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

Carol Sparling[1], Bill Band, Joe Onoufriou[2], Dave Thompson[2], Ruth Joy[3,4], Jason Wood[4], Elena San Martin[5] and Nigel West[5]

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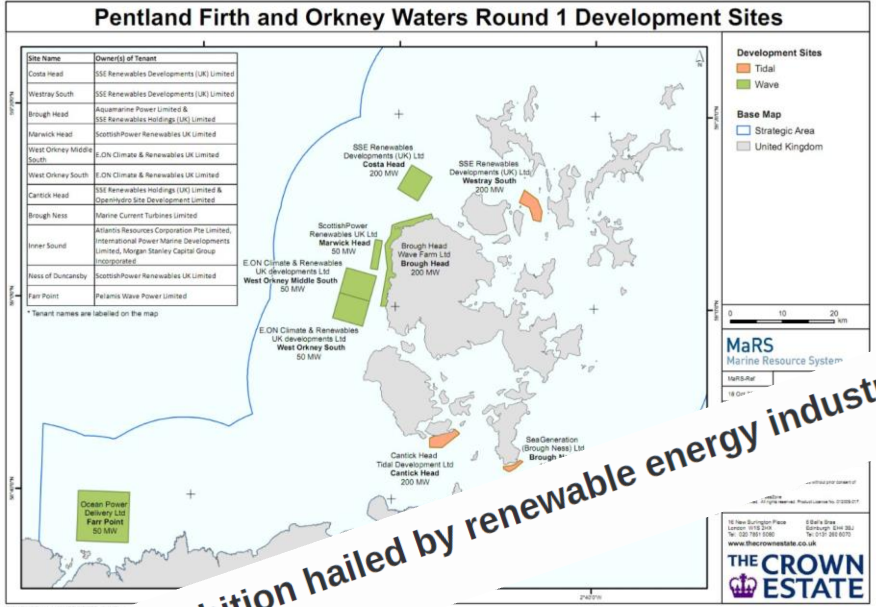

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Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines

Scottish Marine and Freshwater Science Vol 7 No 17

B Band, C Sparling, D Thompson, J Onoufriou, E San Martin and N West

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Harbour seals' decline 'alarming'

By James Morgan
Science reporter, BBC News

Harbour seals, or common seals, are familiar faces along coastlines across the northern hemisphere.

But they are now vanishing in the UK at an alarming rate, warn scientists from St Andrews University.

Numbers have halved in the hardest hit area, the Orkney Islands, since 2001 - falling almost 10% each year.

There will soon be "no harbour seals left" in some areas if the mysterious decline continues, said

Drowning, not waving - harbour seal numbers have halved in some areas

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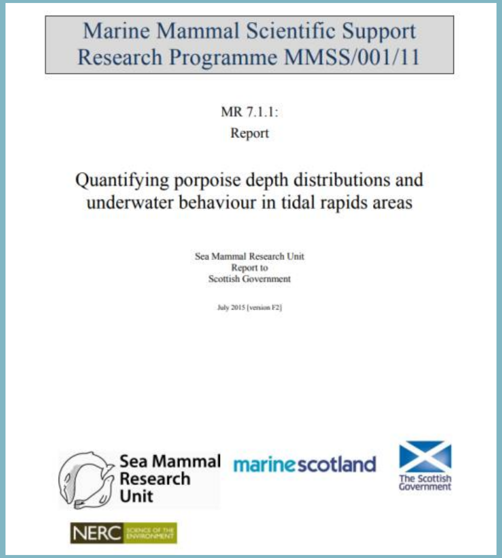
Marine Scotland's Strategic approach to reducing knowledge gaps and enabling tidal energy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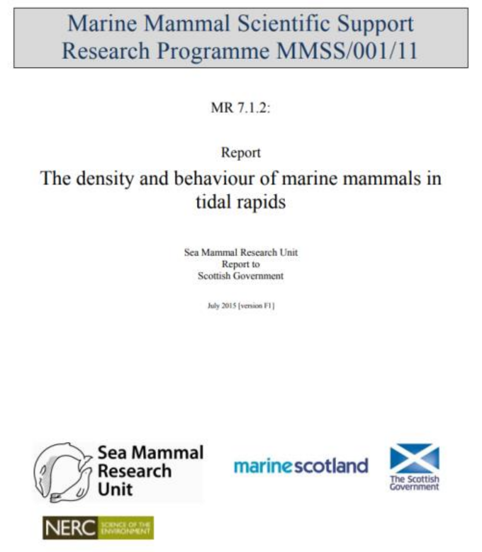
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The density and behaviour of marine mammals in tidal rapids

