Empirical determination of severe trauma in seals from collisions with tidal turbine blades.

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Special thanks to…

Field trials team: **Matt Bivins, Steve Balfour, Alex Coram.**

Sample collection and analysis: **Nick Davison, Mariel ten Donetsche, Simon Northridge, Alex Coram.**

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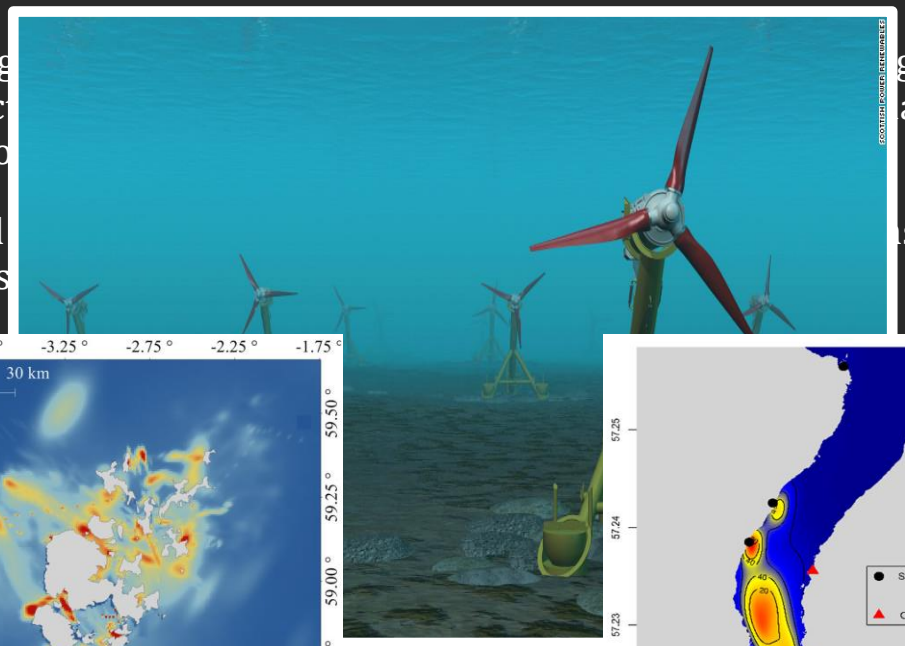
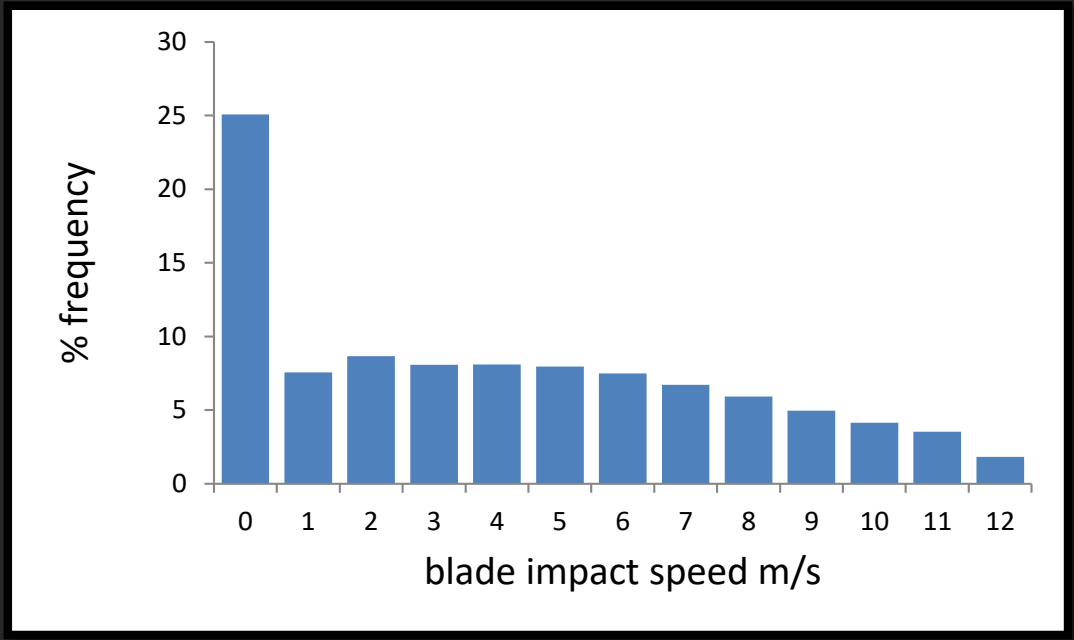
Background

