Collision risk to marine animals (marine mammals) from tidal turbines: next steps towards understanding and retiring risk

March 18, 2021

7:30 – 10:30am Pacific Time

Andrea Copping, Lysel Garavelli &
Lenaïg Hemery (PNNL)
Jennifer Fox & Raeanne Miller (Aquatera)
Carol Sparling (University of St Andrews)

PNNL is operated by Battelle for the U.S. Department of Energy

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Agenda

Introduction & goal of the workshop

Introduction to collision risk & encounter risk models

Background presentation on marine mammals

Instructions and goals for the breakout sessions

First breakout session and report out

Quick Break ~ 16:05-16:15 UTC (9:05-9:15 PDT)

How models have been used so far

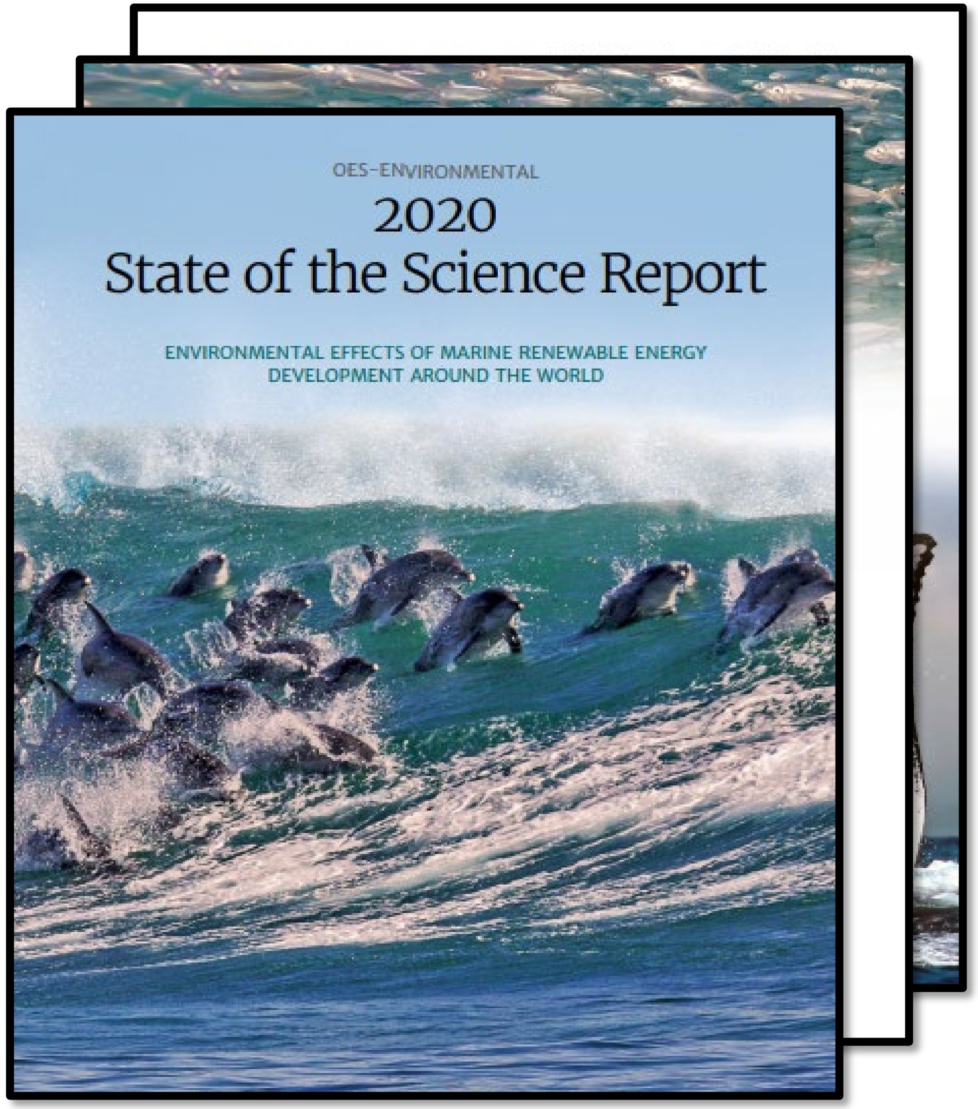
Second breakout session and report out

Open discussion of collision risk progress

Wrap up

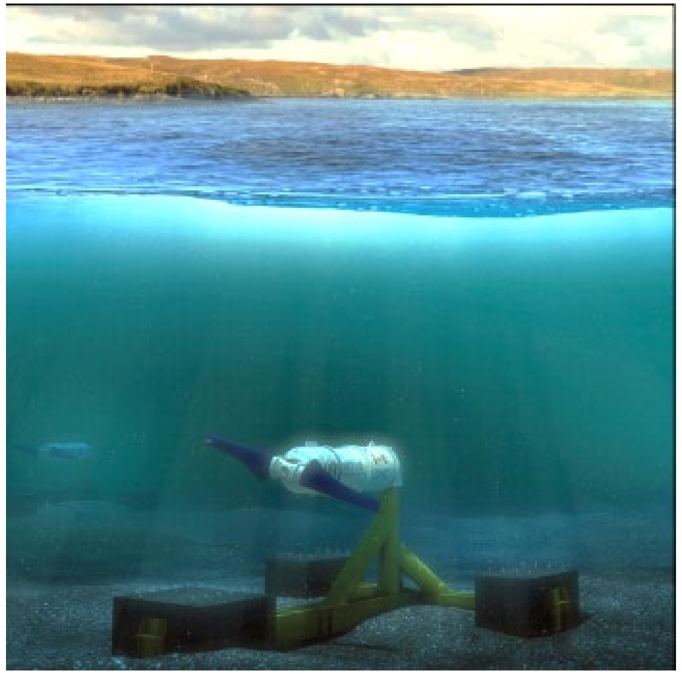
OES-Environmental

- Established by the International Energy Agency (IEA) Ocean Energy Systems (OES)
- Led by the U.S. Department of Energy's Pacific Northwest National Laboratory
- 15 countries currently involved
- Examines the environmental effects of MRE
- Activities coordinated and recorded on *Tethys* (*https://tethys.pnnl.gov/*)



ORJIP Ocean Energy

- UK funded programme
- The aim is to reducing consenting risks for wave, tidal stream and tidal range projects.
- Facilitates a strategic, coordinated and prioritised approach to monitoring and research which is endorsed by industry, regulators and SNCBs.
- Key outputs:
  - Forward Look
  - Critical Evidence Gaps of wave and tidal energy
- Join our network to hear more by emailing ORJIP@aquatera.co.uk



Goal of the Workshop

- How can models help us understand collision risk between marine animals and turbines, and facilitate consenting/permitting requirements?

    - Highlight knowledge and data gaps limiting our understanding of collision risks
    - Identify methods for collecting the necessary data
    - Determine the suitability of models to assess collision risk and population effects
    - Identify the data needs for parameterizing and validating the models

- Leverage participants' interests and expertise to trigger international collaborations

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Introduction to Collision Risk Models

Lysel Garavelli, PhD

Pacific Northwest National Laboratory

lysel.garavelli@pnnl.gov

Some definitions

- **Avoidance**: Animal responding to and moving away from a device at great distances
- **Evasion**: Animal changing their behavior to escape a contact with a device at close distance (after the encounter, but adverting the collision)

Some definitions

- **Encounter**: Animal being in the nearfield of a turbine (1-5 devices length)
- **Collision**: Animal being in contact with the blade of a turbine
- **Exposure Time**: Amount of time animal spends at the depth and in the field of a device.

What do we use collision risk models for?

- **Purpose**:
  - To estimate the likelihood of an **encounter** between an animal and a device
  - To estimate the likelihood of **contact (collision)** between an animal and a device

- **Rates of encounter/collision depend on**:
  - Size and location of the device
  - Animal behavior
  - Animal ability to detect the device
  - Animal behavior in response to the device

- **Outcomes**: Probabilities of encounter/collision
  Did the animal survive after collision? If not, what is the effect on the population?

Types of Models

To estimate interactions between animals and devices:

- **Encounter Rate Model**: estimates the likelihood of being in the nearfield of the turbine
- **Collision Risk Model**: estimates the probability of contact between an animal and the turbine

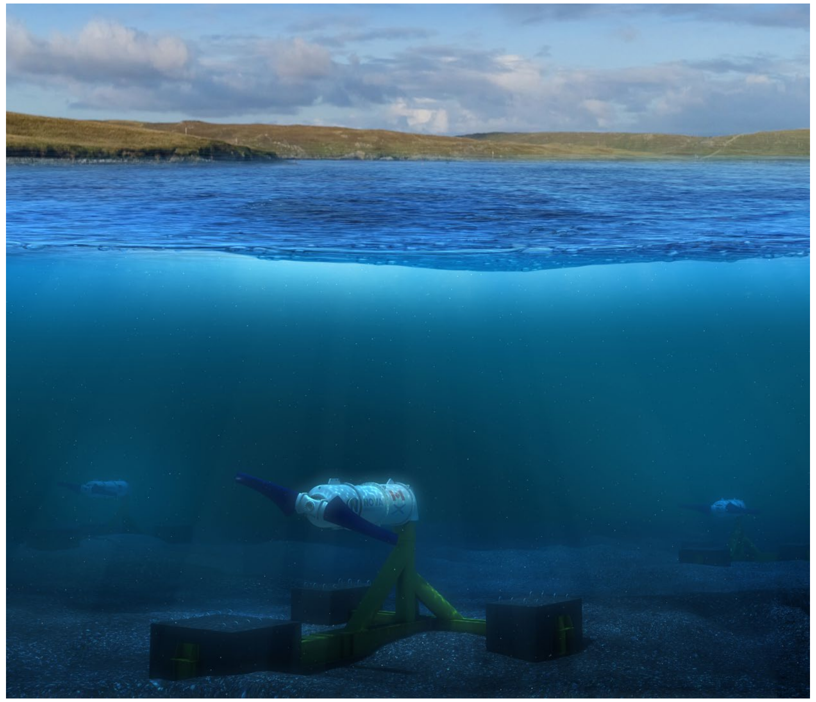
To estimate the potential effect of a collision to the population:

- **Exposure Time Population Model**: associates collision risk to population effects by estimating the rates of fatal collision that leads to a specified detrimental effect on the population

Encounter Rate Model

Wilson et al. 2007

- Predator-prey model integrating:
  - Volume of water swept by a predator (i.e., the blade of a turbine)
  - Size of the prey
  - Prey density
  - Relative swimming speeds of predator and prey (i.e., blade and animal)



Nova Innovation

- A turbine blade, viewed from the side, sweeps a certain volume of water in a unit of time that an animal has some probability of occupying.

→ Estimate the likelihood of encounter between prey and predator
Assume no behavioral response to a turbine
Best suited for horizontal axis turbine

Collision Risk – Numerical Model

- Based on Band (2012): birds and offshore wind farm

- Model integrating:
    - Area covered by the rotor
    - Size of the animal
    - Animal's transit time across the plane of the rotor
    - Animal's behavior and density

→ Estimate the probability of collision between an animal and a turbine
Sensitive to assumptions about avoidance rate
Best suited for horizontal axis turbine

Few models included avoidance/evasion behavior
- Based on behavioral observations of fish
(Hammar et al. 2015)
- Injury risk based on the part of the animal's body that contacts the rotor
(Copping and Grear 2018)

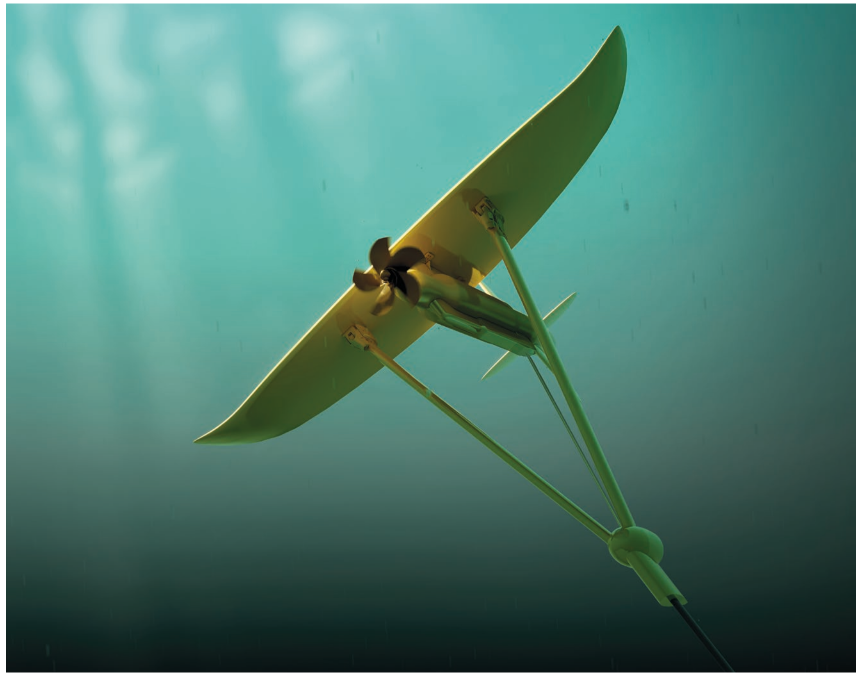
Collision Risk – Spatial Simulation

- 3D representation of an animal and a device over time

- Model integrating:
  - Shape and movement of a device
  - Animal's behavior
  - Animal's size