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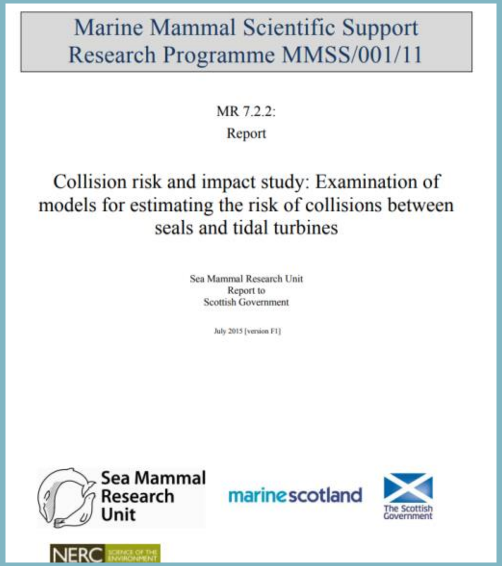
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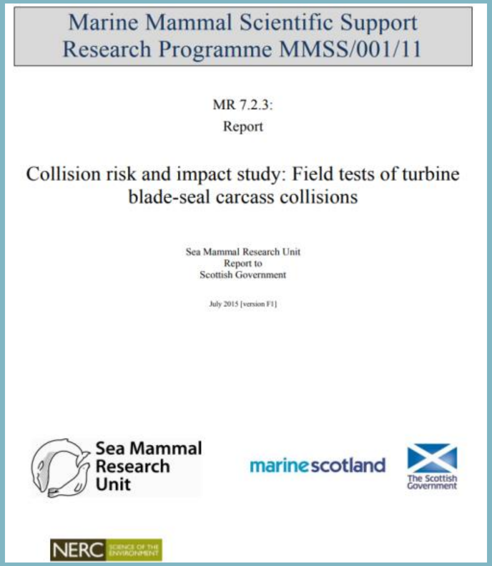
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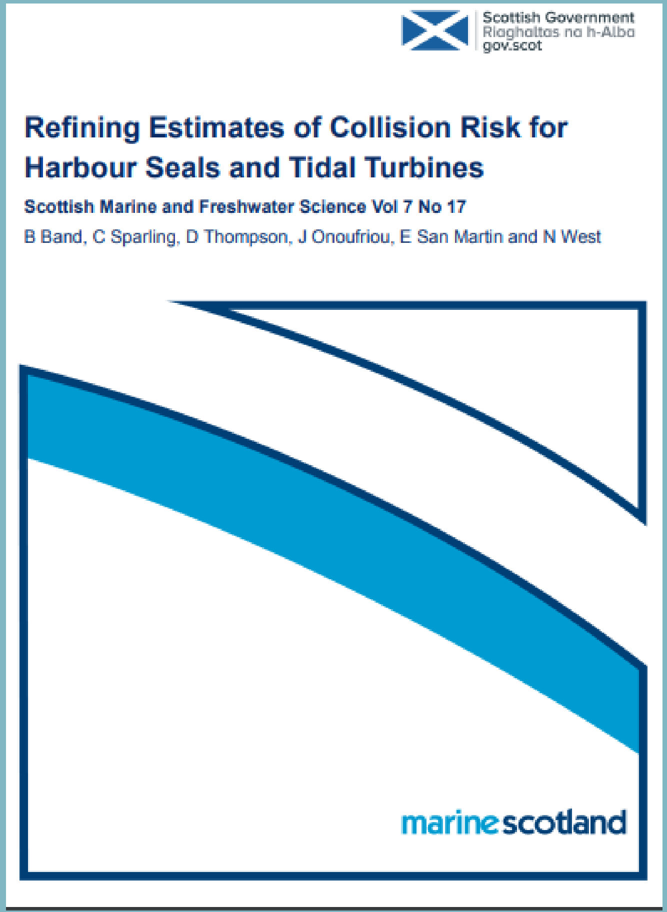
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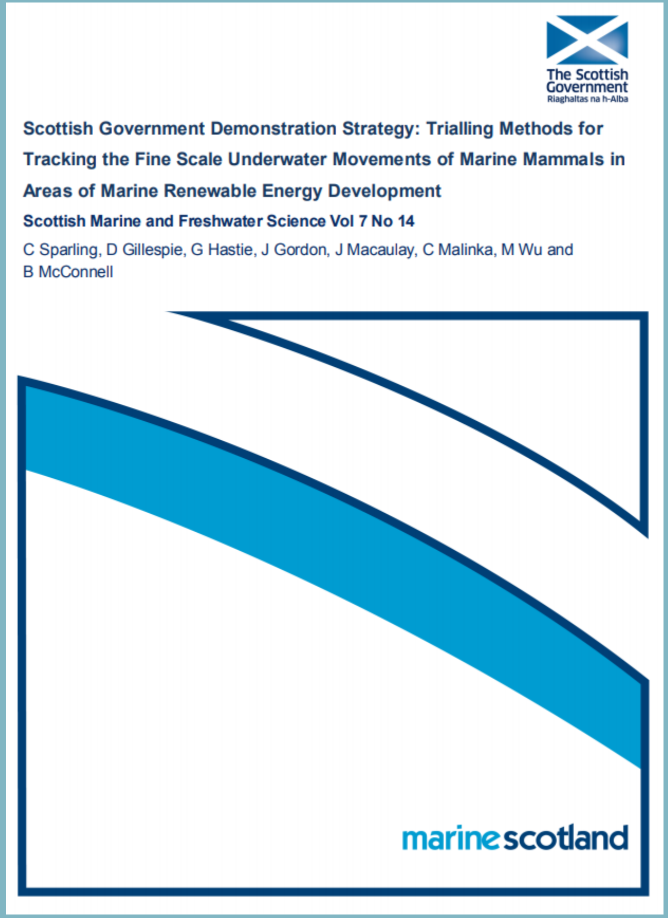
Scottish Government Demonstration Strategy: Trialling Methods for Tracking the Fine Scale Underwater Movements of Marine Mammals in Areas of Marine Renewable Energy Development

Scottish Marine and Freshwater Science Vol 7 No 14

C Sparling, D Gillespie, G Hastie, J Gordon, J Macaulay, C Malinka, M Wu and B McConnell