- Tidal stream energy extraction is being developed in several countries; this is typically carried out using large floating or seabed-mounted turbines that extract kinetic energy from tidally-driven, moving water and may require being installed in arrays in order to maximise efficiency.
- Several of these designs have been identified as potentially lethal to a range of marine megafauna
- Evidence also sug getic regions
  - Static struct al reefs which are known to attract to
- The likely spatial s led to concerns about potential impacts



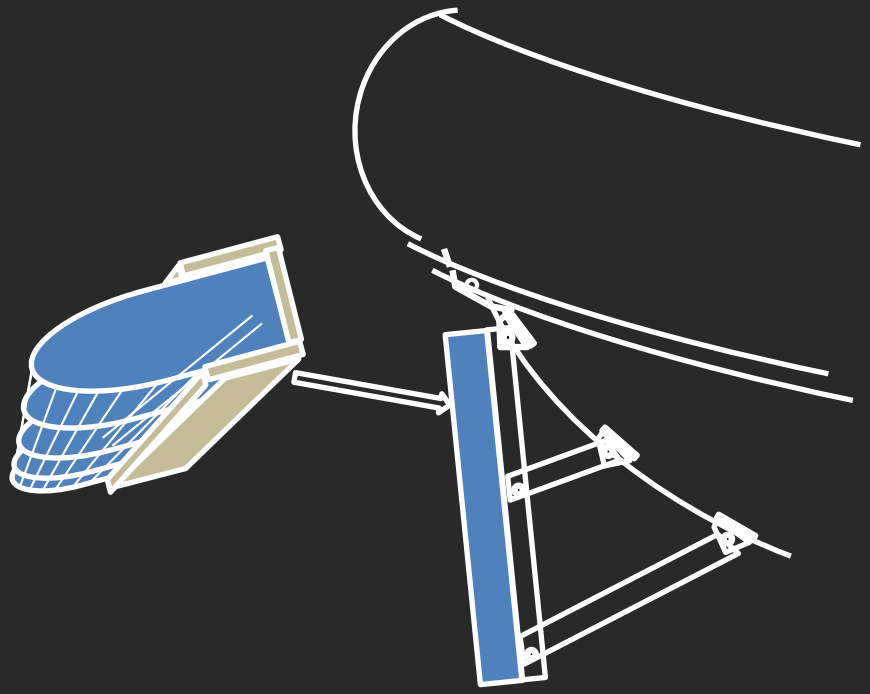
Assessing mortality

- Physical damage can be hypothesised using morphometrics derived from pathological analysis
- Blunt force trauma and skeletal vulnerability difficult to resolve hypothetically
- Empirical determination is more robust given an accurate experimental design
  - Blade speeds and shape would suggest varying degrees of collision severity.

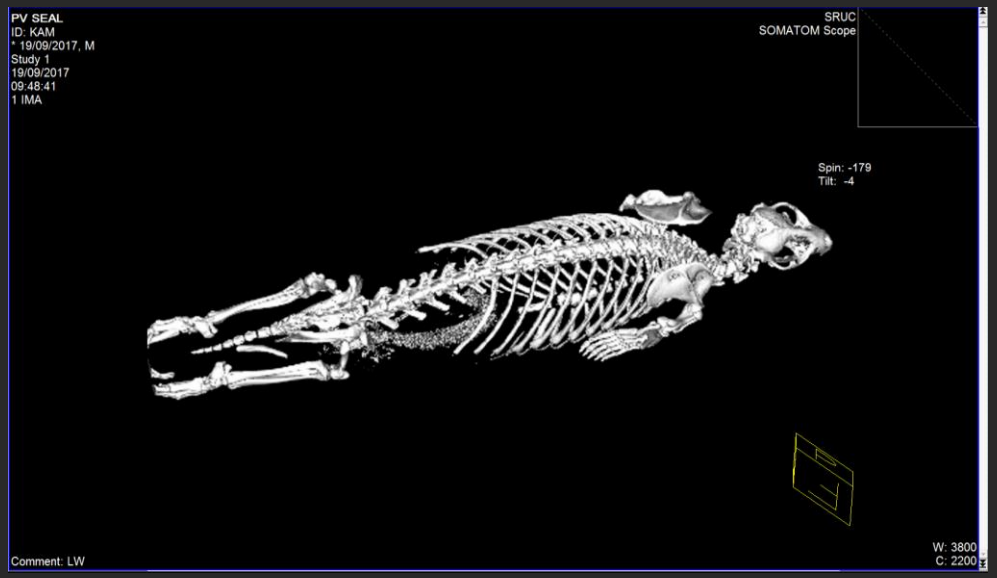



And now for something completely different....