→ Estimate the probability of collision between an animal and a device
Variation in input parameters influences collision probabilities (e.g., vertical migration)

- Integration of the relative complexity of a tidal kite (Horne et al. 2021)
- Interactions with flow (Rossington and Benson 2020)



Minesto

Exposure Time Population Model

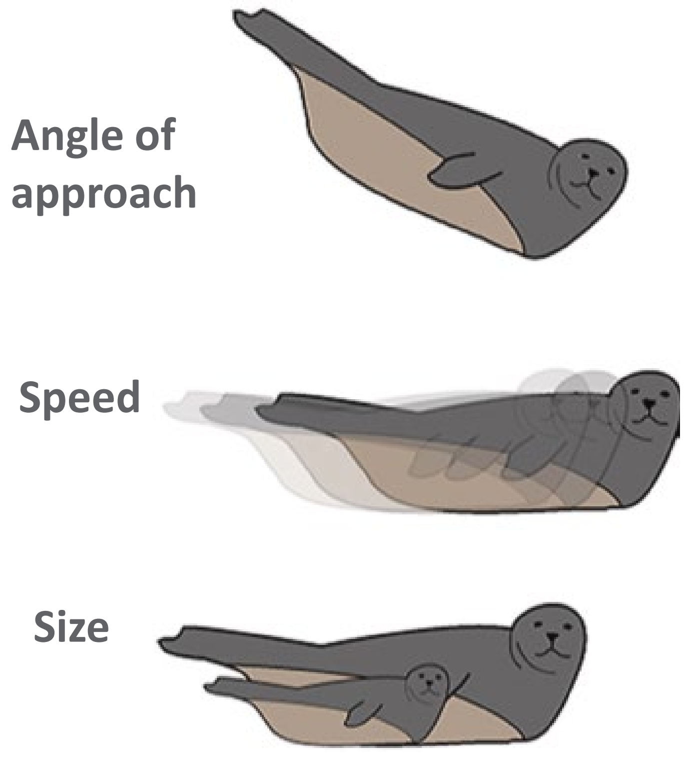
- Developed for diving birds (Grant et al. 2014)
- Approaches collision risk from the perspective of populations
- Model integrating:
  - **Population model**: to estimate the amount of additional mortality caused by collisions that would not decrease the population growth rate
  - **Exposure time model**: to estimate collision probability from the amount of time animals spend at the depth of the device and the proportion of that depth occupied by the device

→ Estimate of collision risk per unit of time based on the population size and individual exposure time
Provides the threshold mortality rate

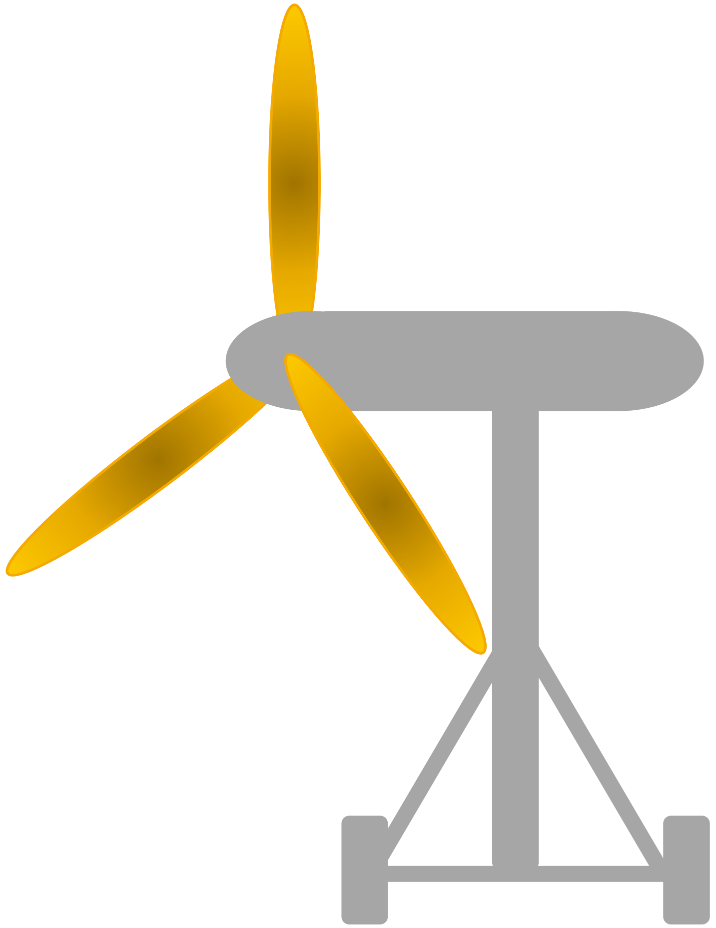
- Assumes that every collision is fatal
- Does not include avoidance/evasion behavior

Inputs Required – Marine Mammals

- Population density
- Angle of approach towards the device
- Swimming speed
- Body size (length/width)
- Diving behavior
  (frequency, depth, proportion of time foraging)
- Reproduction and survival of the population (for ETPM only)



Horne et al. 2021



Conclusions on Collision Risk Models

- Probabilities of encounter/collision
  Mortality threshold that would affect a population

- Behavior can have large effects on model outcomes
  - Create uncertainties when using behavior with limited information

- Injury outcomes, death, and population effects usually not considered in models

- Model outputs mainly predicted for one single turbine, what about arrays?

→ Empirical parameterization of behavior/density in models is rare
No existing validation of predicted collision probabilities

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Thank you

Lysel Garavelli

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Marine mammals and collision risk – current knowledge, gaps and improving how we predict risk

Carol Sparling[1], Gordon Hastie[1], Doug Gillespie[1], Laura Palmer[1,4], Joe Onoufriou[1,2] & Nicholas Horne[3]

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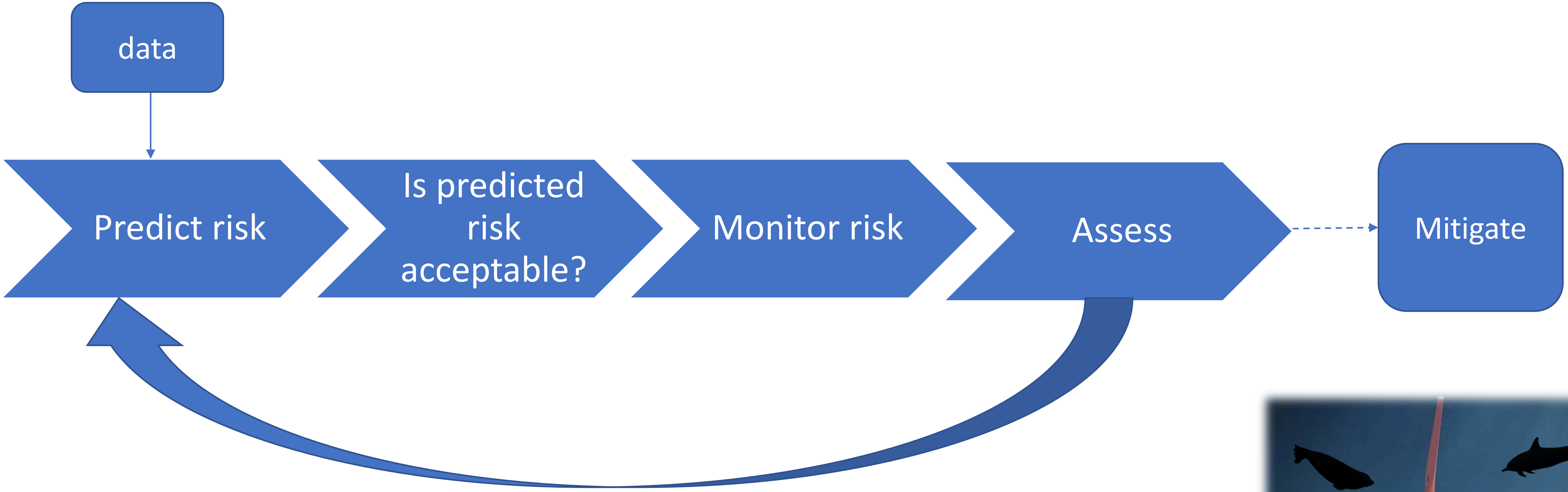
Prediction, monitoring and adaptive management of risk



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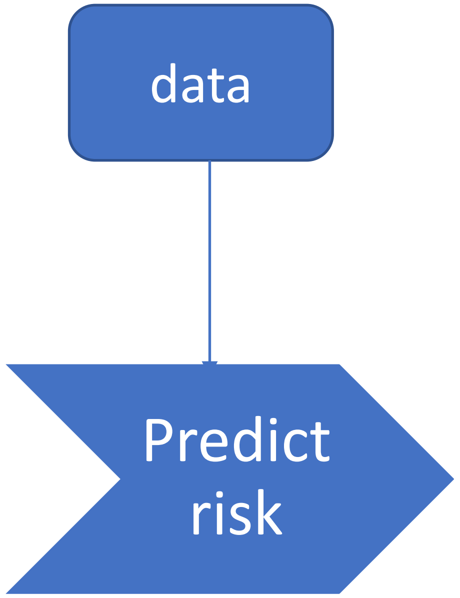
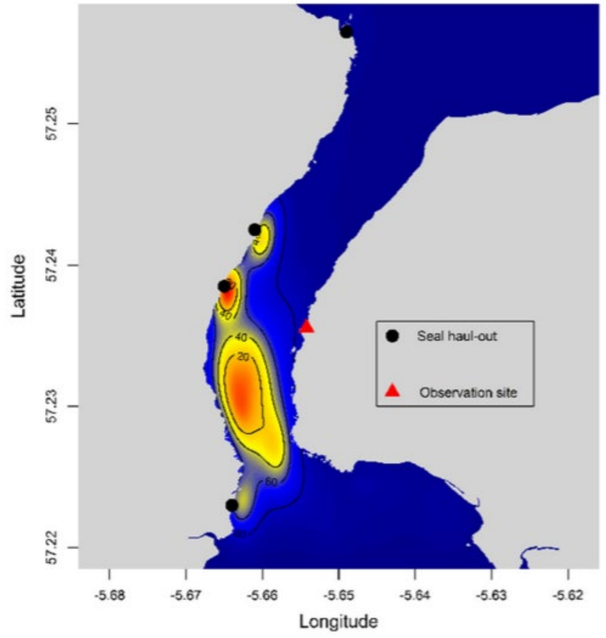
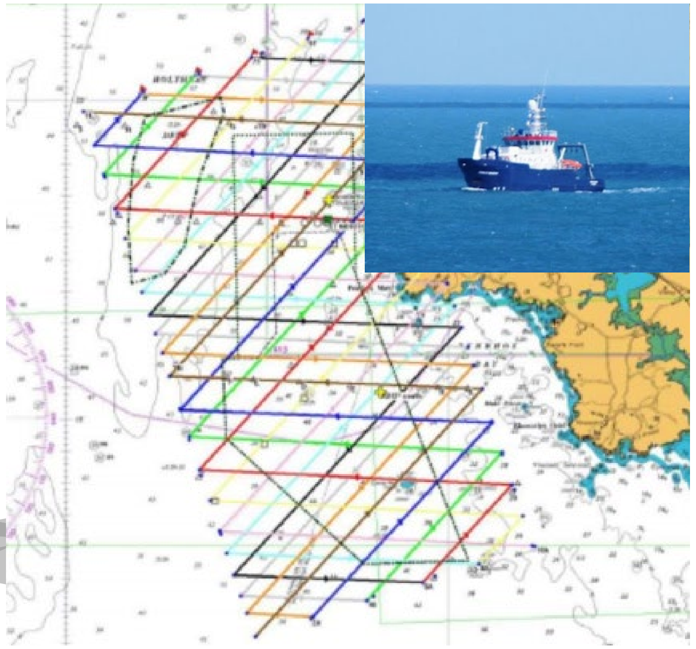
What do we know? Baseline use of tidal sites

