags in 3D around tidal turbines</td>
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<tr>
<td>MM.04</td>
<td>Likelihood and rate of collision with tidal turbines</td>
<td>Harbour seal</td>
<td>North Scotland; West Scotland; Northern Isles</td>
<td>Tidal</td>
<td>x, x</td>
<td>To increase evidence base for use in estimation of collision rates in collision risk modelling</td>
<td>3, 0, 1, 1, 1, Y, 6</td>
<td>Using active acoustic tags in 3D around tidal turbines</td>
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<tr>
<td>MM.05</td>
<td>Likelihood and rate of collision with tidal turbines</td>
<td>Harbour porpoise</td>
<td>North Scotland; Northern Isles</td>
<td>Tidal</td>
<td>x, x</td>
<td>To increase evidence base for use in estimation of collision rates in collision risk modelling</td>
<td>3, 0, 1, 1, 1, Y, 2</td>
<td>Using active acoustic tags in 3D around tidal turbines</td>
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<tr>
<td>MM.06</td>
<td>Likelihood and rate of collision with tidal turbines</td>
<td>Grey seal</td>
<td>North Scotland; Northern Isles</td>
<td>Tidal</td>
<td>x, x</td>
<td>To increase evidence base for use in estimation of collision rates in collision risk modelling</td>
<td>3, 0, 1, 1, 1, Y, 0</td>
<td>Using active acoustic tags in 3D around tidal turbines</td>
</tr>
<tr>
<td>MM.07</td>
<td>Incorporating understanding of how marine mammals use local areas into collision risk models</td>
<td>Harbour seal</td>
<td>North Scotland</td>
<td>Tidal</td>
<td>x, x</td>
<td>To increase evidence base for use in estimation of collision rates in collision risk modelling</td>
<td>3, 0, 1, 1, 1, Y, 6</td>
<td>Tracking of animals in active areas</td>
</tr>
<tr>
<td>MM.08</td>
<td>Abundance and distribution of marine mammals in locations and habitats suitable for non-military developments</td>
<td>Cetaceans</td>
<td>All</td>
<td>All</td>
<td>x</td>
<td>Required to inform sectoral plans and species responses. Existing data become dated; some regions have fewer data than others (e.g., across species, seasons, years)</td>
<td>1, 1, 1, 1, Y, 3</td>
<td>Static acoustic monitor traffic surveys (air based)</td>
</tr>
<tr>
<td>MM.09</td>
<td>Abundance and distribution of marine mammals in locations and habitats suitable for renewable developments</td>
<td>Pinnipeds</td>
<td>All</td>
<td>All</td>
<td>x</td>
<td>Required to inform sectoral plans and species responses. Existing data become dated; some regions have fewer data than others (e.g., across species, seasons, years)</td>
<td>1, 1, 1, 1, Y, 3</td>
<td>Fine scale usage map telemetry and haul-out</td>
</tr>
</tbody>
</table>
Identify and prioritise knowledge gaps

Research to address knowledge gaps
Factors with the potential to affect predicted collision risk

Factors influencing level of risk

‘physical’ factors:
- Integrating variation in risk over site specific tidal cycle
- Device specific characteristics – blade profile shape, width

‘biological’ factors:
- Abundance/density (and variation therein e.g. with depth)
- Animal movement patterns – swim speed, direction etc
- Behaviour in the presence of turbines – avoidance/evasion
- Consequences of collisions (convert CRM to ‘MRM’)
Refinements of CRM: Physical factors

Calculating collision risk over the tidal cycle using site specific frequency distribution of current speeds and device specific operational characteristics to average the collision risk over each current speed across the tidal cycle:

Typically risk was 3-4 % lower than calculated estimated on the basis of a single mean rotor speed.

Blade thickness – taking account of the blade thickness and accounting for the potential for trailing edge collisions (in addition to leading edge collisions) made a small but significant difference for upstream transits, and a more substantial addition to risk for downstream transits – consequence for mortality depends on view of risk of injury from leading edge vs trailing edge.

Overall physical refinements led to only modest changes in CR.....
‘Biological’ Refinements of CRM:

• Depth distribution – empirically derived vs Uniform or U shaped dives

• Density – derived from tagged seal transit rates vs static density estimates

• Behaviour – empirically derived movement data vs assumption of mean swimming speed or passive drift

• Avoidance – incorporating empirical evidence on mid-range avoidance from a range of more recent studies

• Consequences of collisions – relaxing assumptions that all collisions = death
At the MeyGen site, seal telemetry data indicated a larger proportion of mid water diving than expected. CRM recalculated using empirical depth distribution, relative to basic Band model (assuming uniform depth distribution):
- 16m rotor = 22% reduction,
- 18m rotor = 13% reduction,
- 20m rotor = 1-2% reduction.

As extent of mid water diving increases, the overlap between depth distribution and position of turbines increases, resulting in a higher risk than assuming all dives to the seabed to forage.
Recalculation of collision risk at MeyGen based on seal telemetry data = lowest estimate was ~16% of original EIA estimates based on a uniform static density from wider scale data

Scale and location matters – fine scale difference in seal activity can have major effects!