Design concept



Pre-trial assessments



Trial set-up

Trial results

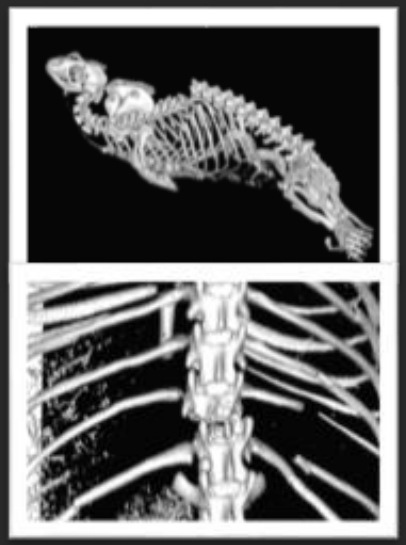
2016

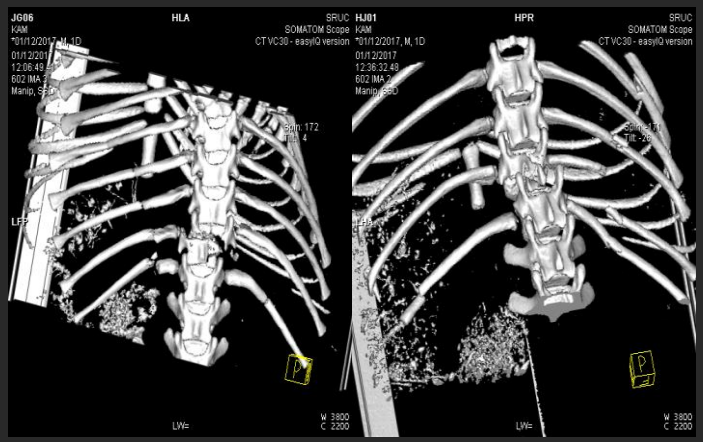
Seal ID	Seal Trial #	Collision Speed	Collision location
HJ05	1	18 Kn (9.26 $m.s^{-1}$)	Lower Jaw
	2	18 Kn (9.26 $m.s^{-1}$)	Thoracic Spine
HJ08	3	19.8 Kn (10.19 $m.s^{-1}$)	Cranium
	4	19.7 Kn (10.13 $m.s^{-1}$)	Ventral Thorax
JG10	5	19.6 Kn (10.08 $m.s^{-1}$)	Thoracic Spine
	6	19.5 Kn (10.03 $m.s^{-1}$)	Dorsal pelvic region
HJ07	7	19.5 Kn (10.03 $m.s^{-1}$)	Upper Ventral Thorax
	8	20.1 Kn (10.34 $m.s^{-1}$)	Cervical spine
	9	20 Kn (10.29 $m.s^{-1}$)	Thoracic Spine
HJ09	10	19.8 (10.19 $m.s^{-1}$)	Thoracic Spine
	11	19.4 Kn (9.98 $m.s^{-1}$)	Dorsal Pelvic Region

2017

Seal ID	Seal Trial #	Collision Speed	Collision location
TA04	1	9.5 Kn (4.89 $m.s^{-1}$)	Central Spine
	2	10.9 Kn (5.6 $m.s^{-1}$)	Missed
	3	10.2 Kn (5.25 $m.s^{-1}$)	Lower Pelvis
HJ02	4	10.7 Kn (5.5 $m.s^{-1}$)	Lower spine/Pelvis
	5	10.6 Kn (5.45 $m.s^{-1}$)	Central Spine
JG07	6	12.3 Kn (6.33 $m.s^{-1}$)	Central Spine
JG06	7	12.6 Kn (6.48 $m.s^{-1}$)	Lower Spine/Pelvis
TA03	8	11.8 Kn (6.07 $m.s^{-1}$)	Neck
	9	13.2 Kn (6.79 $m.s^{-1}$)	Pelvis
HJ01	10	15.9 Kn(8.18 $m.s^{-1}$)	Lower Spine/Pelvis
HJ03	11	13.8 Kn (7.1 $m.s^{-1}$)	Central Spine
	12	14.6 Kn (7.51 $m.s^{-1}$)	Neck/Shoulders
JG03	13	10.9 Kn (5.61 $m.s^{-1}$)	Lower spine/Pelvis
	14	10.3 Kn (5.3 $m.s^{-1}$)	Neck/Shoulders
Pv	15	16.4 Kn (8.44 $m.s^{-1}$)	Central Spine
	16	15.6 Kn (8.03 $m.s^{-1}$)	Pelvis
	17	15.5 Kn (7.97 $m.s^{-1}$)	Head