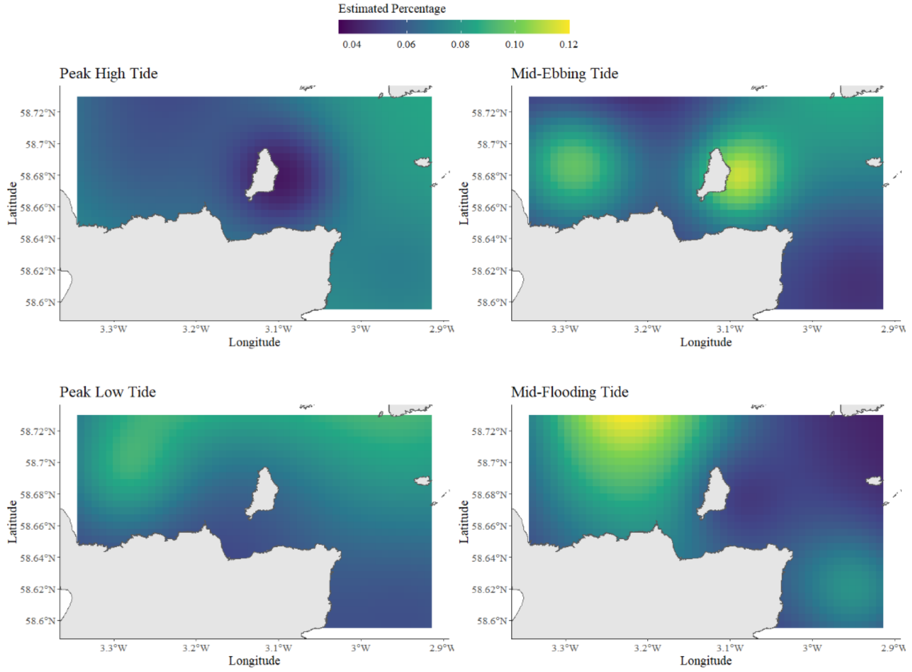


- Animal body size
- **Animal Density**
- Depth distribution
- Swim speed and orientati



Hastie *et al.* (2017) *Behav. Ecol. Sociobiol*





Onoufriou *et al.* (in review)

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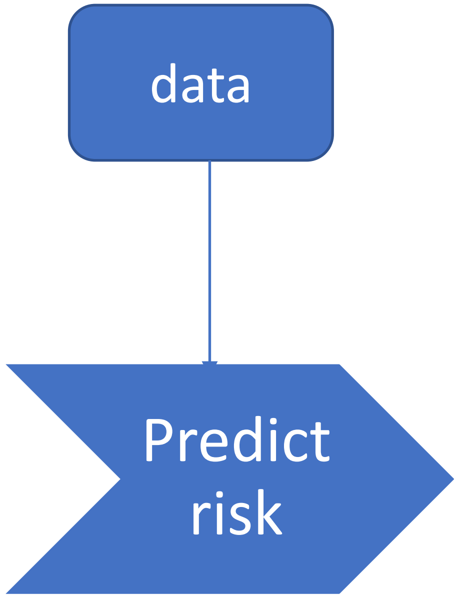
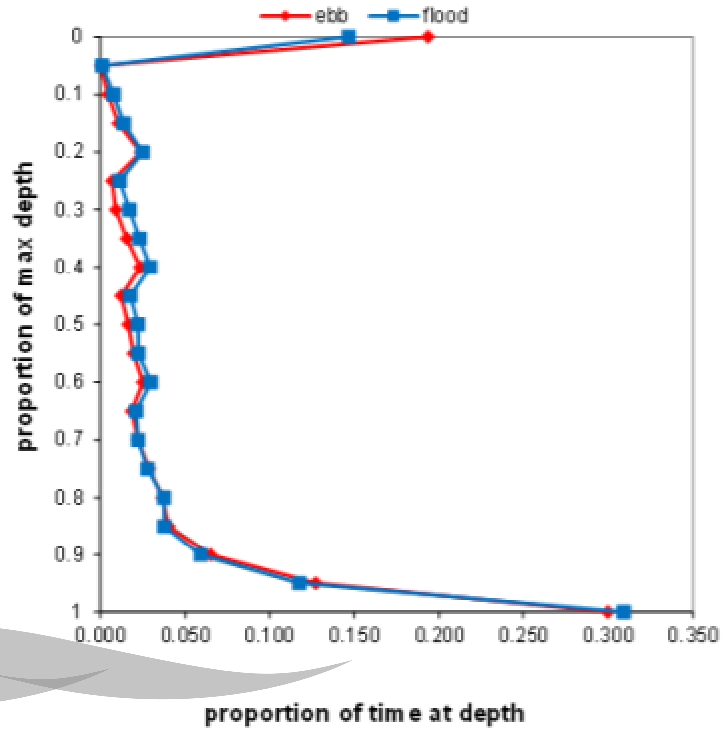
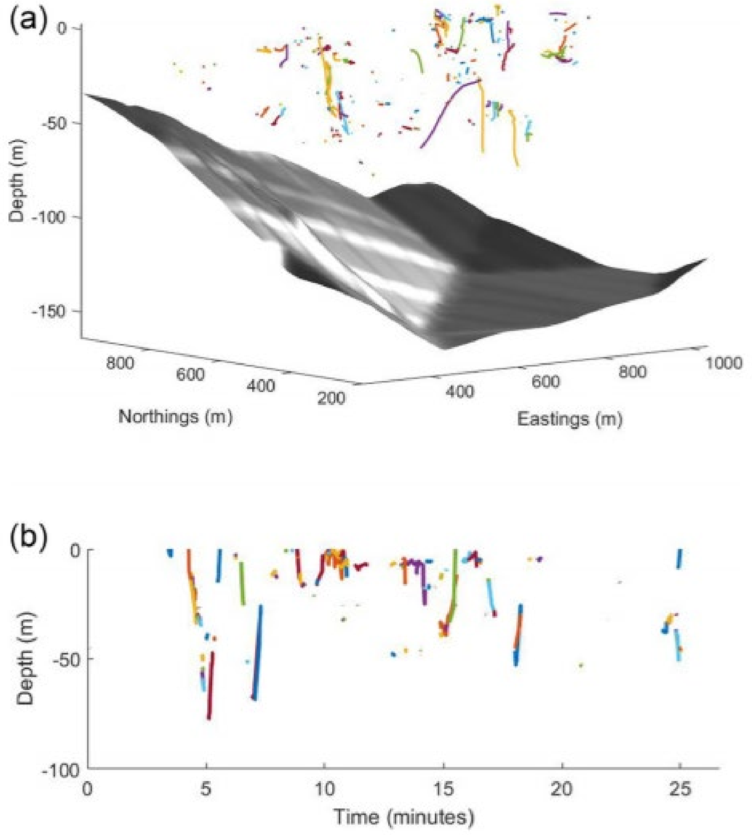


- Animal body size
- Animal Density
- **Depth distribution**
- Swim speed and orientation



Band *et al.* (2016) *Scottish Marine and Freshwater Science*



Macaulay *et al.* (2017) *JASA*

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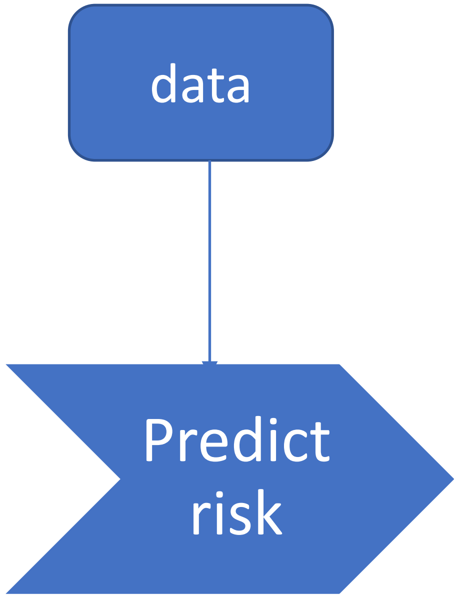
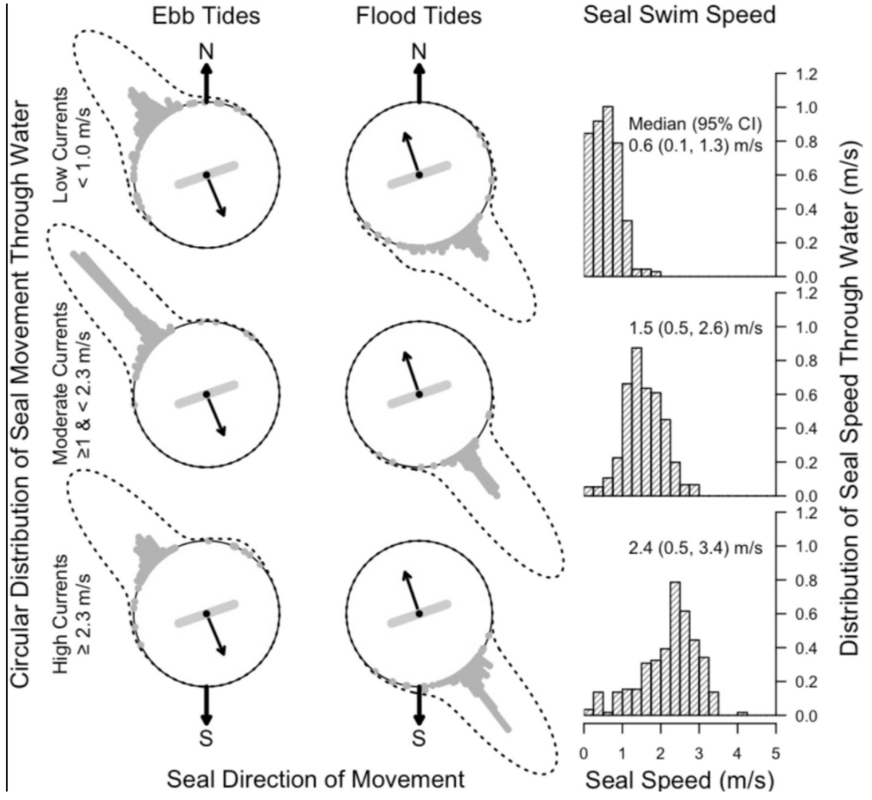
What do we know? Baseline use of tidal sites

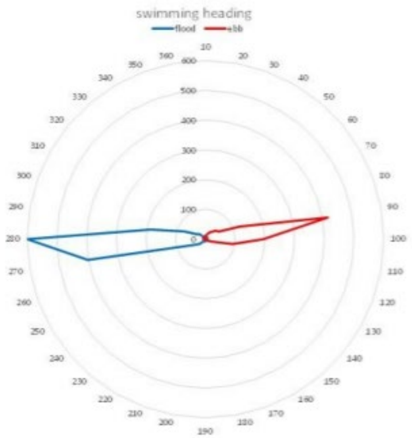


- Animal body size
- Animal Density
- Depth distribution
- **Swim speed and orientation**