MARINE MAMMALS																		
Information						**Themes**				**Reasoning**	**Prioritisation**							
ID	Knowledge Gap	Target Species/Group	Seasons	Target Regions	Renewables Sector	Acute effects	Chronic effects	Baseline	Methodologies	Relevance	Current or Very Likely Future Constraint?	Relevant to >1 Sector?	Relevant to >1 Project?	Relevant to >1 Region?	Currently feasible	Score	Potential activity
MM.01	Fine scale behavioural responses of marine mammals around tidal turbines	Harbour seal	All	North Scotland; West Scotland; Northern Isles	Tidal	x	x			To increase evidence base for use in estimation of collision rates in collision risk modelling	3	0	1	1	Y	6	Using active acoustics seals in 3D around tida
MM.02	Fine scale behavioural responses of marine mammals around tidal turbines	Harbour porpoise	All	North Scotland; Northern Isles	Tidal	x	x			To increase evidence base for use in estimation of collision rates in collision risk modelling	1	0	1	1	Y	2	Using passive acousti porpoises in 3D aroun turbines
MM.03	Fine scale behavioural responses of marine mammals around tidal turbines	Grey seal	All	North Scotland; Northern Isles	Tidal	x	x			To increase evidence base for use in estimation of collision rates in collision risk modelling	0	0	1	1	Y	0	Using active acoustics seals in 3D around tida
MM.04	Likelihood and rate of collision with tidal turbines	Harbour seal	All	North Scotland; West Scotland; Northern Isles	Tidal	x	x			To increase evidence base for use in estimation of collision rates in collision risk modelling	3	0	1	1	Y	6	GPS/UHF tracking com active acoustics to det avoidance rates
MM.05	Likelihood and rate of collision with tidal turbines	Harbour porpoise	All	North Scotland; Northern Isles	Tidal	x	x			To increase evidence base for use in estimation of collision rates in collision risk modelling	1	0	1	1	Y	2	Using active and pass acoustics to track porp around tidal turbines
MM.06	Likelihood and rate of collision with tidal turbines	Grey seal	All	North Scotland; Northern Isles	Tidal	x	x			To increase evidence base for use in estimation of collision rates in collision risk modelling	0	0	1	1	Y	0	Using active acoustics seals in 3D around tida
MM.07	Incorporating understanding of how marine mammals use tidal areas into collision risk models	Harbour seal	All	North Scotland	Tidal	x	x		x	To increase evidence base for use in estimation of collision rates in collision risk modelling	1	1	1	1	Y	3	Tracking of animals in active areas
MM.08	Abundance and distribution of marine mammals in locations and habitats suitable for renewable developments	Cetaceans	All	Scotland	All			x		Required to inform sectoral plans and scoping responses. Existing data become dated, some regions have fewer data than others (e.g. across species, seasons, years)	1	1	1	1	Y	3	Static acoustic monitor transect surveys (aeri based)
MM.09	Abundance and distribution of marine mammals in locations and habitats suitable for renewable developments	Pinnipeds	All	Scotland	All			x		Required to inform sectoral plans and scoping responses. Existing data become dated, some regions have fewer data than others (e.g. across species, seasons, years)	1	1	1	1	Y	3	Fine scale usage maps telemetry and haul out
										Required to inform sectoral plans and scoping responses. Existing							

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Identify and prioritise knowledge gaps

Research to address knowledge gaps

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Factors with the potential to affect predicted collision risk

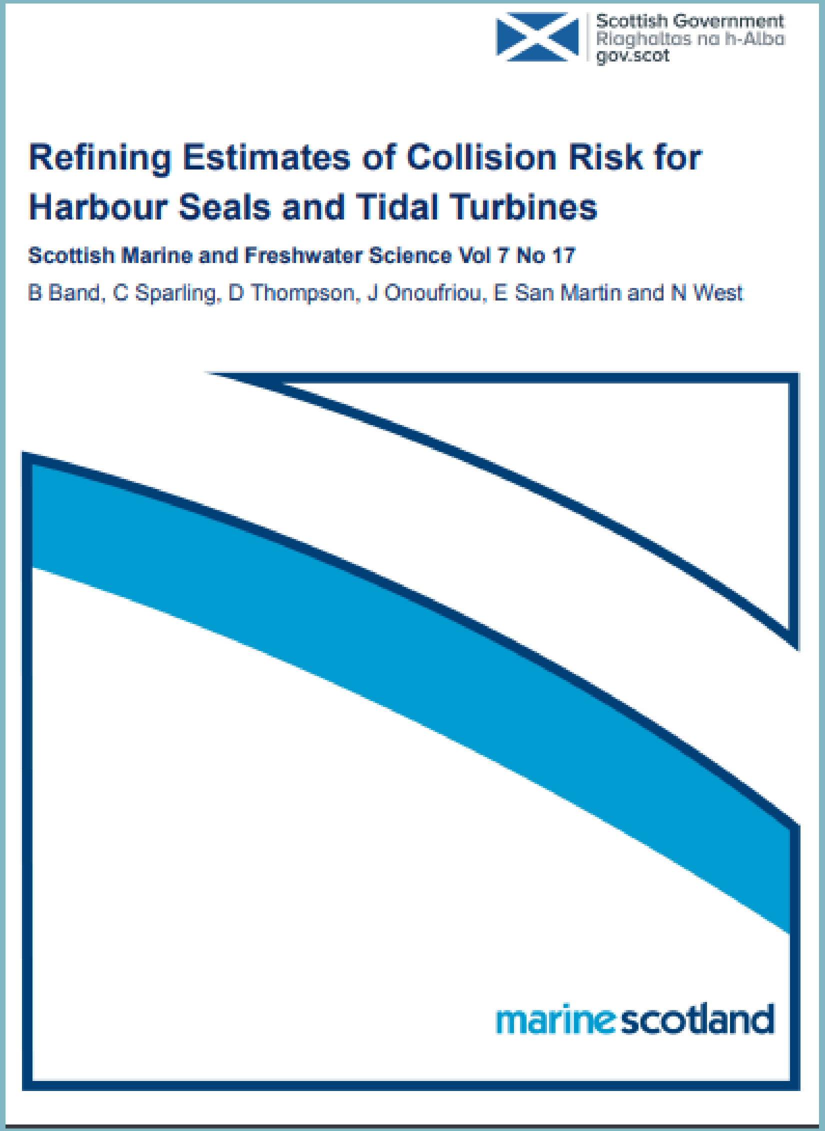
Factors influencing level of risk

‘physical’ factors:

- Integrating variation in risk over site specific tidal cycle
- Device specific characteristics – blade profile shape, width