Increasing area doubled the density

Shifting area south by 500 m and 1000 m into higher density area resulted in a density of 0.24 and 0.66 seals per km² respectively

<table>
<thead>
<tr>
<th>Source of density estimate</th>
<th>Density, seals per km² (95% CI)</th>
<th>Resulting CRM* per year (no avoidance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMRU Seal usage maps (Jones et al., 2015)</td>
<td>0.40 (0.17-0.64)</td>
<td>93 (40-149)</td>
</tr>
<tr>
<td>Site specific survey data (MeyGen ES)</td>
<td>0.202 (no CI given)</td>
<td>47</td>
</tr>
<tr>
<td>Scaled local telemetry data equivalent inc 500m buffer</td>
<td>0.10 (0.008-0.251)</td>
<td>23 (2-59)</td>
</tr>
<tr>
<td>Scaled local telemetry data equivalent inc 250m buffer</td>
<td>0.05 (0.004-0.138)</td>
<td>12 (1-32)</td>
</tr>
</tbody>
</table>

*using refined model
Movement behaviour

- Transits were largely against the direction of current at slow speeds over ground.
- Animals working to maintain position against the current – would move through swept area very slowly.
- Increased risk of individual collision for a given pass through swept area BUT decreased rate of passage per unit time and also have more time to detect and react.
- Using empirical speed over ground distributions in the Band CRM resulted in a decrease of ~10% relative to assuming a single average swimming speed.
Behaviour in the presence of a turbine: Swim speed/direction

- Very similar to Pentland Firth seals:
- Seals oriented against the current
- Over ground speeds were low
- Swimming speeds increased in stronger currents to maintain similar overground speeds

Joy et al. 2018
Consequences of collision:

<table>
<thead>
<tr>
<th>Rotation Speed</th>
<th>12 rpm</th>
<th>6 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction</td>
<td>Upstream</td>
<td>Downstream</td>
</tr>
<tr>
<td>Collision integral</td>
<td>Total</td>
<td>0.283</td>
</tr>
<tr>
<td>Mortality integral</td>
<td>Total</td>
<td>0.220</td>
</tr>
<tr>
<td>Mortality as a proportion of collisions</td>
<td>77.7%</td>
<td>80.3%</td>
</tr>
</tbody>
</table>

Figure 5. View from bow mounted camera indicating direction of movement and line of impact during an abdomen impact trial. The green arrows indicate the center point of the boat given the position of the nose piece and the red arrow indicates direction of movement. The point at which the green arrows converge indicates the point of impact on the animal.
Combined refinements

Basic – mean swim speed, mean rotor speed, uniform depth distribution

Empirical depth distribution
As above plus integrated over tidal cycle plus mortality correction
As above plus empirical ground speeds
Overall reduction in CR >40%

Figure 39  Comparison of collision estimates using progressively refined methods
Behaviour in the presence of a turbine

- Tagged seals at Strangford Lough: 68% decrease in usage within 200 m of the turbine (95% CI 37-83%)
- Detectable difference to within 600 m. No evidence beyond 600 m
- Play back experiments suggest seals responding to similar distances
- Joe’s analysing Pentland Firth telemetry data from period of turbine deployment to look for change in usage
- Evidence for avoidance?

Similar to playback studies

Hastie et al. 2017
Joy et al. 2018
Analysis from Strangford Lough tagged seals and collision risk modelling

Incorporating empirical info on:
• Depth distribution
• Plus behavioural avoidance and swim speed and direction

Overall ~90% reduction in computed strike risk compared to assumptions of uniform depth and no avoidance
Conclusions

Biological factors had much bigger potential to influence predictions than physical tidal or device characteristics.

Detailed site specific information provided quite different encounter rates compared to those based on static density estimates – scale and location matters.

Behaviour important: in some cases behaviour very different to general assumptions made by most models.

Consequences are important – moving away from assumption that all collisions are equal and worst case – Joe Onoufriou’s talk later this session.

Empirical estimates of avoidance ~68% within 200 metres compared to baseline – acoustic output may be important in terms of this response – Ben Wilson’s talk later this session.

Near field/evasion remains the ‘holy grail’ – next couple of talks will highlight the steps that we’re making in this area, in collaboration with Marine Scotland and Industry partners.
Predicting responses to multiple devices?

Combining physical mechanistic models of strike probability with information on animal behaviour derived from single devices – are simulation based approaches the way forward?

Don’t currently have the data to fully parameterize such models but could be used to explore scenarios, determine sensitivities and drive future data collection/analyses

Really need to be thinking hard about how the data from monitoring can best be incorporated to inform predictions at array scale
Thank you

Doug Gillespie, Laura Palmer, Jamie Macaulay, Dom Tollit, MeyGen & Atlantis, Cara Donovan, Fraser Johnson, Elaine Tait, Kate Brookes, Ross Culloch, Janelle Braithwaite, Scottish Natural Heritage, Andrea Copping

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