Seals swam slowly against the current in Strangford Narrows



Joy *et al.* (2018) *Marine Pollution Bulletin*



and in the Pentland Firth

Band *et al.* (2016) *Scottish Marine and Freshwater Science*

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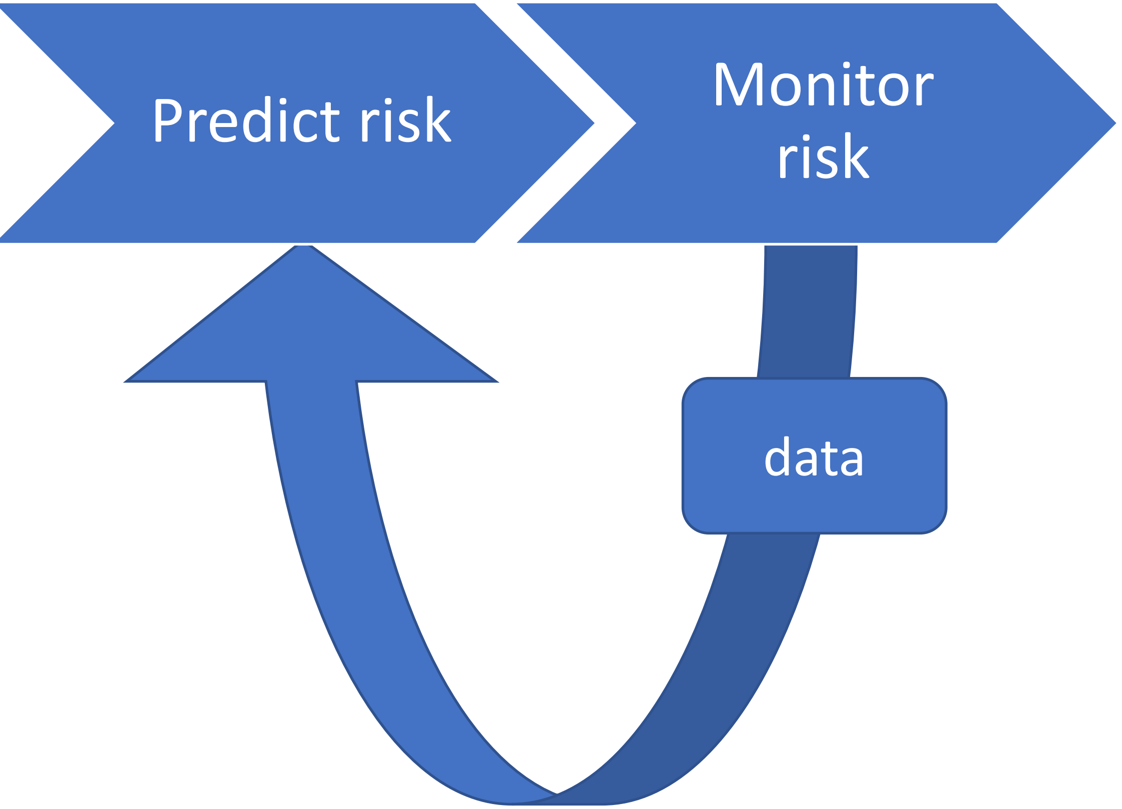
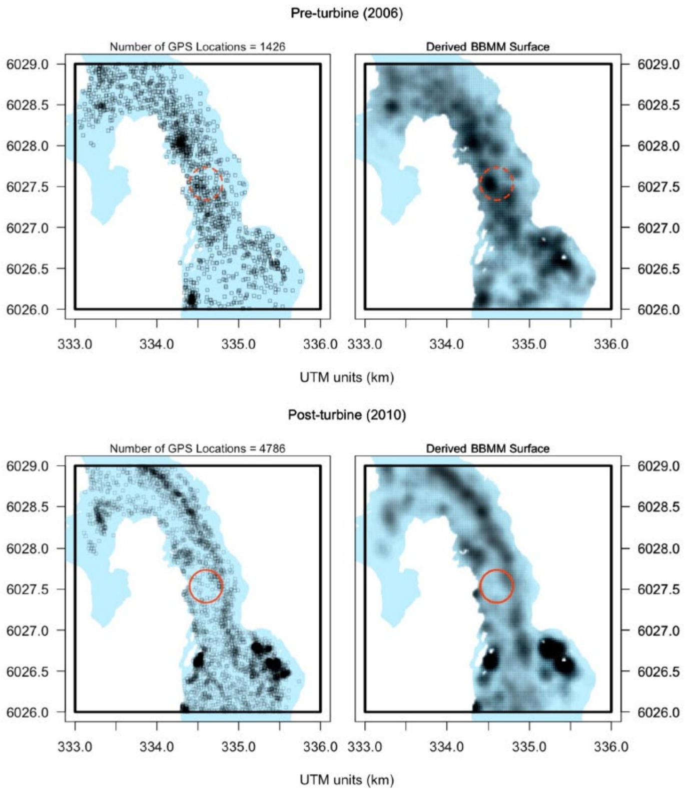
What do we know? Avoidance..



SeaGen in the Strangford Narrows



- Tagged seals showed moderate changes in transit frequency past the turbines and transited at greater distances when the turbine was operational.

  Sparling *et al.* (2018) *Aquatic Conservation*

- Modelling movement with respect to turbine characteristics and tidal state showed ~68% spatial avoidance within 200metres of the turbine.

- Incorporation of measured behaviour in updated collision risk assessment resulted in a 90% reduction in predicted collision risk

Joy *et al.* (2018) *Marine Pollution Bulletin*

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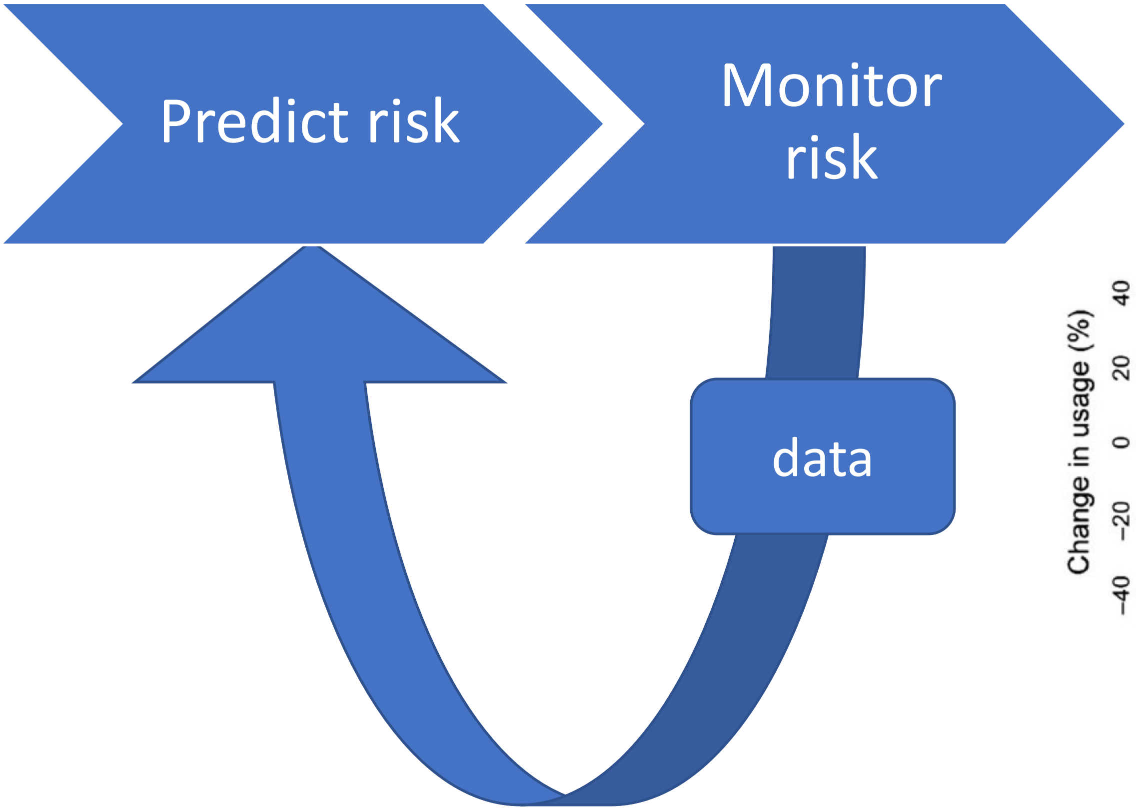
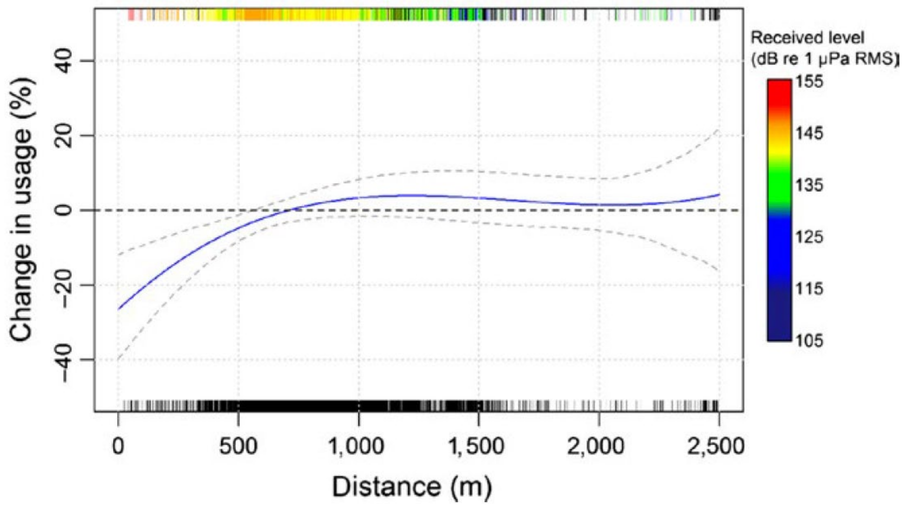
What do we know? Avoidance..



Acoustic exposure at Kyle Rhea



- Measured behaviour of tagged and observed harbour seals as a response to acoustic exposure of tidal turbine recordings.
- Significant decrease in abundance of seals within 500 metres of the sound source during exposure

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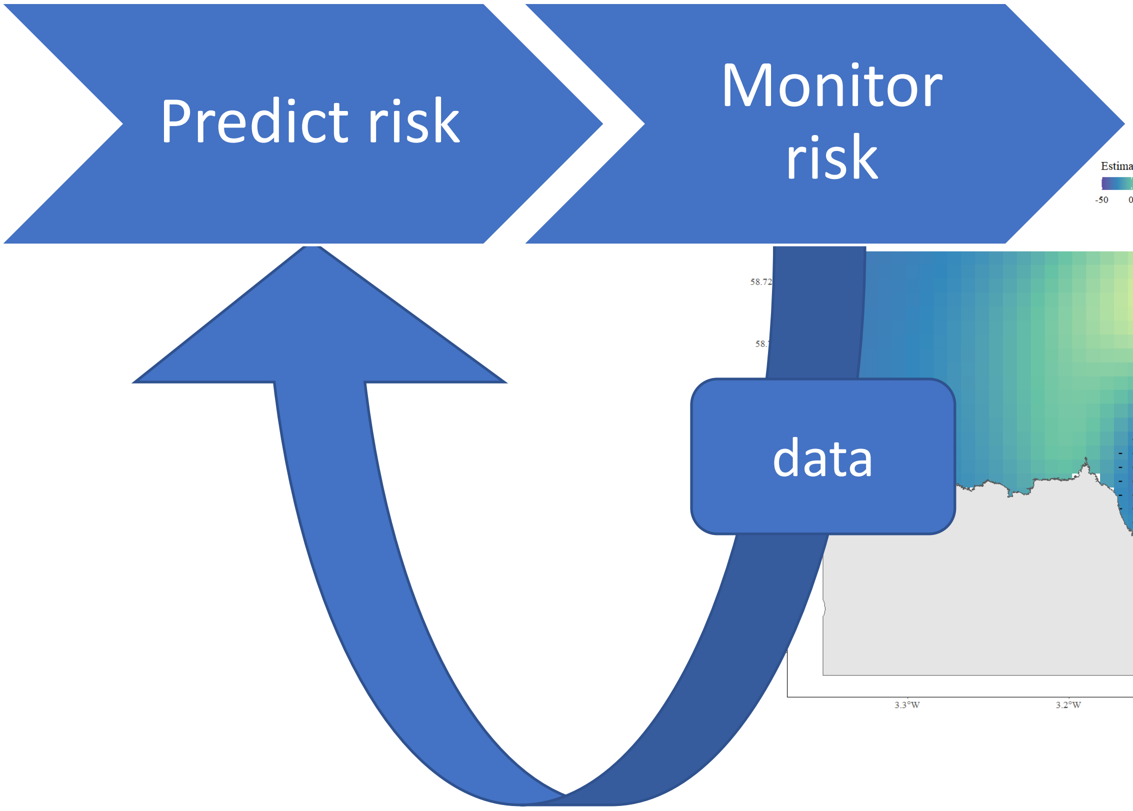
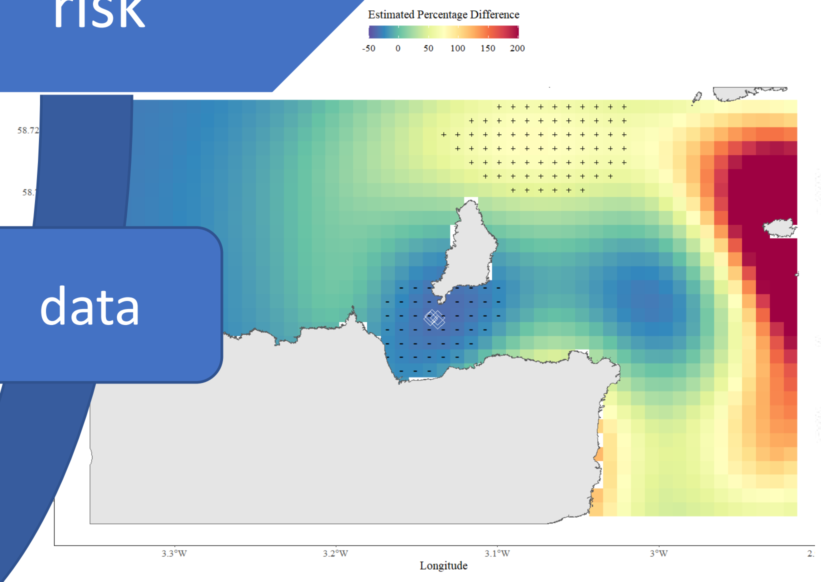
Hastie *et al.* (2017) *Marine Pollution Bulletin*

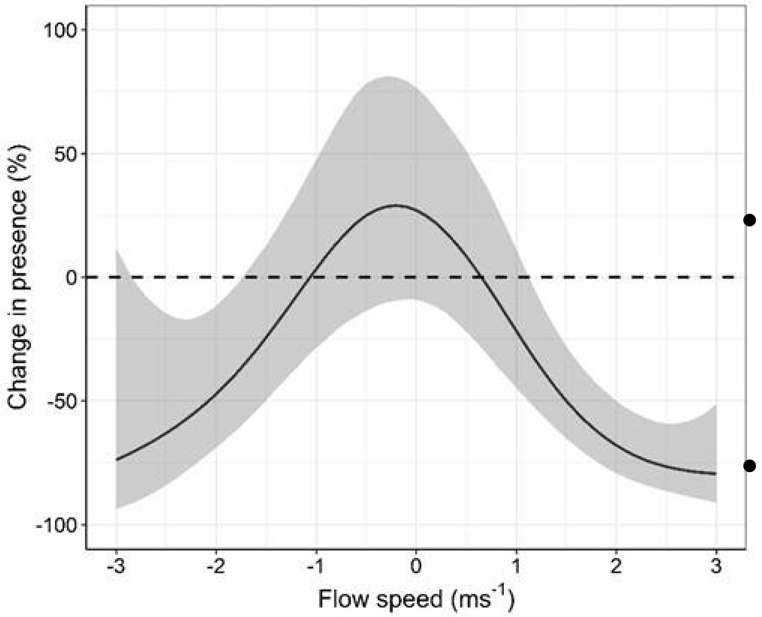
What do we know? Avoidance..