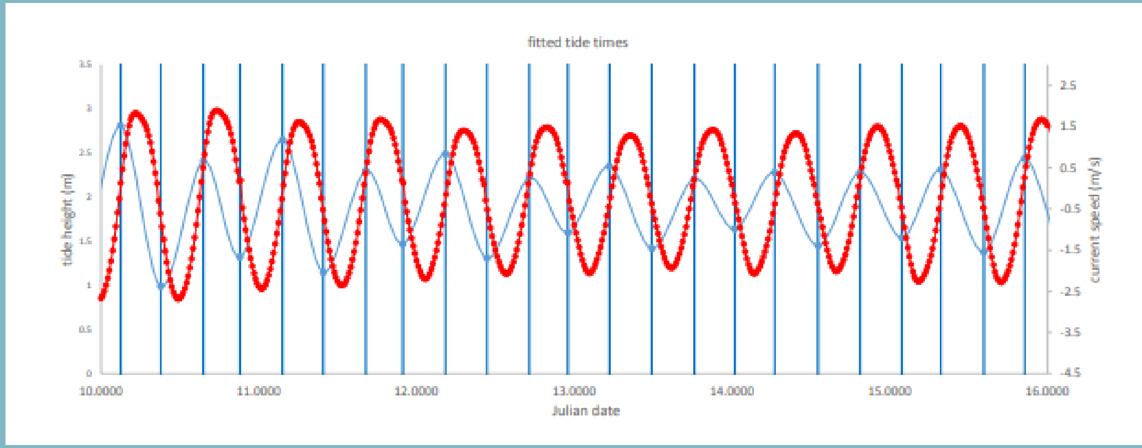
‘biological’ factors:

- 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’)

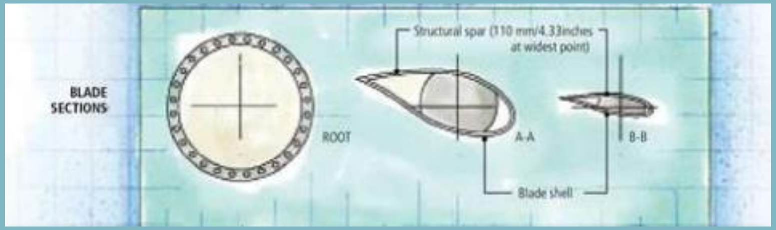


Refinements of CRM: Physical factors

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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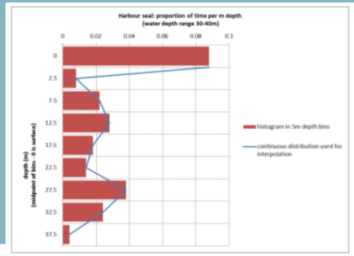

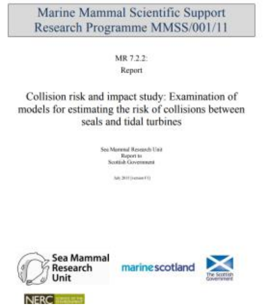
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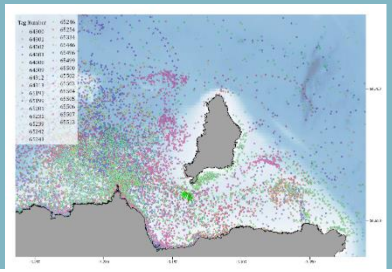

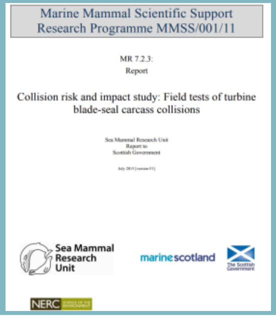
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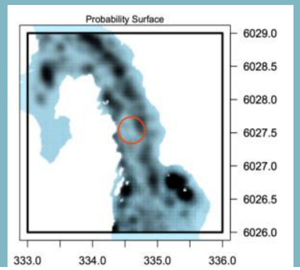

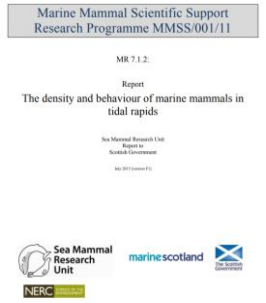
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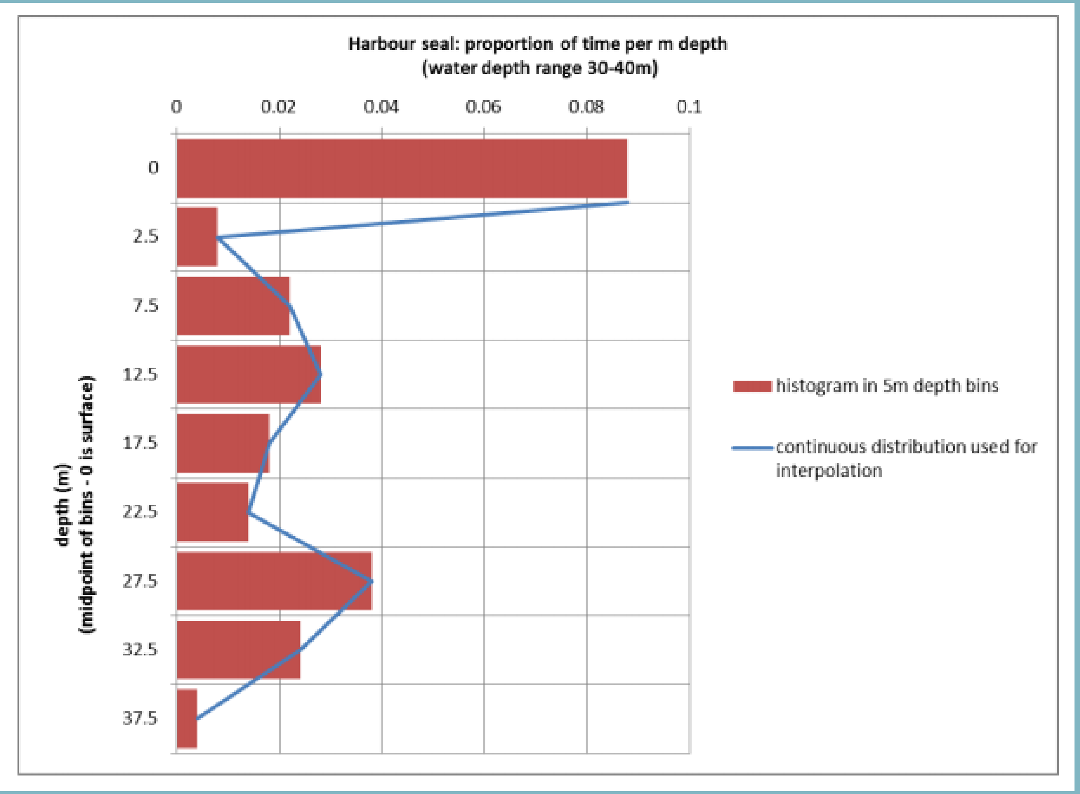
The density and behaviour of marine mammals in tidal rapids

Depth distribution

At the MeyGen site, seal telemetry data indicated a larger proportion of mid water diving than expected



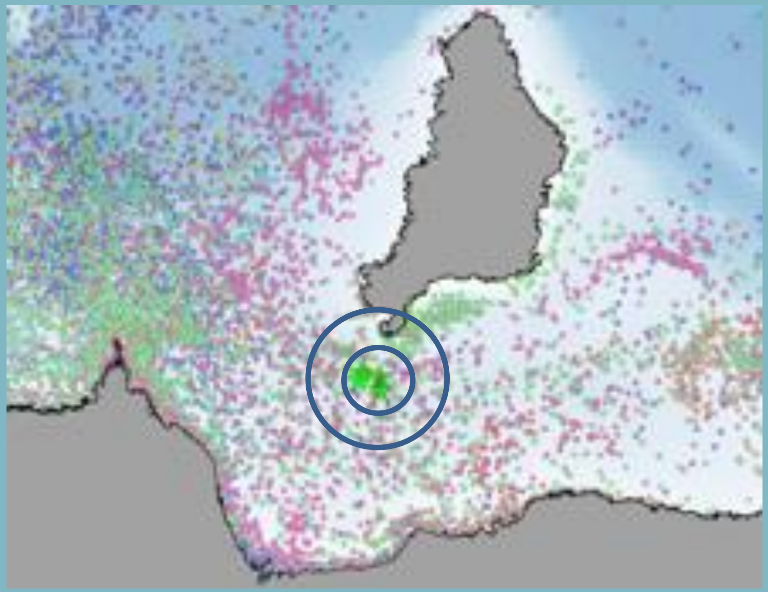
CRM recalculated using empirical depth distribution, relative to basic Band model (assuming **uniform** depth distribution):
16m rotor= 22% reduction,
18m rotor = 13% reduction,
20m rotor = 1-2% reduction

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

local abundance/ density

Source of density estimate	Density, seals per km^2 (95% CI)	Resulting CRM* per year (no avoidance)
SMRU Seal usage maps (Jones et al., 2015)	0.40 (0.17-0.64)	93 (40-149)
Site specific survey data (MeyGen ES)	0.202 (no CI given)	47
Scaled local telemetry data equivalent inc 500m buffer	0.10 (0,008-0.251)	23 (2-59)
Scaled local telemetry data equivalent inc 250m buffer	0.05 (0.004-0.138)	12 (1-32)

*using refined model

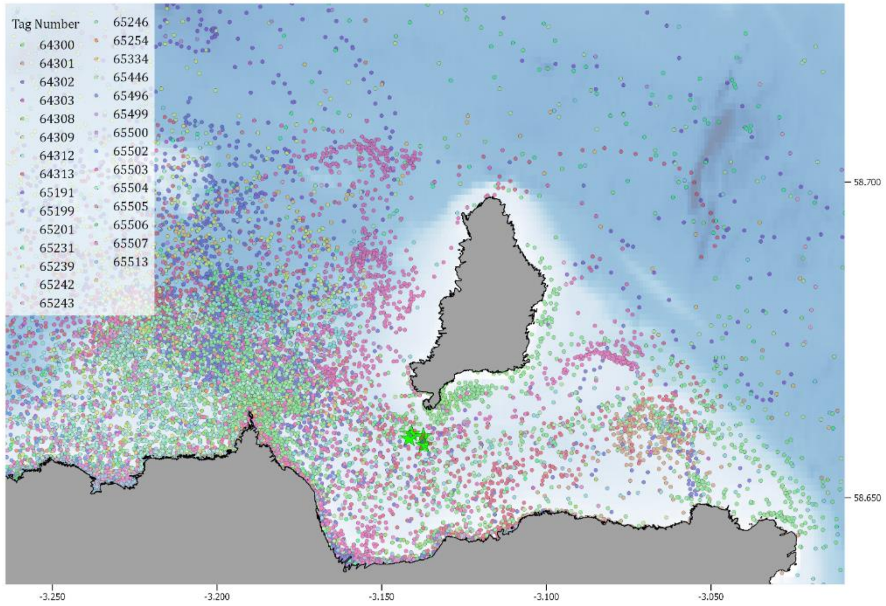


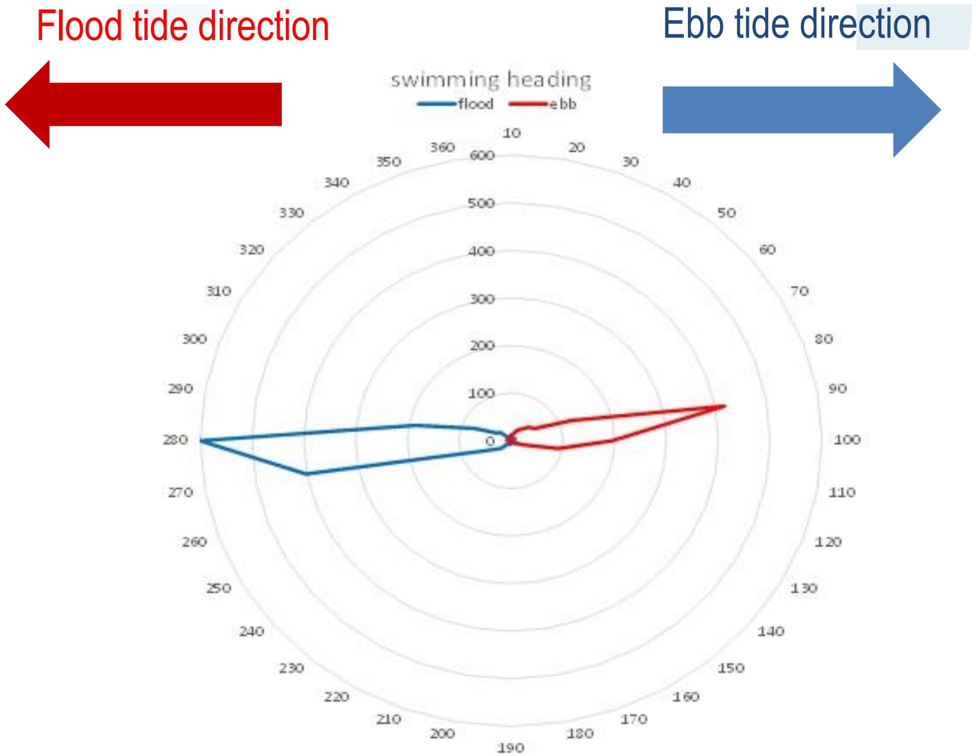
Recalculation of collision risk at MeyGen based on seal telemetry data = lowest estimate was **~16%** of original EIA estimates based on a uniform static density from wider scale data