MeyGen in the Pentland Firth



Onoufriou *et al.* (*in review*)



Palmer *et al.* (in review)

- Tracked tagged seals between 2016-2019 and used passive acoustic monitoring (PAM) to track porpoises and identify porpoise presence around the turbines.
- Significant reduction in seal abundance within 2km of the turbines during operations.
- Porpoises presence within 150m of the turbine reduced significantly during operational periods, especially at high flow speeds during both flood and ebb tides.

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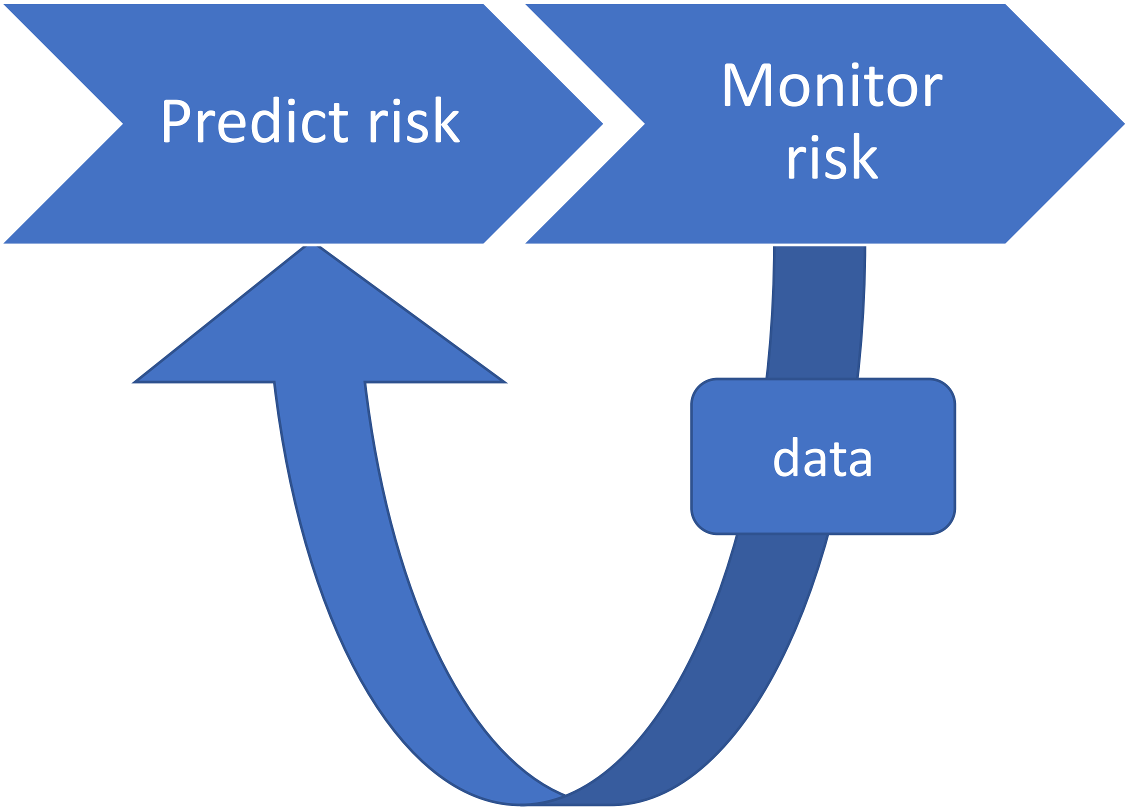
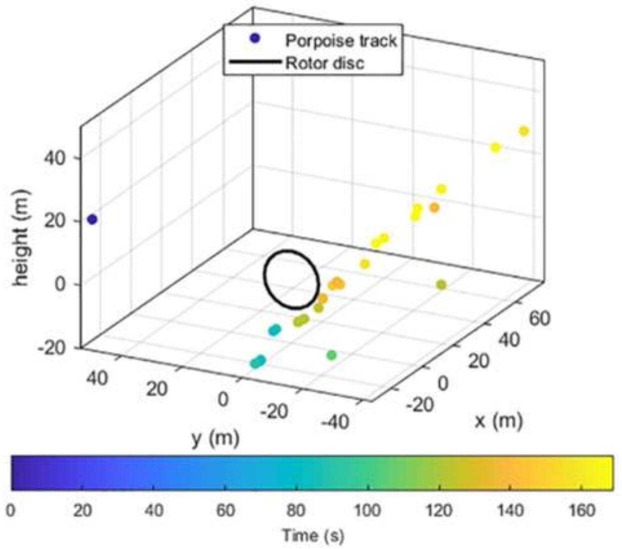
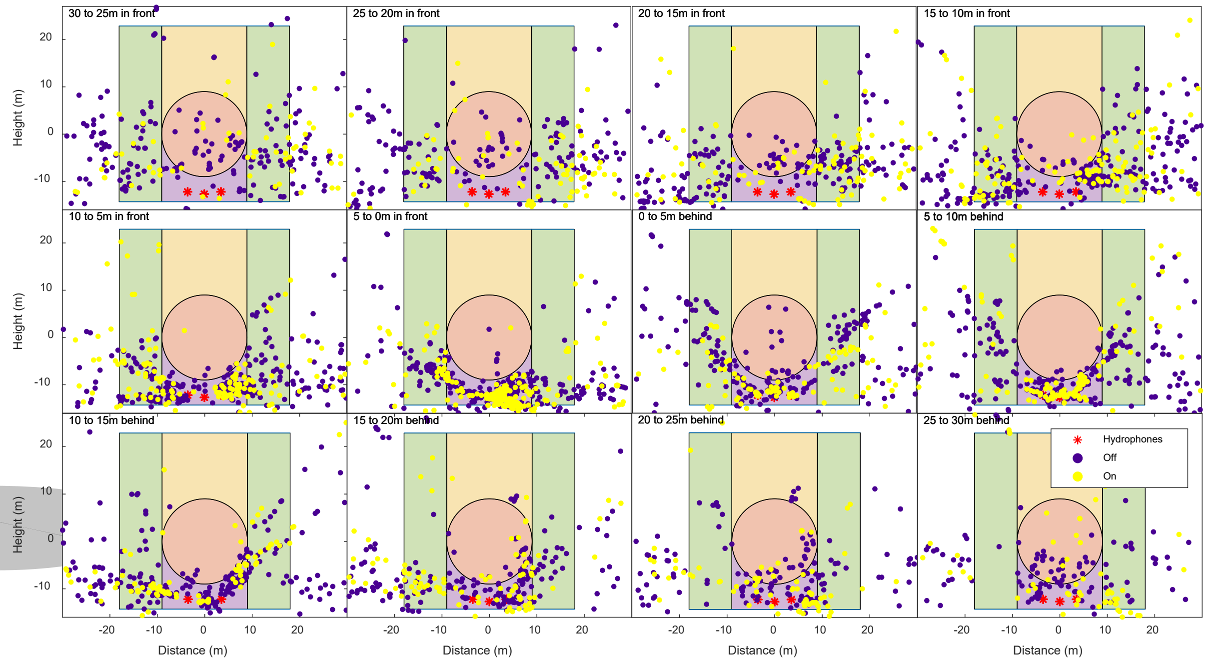
What do we know? Fine scale behaviour around turbines....





PAM tracking at MeyGen at the Pentland Firth

- Porpoises avoided the rotor swept area
- ‘aggregation’ around the base?



Gillespie et al (in press)

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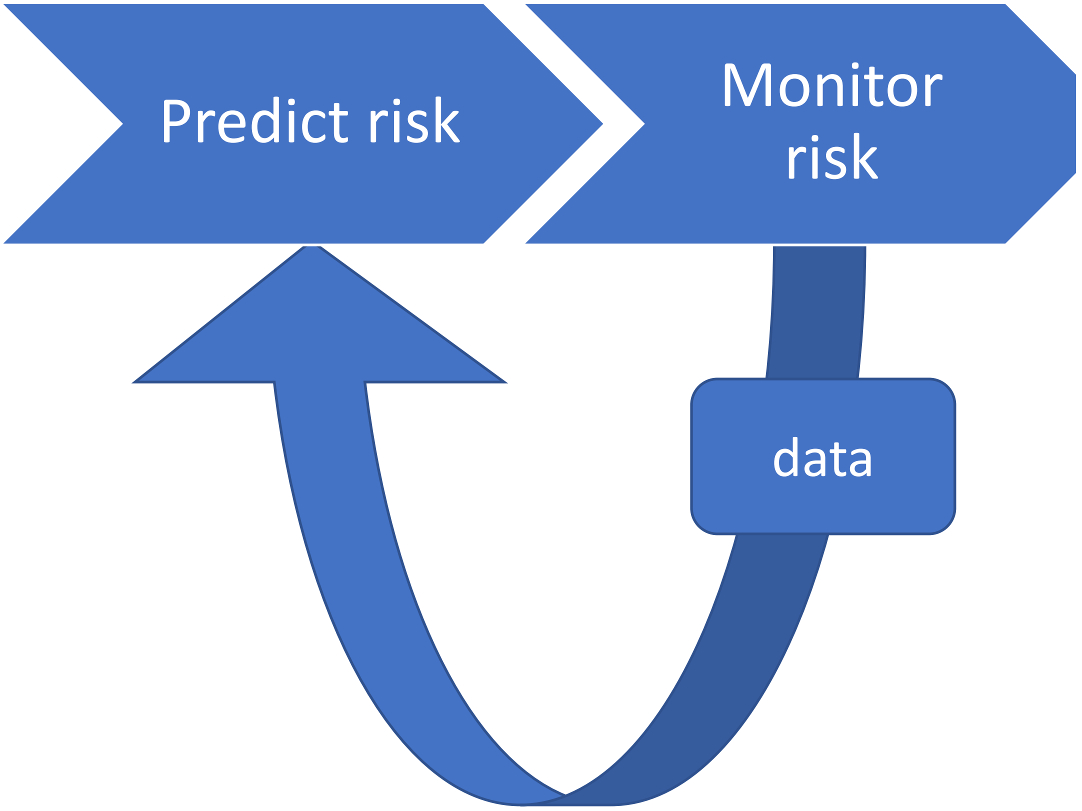
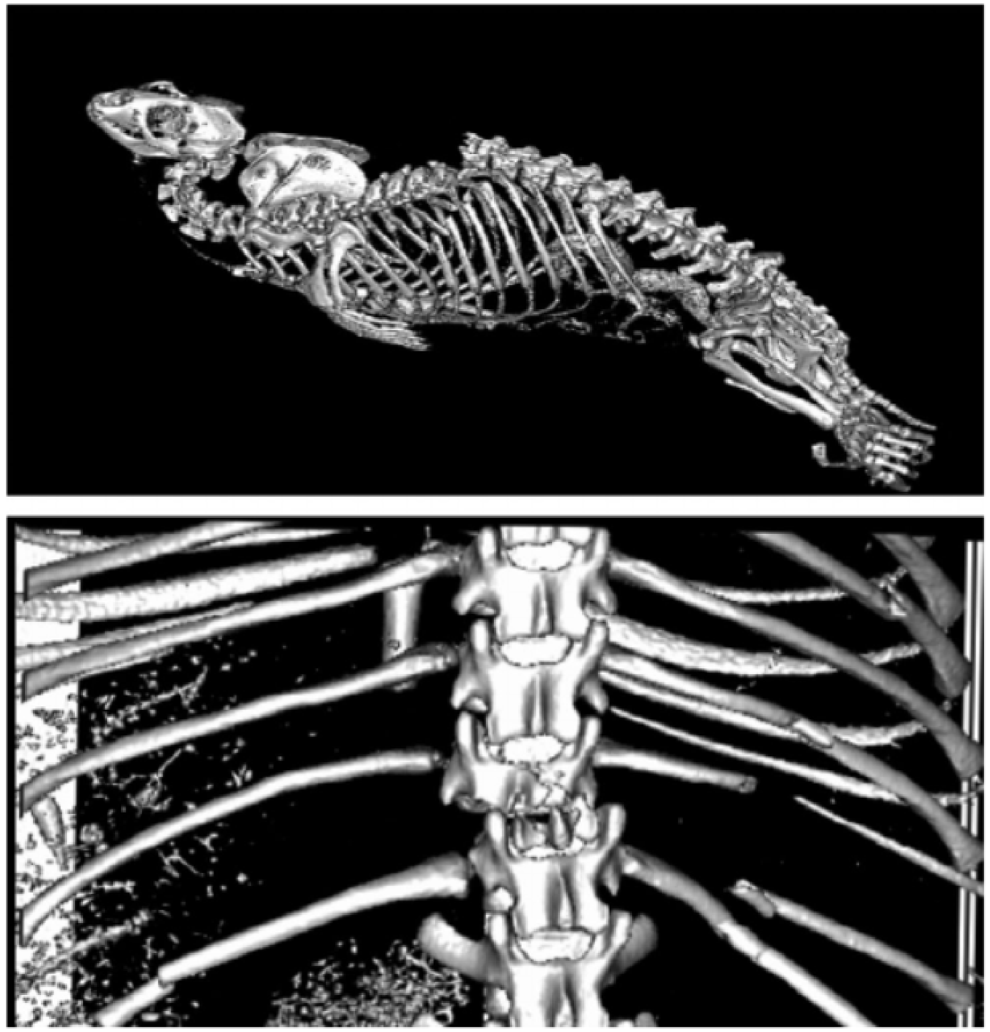
What do we know? Consequences of collisions ….