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 km^2 respectively

Movement behaviour

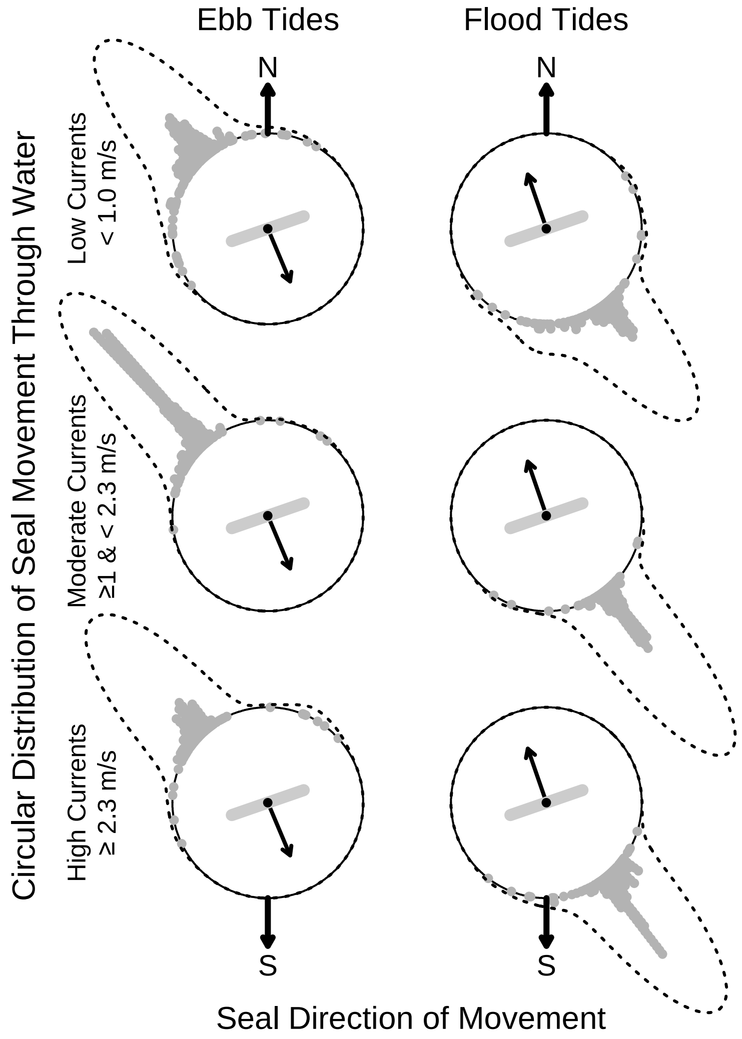
- Transits were largely against the direction of current at slow speeds over ground
- Animals working to maintain position against the current – would move through swept area very slowly
- Increased risk of individual collision for a given pass through swept area BUT decreased rate of passage per unit 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



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Empirical measures of harbor seal behavior and avoidance of an operational tidal turbine

Ruth Joy[a,b,*], Jason D. Wood[c], Carol E. Sparling[d], Dom J. Tollit[a], Andrea E. Copping[e], Bernie J. McConnell[f]

Consequences of collision:

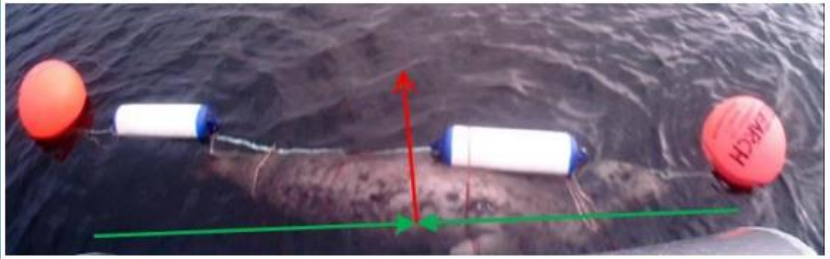


Figure 5. View from bow mounted camera indicating direction of movement and line of impact during an abdomen impact trial. The green arrows indicate the centre point of the boat given the position of the nose piece and the red arrow indicates direction of movement. The point at which the green arrows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

Comparison of Collision Risk with Mortality Risk					
Rotation Speed		12 rpm		6 rpm	
Direction		Upstream	Downstream	Upstream	Downstream
Collision integral	Total	0.283	0.239	0.169	0.143
Mortality integral	Total	0.220	0.192	0.042	0.040
Mortality as a proportion of collisions		77.7%	80.3%	24.9%	28.0%