Onoufriou *et al (2019)*

Collision trials with carcasses

- Severe trauma was restricted to the thoracic region, with no evidence of injury to the lumbar or cervical spine.
- Pathological indicators of mor-tality were only predicted to occur in collision speeds in excess of 5.1 m/s (95% C.I. 3.2–6.6)
- Increasing blubber depth reduced the likelihood of severe trauma

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What do we know? Study species..

Harbour seal

Harbour porpoise

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What do we NOT know? Study species..

Grey seal

Risso's dolphin

Common dolphin

Bottlenose dolphin

Killer whale

Minke whale

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What do we know? locations..

Strangford Narrows

Inner Sound, Pentland Firth

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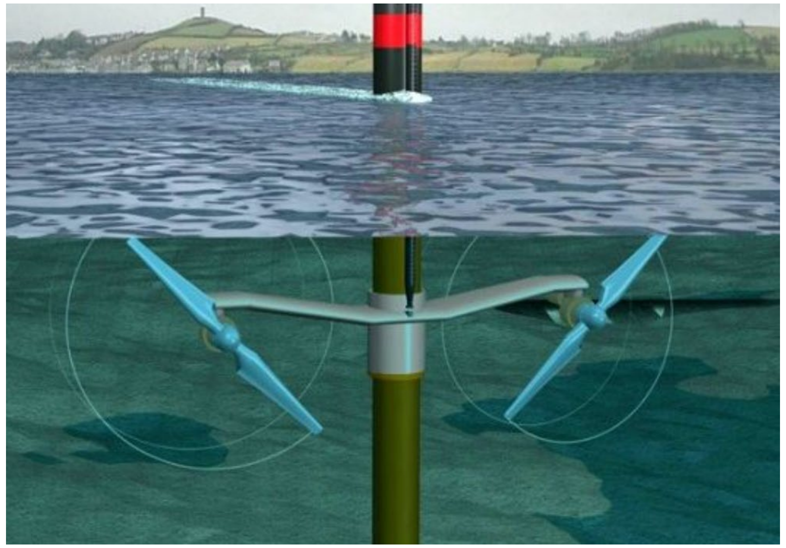
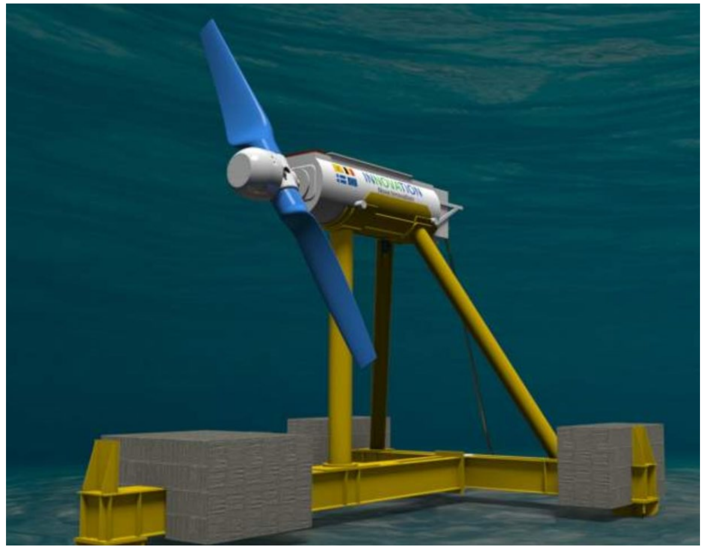
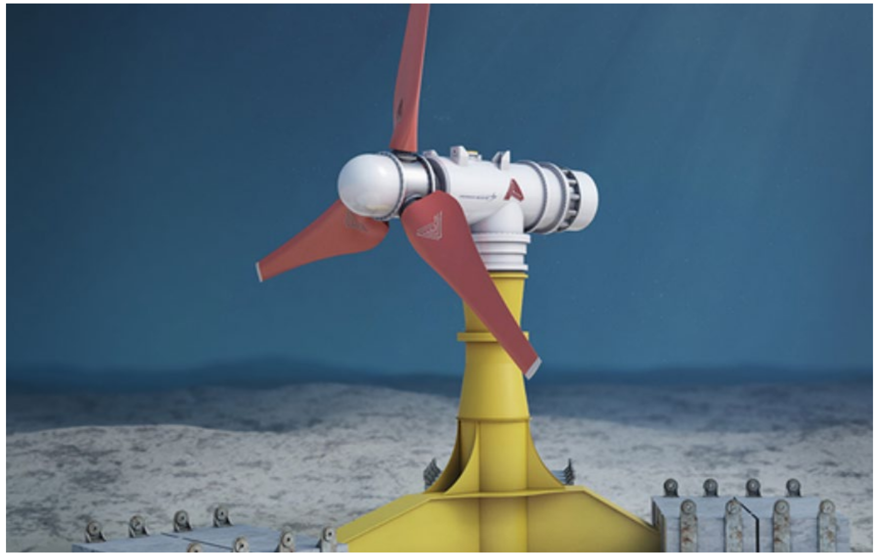
What do we know? Technologies….







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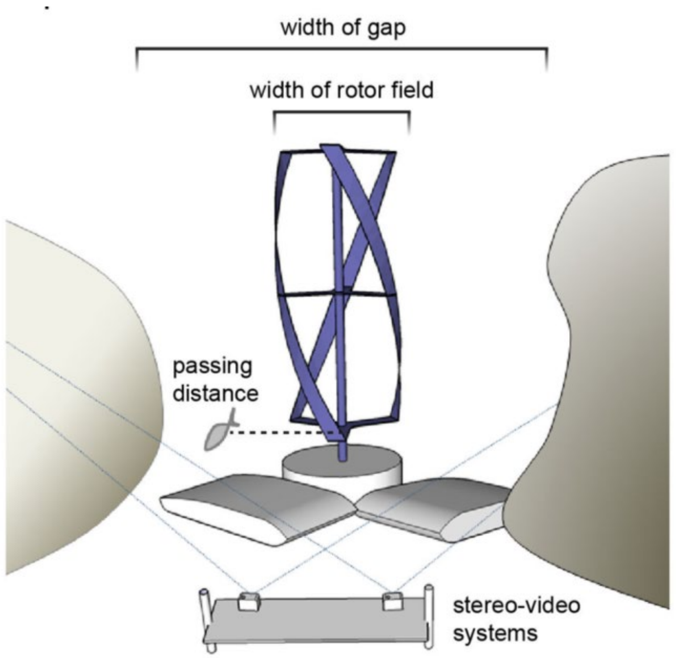
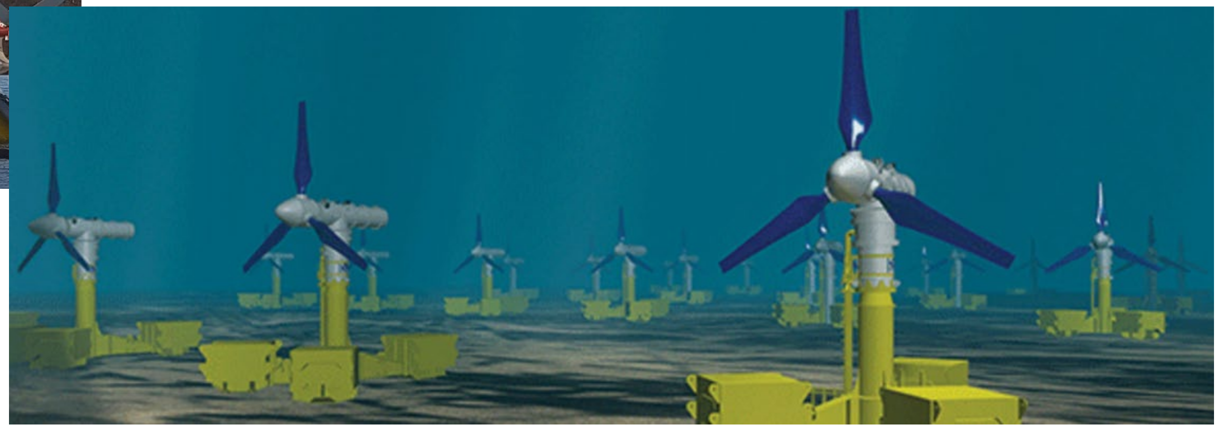
What do we NOT know? Technologies….





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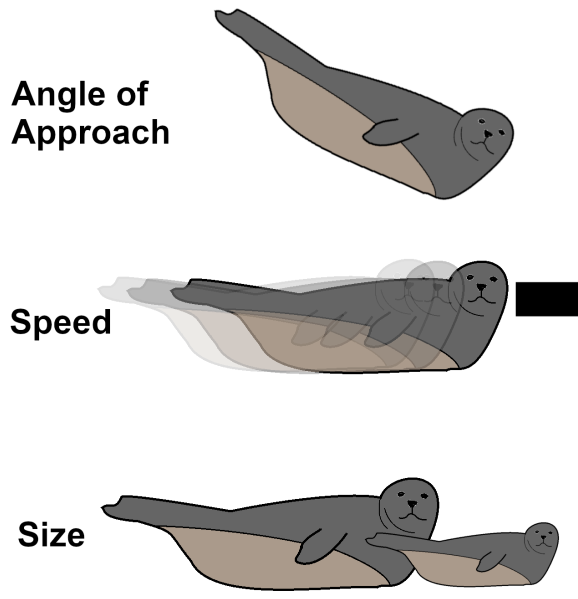
How can we best use the data we are collecting?

Simulation-based approach is a tool that is being developed to adapt and change based on best available data

INPUTS

Flexible approach to estimating collision risk allows inputs to be altered.



SIMULATIONS

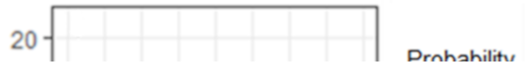
Simulating a novel tidal energy kite using an open-source game-engine.

POST-PROCESSING

Results can be post-processed to incorporate additional data e.g. dive profiles.

COLLISION PROBABILITY

Refined collision probabilities for better informed management decisions.



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Research article

Collision risk modelling for tidal energy devices: A flexible simulation-based approach

Nicholas Horne[a,*], Ross M. Culloch[b], Pál Schmitt[c], Lilian Lieber[c], Ben Wilson[d], Andrew C. Dale[d], Jonathan D.R. Houghton[e], Louise T. Kregting[a]

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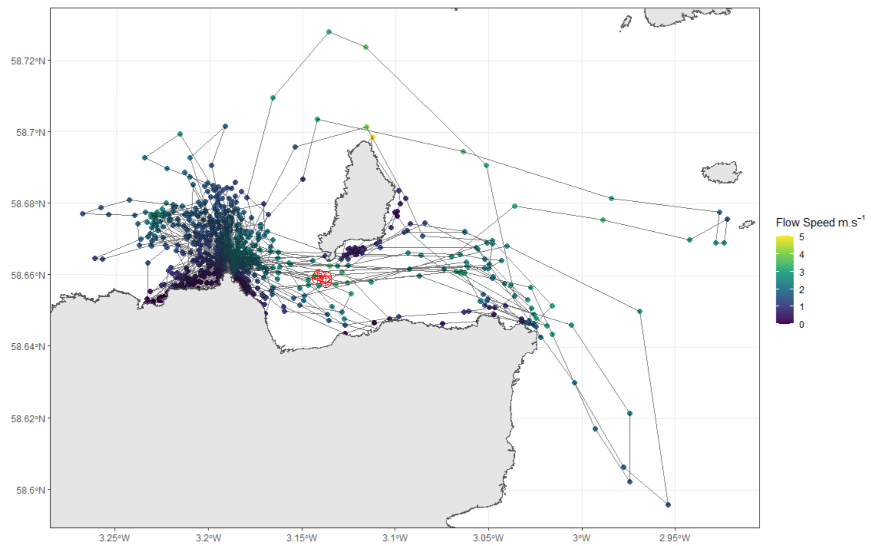
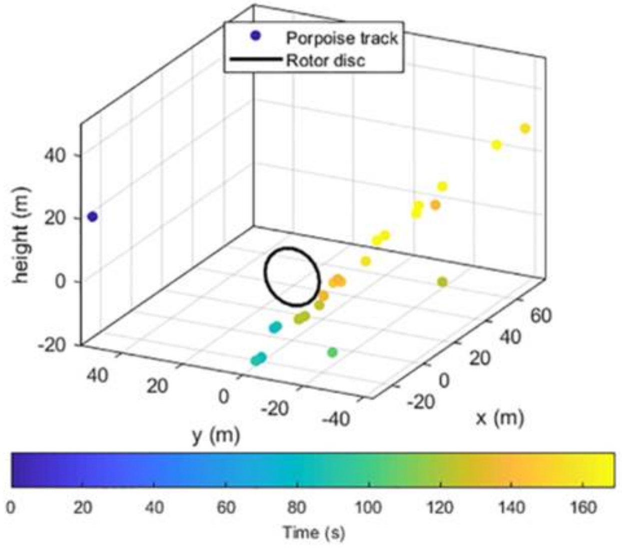
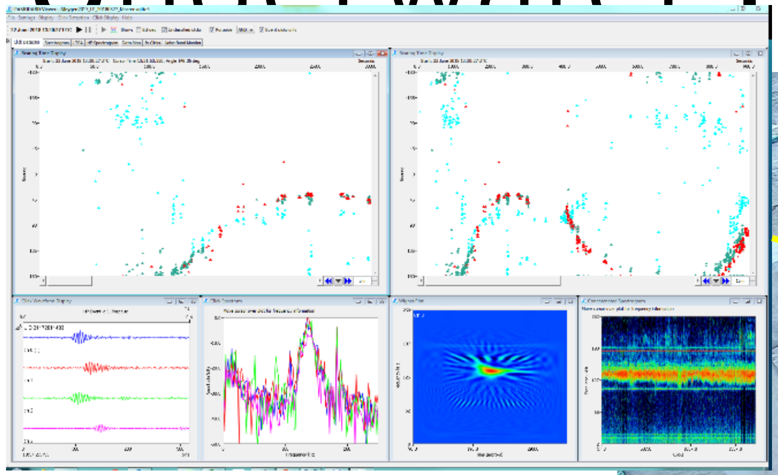
Future work: Using data to refine CRM: seal telemetry data and porpoise tracking

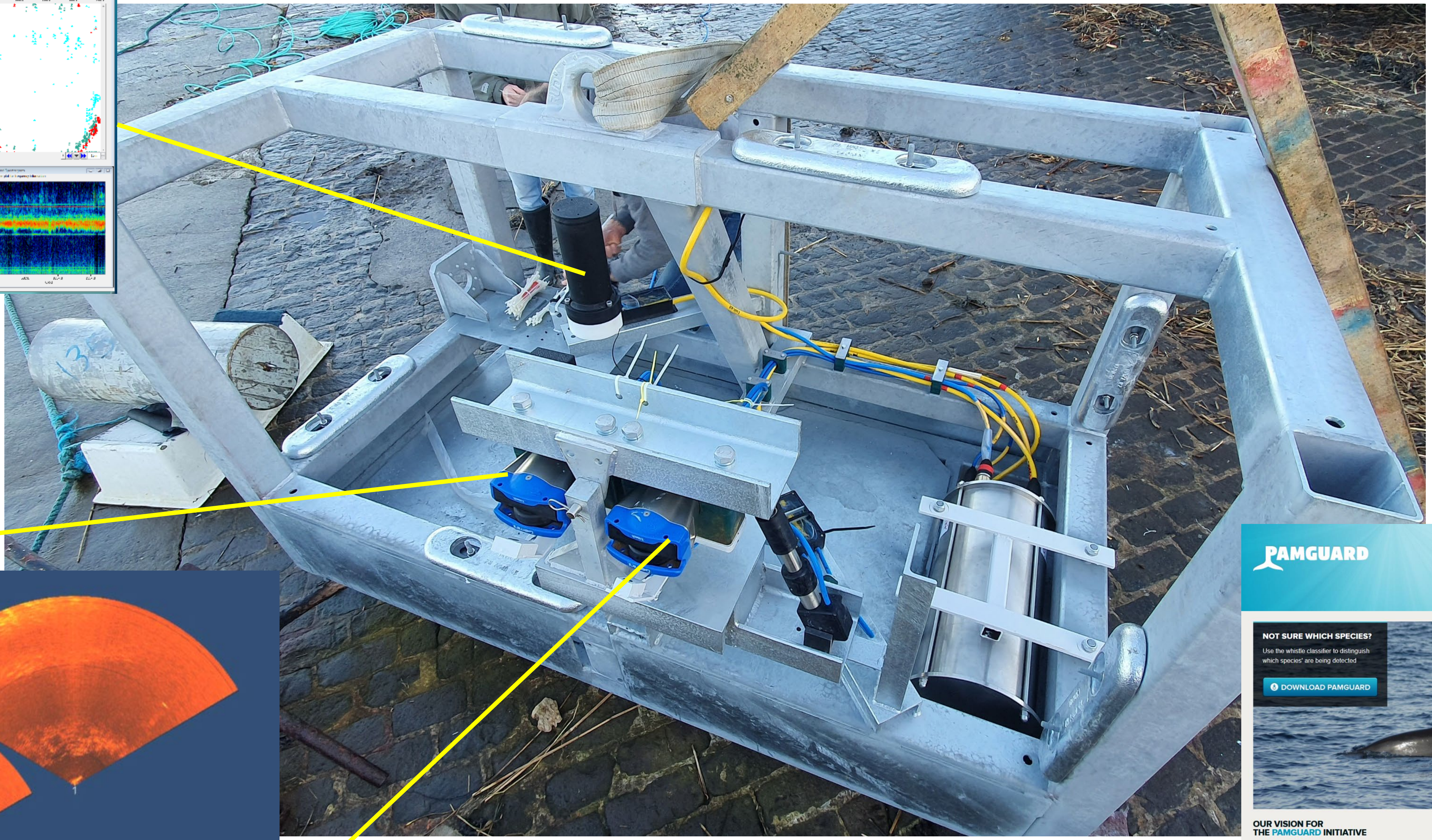
- Use measured data on distribution and behaviour close to turbine and in relation to current and model the effects of turbine operations and hydrodynamics on behaviour…
- can extrapolate to future turbine locations within the lease site.
- This will provide real world context to the simulations and provide more empirically informed estimates of rate and severity of collisions at array scale

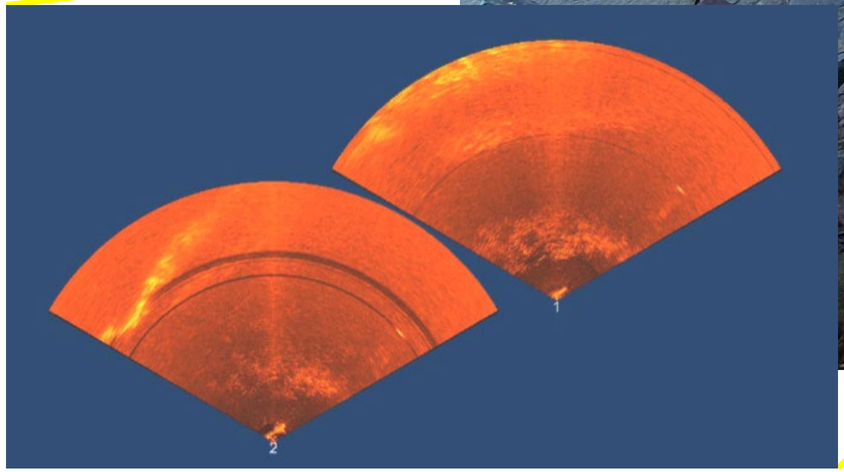


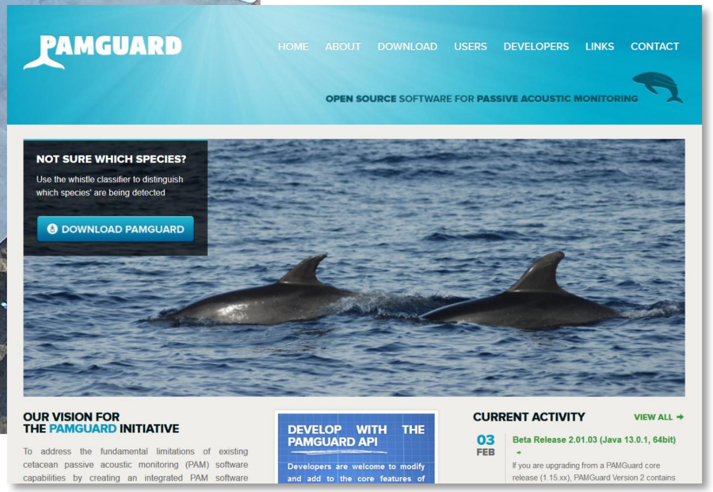


Marine mammal HiCUP: **H**igh **Cu**rrent **U**nderwater **P**latform



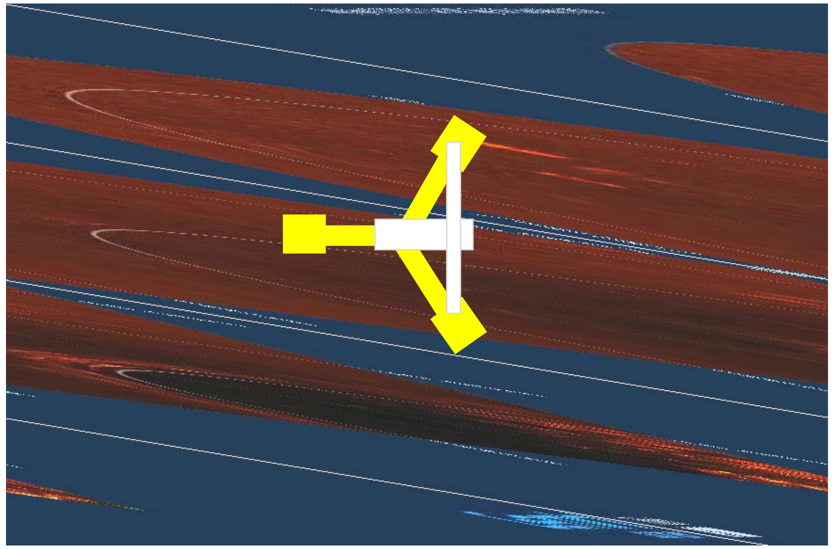


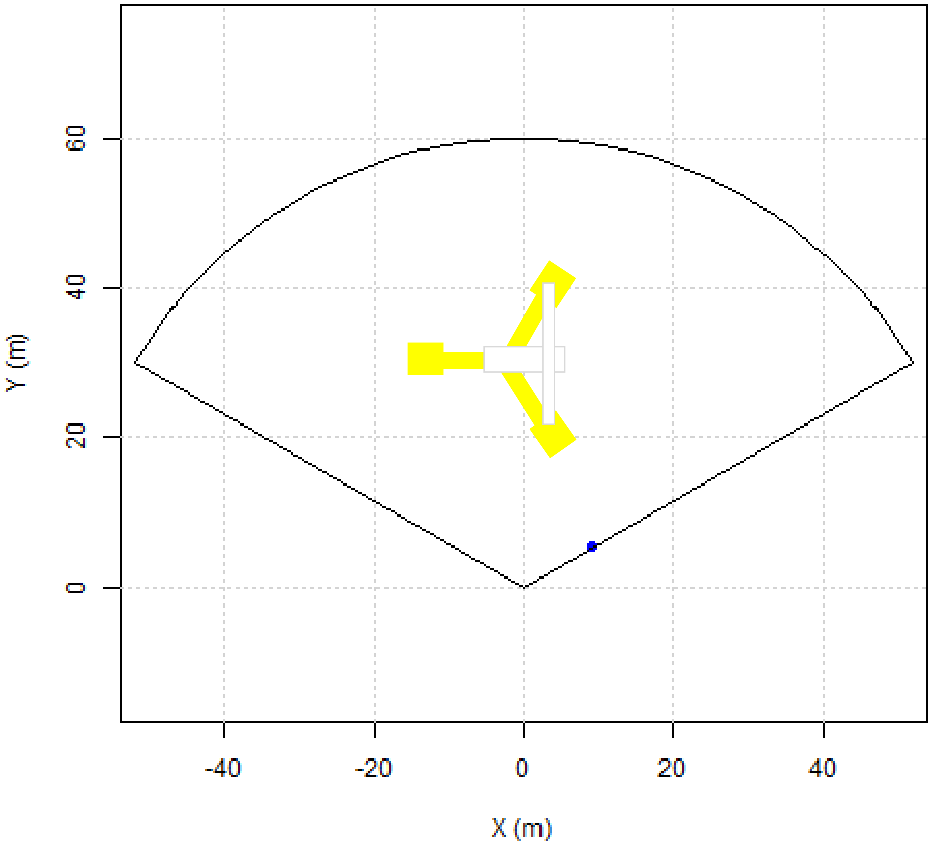




www.pamguard.org

Marine Mammal HiCUP:
avoidance behaviour to collision risk models





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QUEEN'S UNIVERSITY BELFAST
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THE BRYDEN CENTRE