Combined refinements

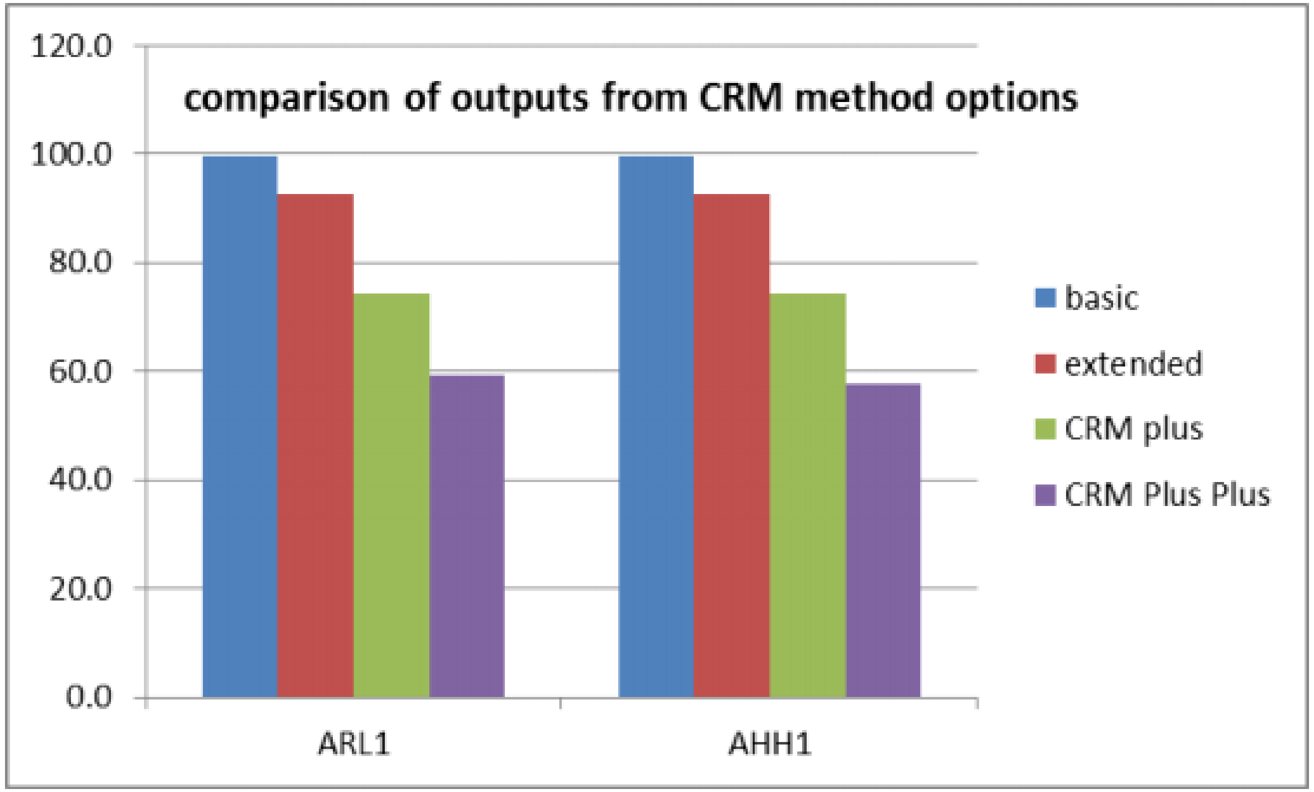


Figure 39 **Comparison of collision estimates using progressively refined methods**

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

Empirical depth distribution

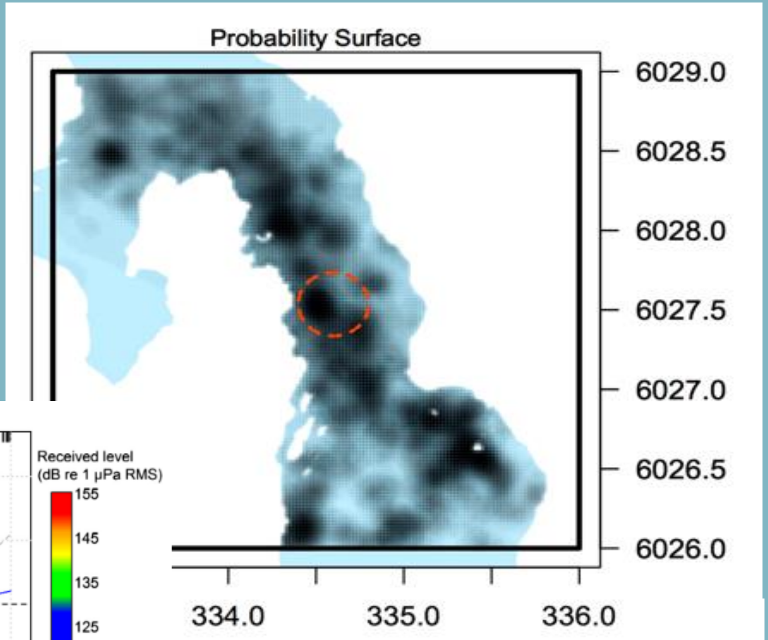
As above plus integrated over tidal cycle plus mortality correction