Thank you

Collision risk modelling in practise- Marine Mammals

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MeyGen

- 2014- EIA completed and Marine License granted
- 2015- Onshore construction commenced
- 2018- MeyGen Phase 1A officially enters into operation
- Consent was sought in phases
  - Phase 1 consent for 86 MW
  - Phase 2 consent will be sought separately (312 MW)
- Turbines 1 MW capacity each, with an export cable to shore each

Source: Gillespie, 2020 Presentation. OES Environmental International Monitoring Forum

Baseline data collection

- Baseline data collection
  - 2-year specific marine mammal surveys carried out by developer
  - Vantage point, boat based and passive acoustic surveys
- From these surveys- data on abundance and behaviour, distribution and seasonality could be qualitatively deduced




Source: MeyGen EIAR

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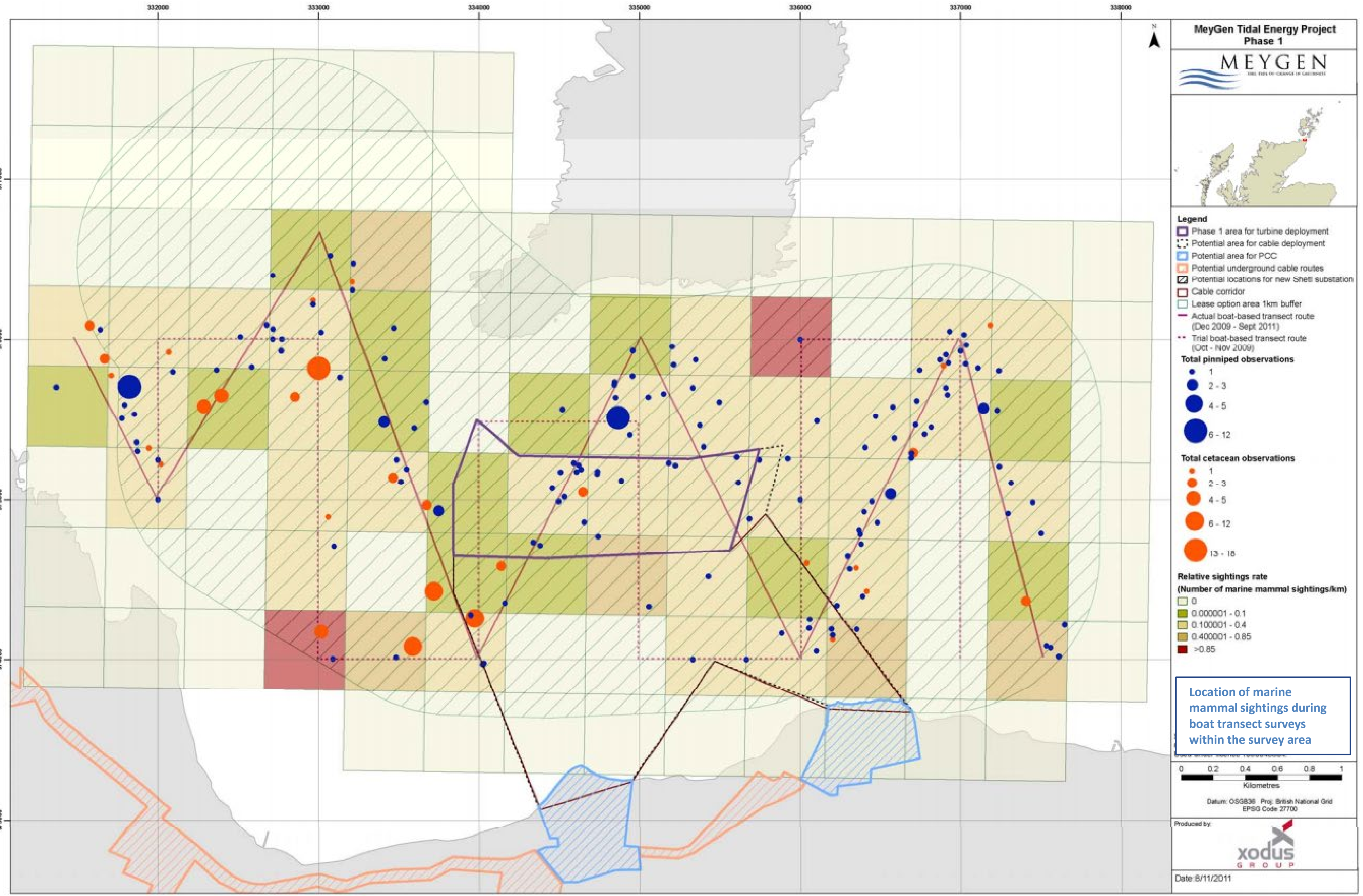

Location of marine mammal sightings during boat transect surveys within the survey area

Source: MeyGen EIAR

Encounter rate

- Encounter rate is calculated between the turbines and marine mammals
- Collision risk is a function of encounter rate
- Encounter rate for a single predator expressed as the product of the volume swept by the predator per unit time and the density of prey (Where the turbine is the predator, and the animal is the prey)
- This is calculated based on:
  - Turbine dimensions
  - Characteristics of the physical environment (e.g. tide)
  - Species selection
  - Density
  - Depth distribution
  - Swimming speed

Source: MeyGen EIAR

Encounter rate

- Four species: harbour porpoise, minke whale and the grey and harbour seals
- Assumption that encounter rate increases linearly as the number of turbines increases through installation period.
- Encounter rates do not predict animals' interaction with the turbine
  - Avoidance, evasion, collision causing injury, collision causing death, collision causing no harm
- Encounter rate expressed as number of animals per turbine per year. Also expressed as percentage of population




Source: MeyGen EIAR

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Results- Cetaceans

Species	Avoidance Rate[18]	Density data from Project specific data (except minke whale as sightings rate too low)						Other species density estimate (harbour seal haul out estimate, harbour porpoise and grey seal upper 95% CI from Project survey)					
		10 turbines		20 turbines		86 turbines		10 turbines		20 turbines		86 turbines	
		Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population
Harbour porpoise	50	25	0.04	49	0.09	211	0.38	47	0.09	94	0.17	404	0.73
	75	12	0.02	25	0.04	105	0.19	24	0.04	47	0.09	202	0.37
	80	10	0.02	20	0.04	84	0.15	19	0.03	38	0.07	162	0.29
	90	5	0.01	10	0.02	42	0.08	9	0.02	19	0.03	81	0.15
	95	2	0.00	5	0.01	21	0.04	5	0.01	9	0.02	40	0.07
	98	1	0.00	2	0.00	8	0.02	2	0.00	4	0.01	16	0.03
	99	0	0.00	1	0.00	4	0.01	1	0.00	2	0.00	8	0.01
	99.5	0	0.00	0	0.00	2	0.00	0	0.00	1	0.00	4	0.01
	100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Minke whale	50							21	0.11	41	0.22	176	0.95
	75							10	0.06	21	0.11	88	0.47
	80							8	0.04	16	0.09	71	0.38
	90							4	0.02	8	0.04	35	0.19
	95							2	0.01	4	0.02	18	0.09
	98							1	0.00	2	0.01	7	0.04
	99							0	0.00	1	0.00	4	0.02
	99.5							0	0.00	0	0.00	2	0.01
	100							0	0.00	0	0.00	0	0.00

- Project specific density data for minke whale too low to be
- Literature suggests that avoidance rate will be at the upper end of the scale
- Harbour porpoise: less than 0.10% of the regional population
- Minke whale: less than 0.20% of the regional population

Source: MeyGen EIAR

Potential Biological Removal

- Potential Biological Removal is a widely used method of calculating whether current levels of anthropogenic mortality are consistent with reaching or exceeding a specific target population for a species.
- The Scottish Government issues limits on the number of seals that can be removed from a population before that population might be affected.
- For seals in the Orkney and North Coast management area in 2012
  - 959 grey seals
  - 18 harbour seals
- Encounter rates that exceed this number are of particular importance,
  - if it is assumed that an encounter may cause serious injury or death

Source: MeyGen EIAR

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Results

Species	Avoidance Rate[18]	Density data from Project specific data (except minke whale as sightings rate too low)						Other species density estimate (harbour seal haul out estimate, harbour porpoise and grey seal upper 95% CI from Project survey)					
		10 turbines		20 turbines		86 turbines		10 turbines		20 turbines		86 turbines	
		Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population	Encounter rate	% of Regional Population
Grey seal feeding	50	27	0.17	54	0.34	232	1.45	84	0.53	168	1.05	722	4.52
	75	14	0.08	27	0.17	116	0.73	42	0.26	84	0.53	361	2.26
	80	11	0.07	22	0.14	93	0.58	34	0.21	67	0.42	289	1.81
	90	5	0.03	11	0.07	46	0.29	17	0.11	34	0.21	144	0.90
	95	3	0.02	5	0.03	23	0.15	8	0.05	17	0.11	72	0.45
	98	1	0.01	2	0.01	9	0.06	3	0.02	7	0.04	29	0.18
	99	1	0.00	1	0.01	5	0.03	2	0.01	3	0.02	14	0.09
	99.5	0	0.00	1	0.00	2	0.01	1	0.01	2	0.01	7	0.05
	100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Grey seal travelling	50	111	0.69	221	1.38	950	5.95	342	2.14	684	4.28	2941	18.41
	75	55	0.35	111	0.69	475	2.97	171	1.07	342	2.14	1471	9.21
	80	44	0.28	88	0.55	380	2.38	137	0.86	274	1.71	1176	7.36
	90	22	0.14	44	0.28	190	1.19	68	0.43	137	0.86	588	3.68
	95	11	0.07	22	0.14	95	0.59	34	0.21	68	0.43	294	1.84
	98	4	0.03	9	0.06	38	0.24	14	0.09	27	0.17	118	0.74
	99	2	0.01	4	0.03	19	0.12	7	0.04	14	0.09	59	0.37
	99.5	1	0.01	2	0.01	10	0.06	3	0.02	7	0.04	29	0.18
	100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Harbour seal	50	33	1.09	65	2.18	280	9.38	39	1.31	78	2.62	335	11.26
	75	16	0.55	33	1.09	140	4.69	20	0.65	39	1.31	168	5.63
	80	13	0.44	26	0.87	112	3.75	16	0.52	31	1.05	134	4.50
	90	7	0.22	13	0.44	56	1.88	8	0.26	16	0.52	67	2.25
	95	3	0.11	7	0.22	28	0.94	4	0.13	8	0.26	34	1.13
	98	1	0.04	3	0.09	11	0.38	2	0.05	3	0.10	13	0.45
	99	1	0.02	1	0.04	6	0.19	1	0.03	2	0.05	7	0.23
	99.5	0	0.01	1	0.02	3	0.09	0	0.01	1	0.03	3	0.11
	100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

- The orange shaded cells in the table indicate where PBR numbers could be breached
- Grey seal- Noted that a higher level of avoidance (90%) is assumed and therefore concludes that PBR will not be breached
- Harbour seal- Noted that if avoidance were to fall below 97% for 86 turbine scenario, PBR may be breached.

Source: MeyGen EIAR

Environmental Impact Assessment

- Collision Risk for common seal for full 86 turbine array deemed significant
  - Mitigation measure to employ Scotland's Survey, Deploy and Monitor policy to better understand avoidance rates.
  - This learning would inform potential requirement for future mitigation.
  - Therefore concluded in the EIA as not significant.
- MSS recommended consent for 6 turbines with a comprehensive monitoring programme
  - Establishment of a monitoring advisory group and provision of adequate funding to undertake monitoring.

Source: MeyGen EIAR

Questions?

Pacific Northwest NATIONAL LABORATORY

OES ENVIRONMENTAL

Thank You!

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