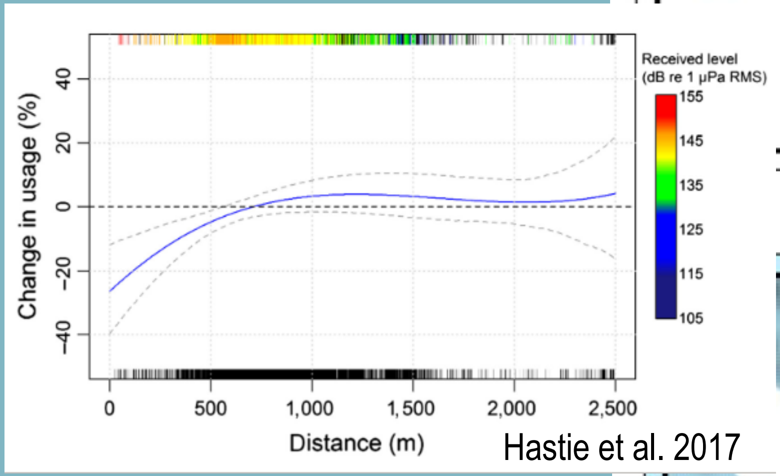
As above plus empirical ground speeds

Overall reduction in CR >40%

Behaviour in the presence of a turbine

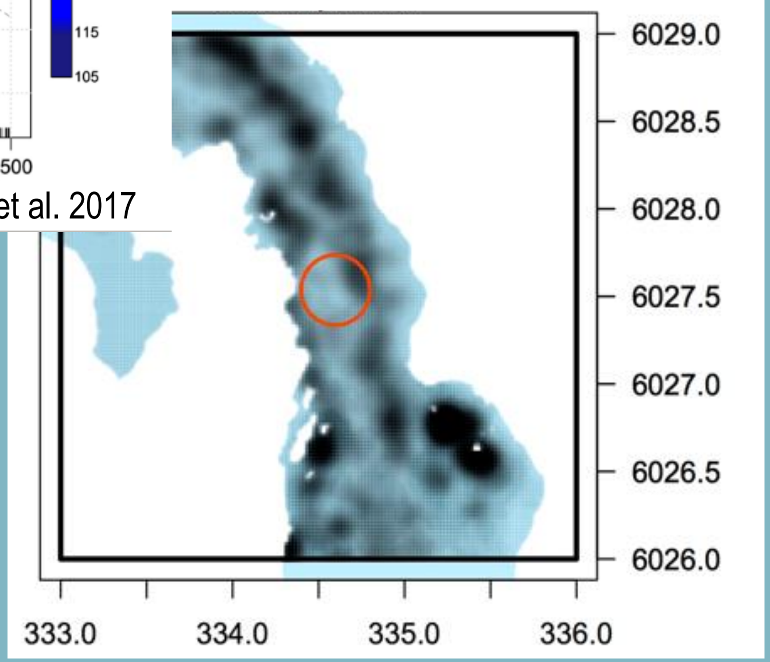
- Tagged seals at Strangford Lough: 68% decrease in usage within 200 m of the turbine (95% CI 37-83%)
- Detectable difference to within 600 m. No evidence beyond 600 m
- Play back experiments suggest seals responding to similar distances
- Joe's analysing Pentland Firth telemetry data from period of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





Hastie et al. 2017

- **Similar to playback studies**



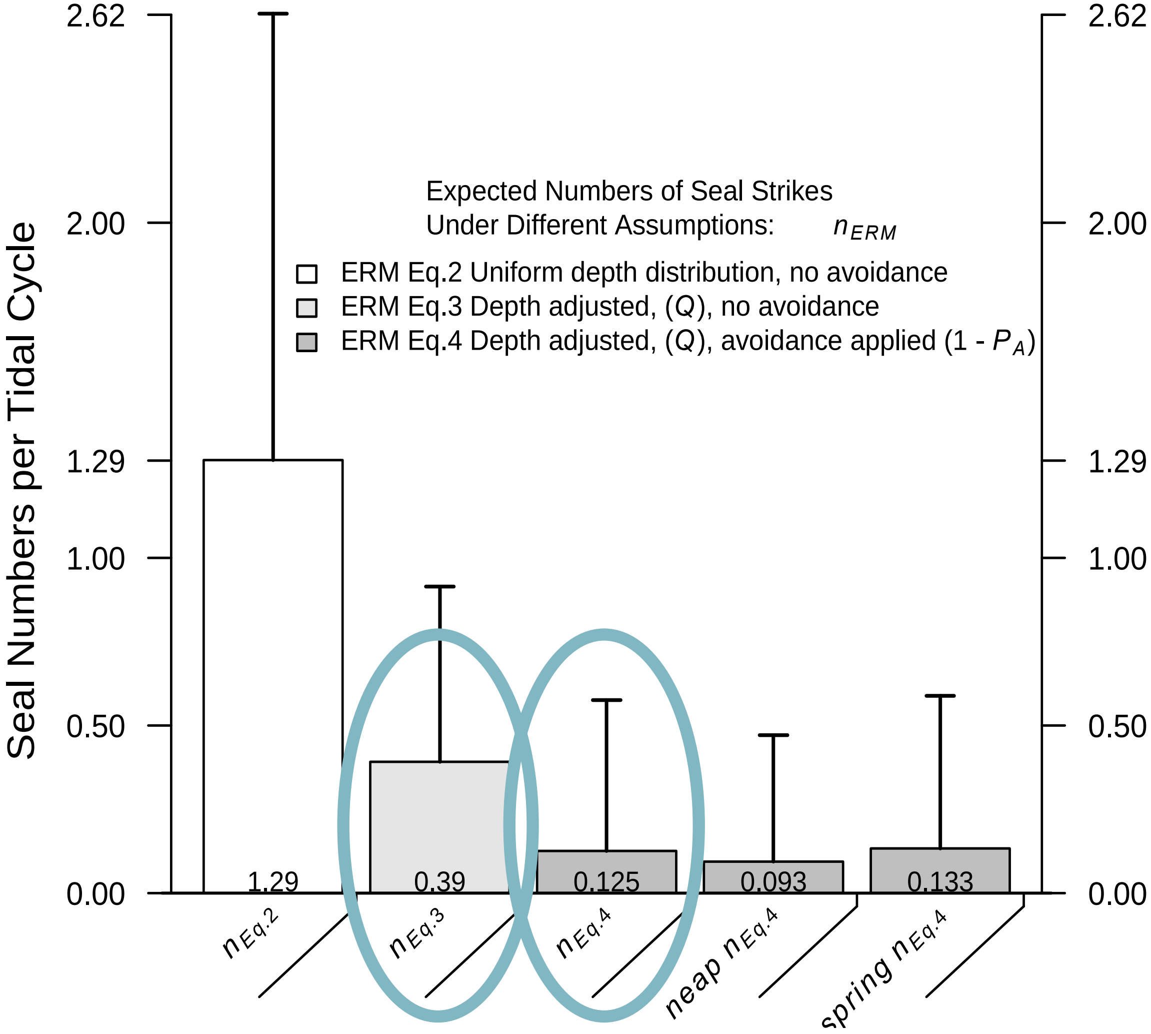
Joy et al. 2018

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



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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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