Pathology

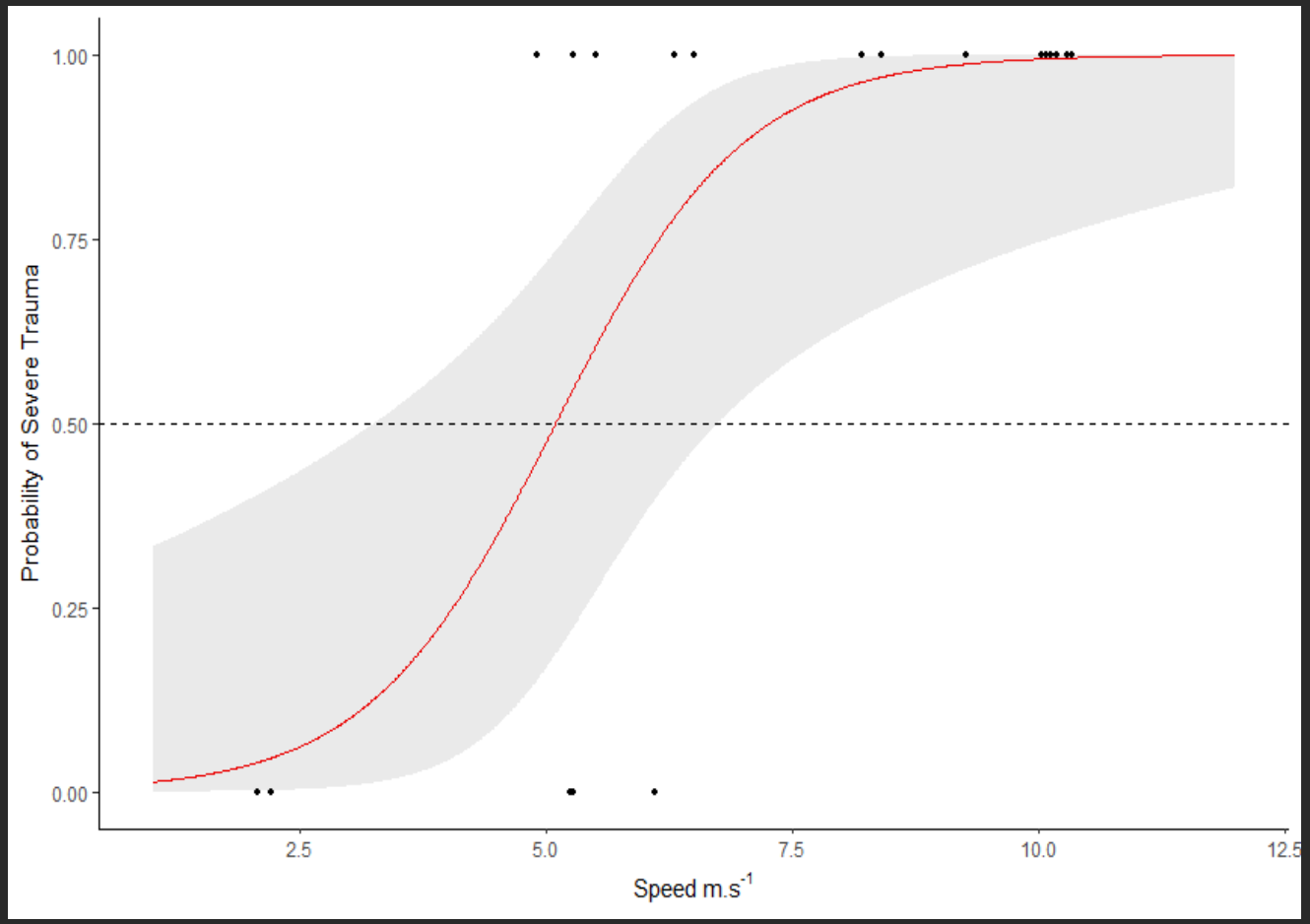



JG06
KAM
HLA
SRUC
SOMATOM Scope
CT VC30 - easyIQ version
HJ01
HPR
W 3800
C 2200

Damage inflicted

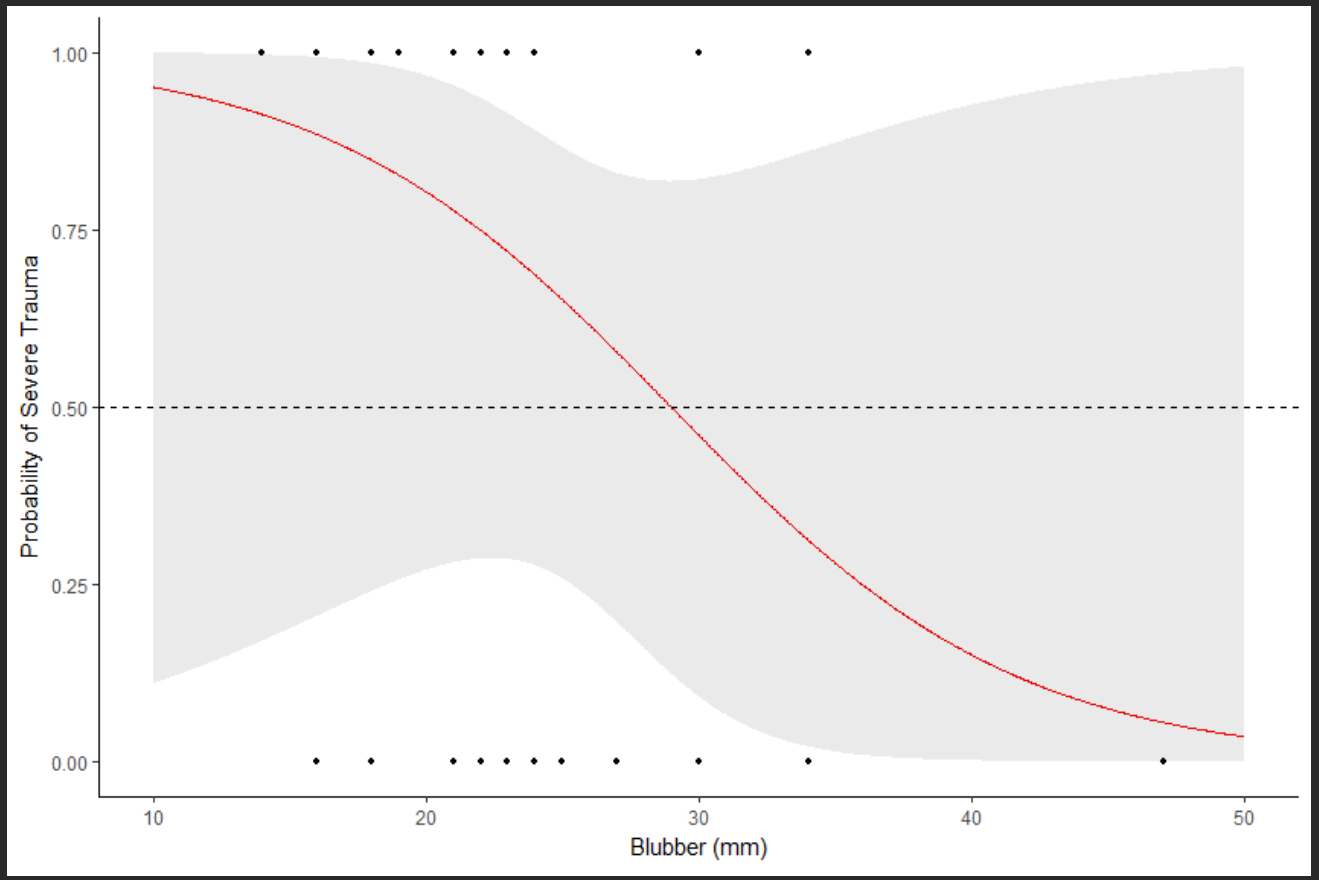
Seal ID	Mean Collision Speed ($m.s^{-1}$)	Diaphrag-matic Rupture	Spinal Fracture	Fractured Rib(s)	Liver Rupture	Liver Herniation	Pulmonary Rupture	Cardiac Rupture
HgB	2.1							
HgA	2.4							
TA04	5.2							
HgC	5.25							
HJ02	5.5							
JG03	5.5		■					
JG07	6.3		■					
JG06	6.5		■	■				
TA03	6.5			■				
HJ03	7.3		■					
PvDV	8.1	■	■	■	■	■	■	■
HJ01	8.2	■	■	■	■			
HJ05	9.26	■	■	■	■			
JG10	10		■				■	
HJ09	10.1	■	■	■	■	■		
HJ08	10.2	■	■	■		■		
HJ07	10.2	■	■		■	■		

Predictions



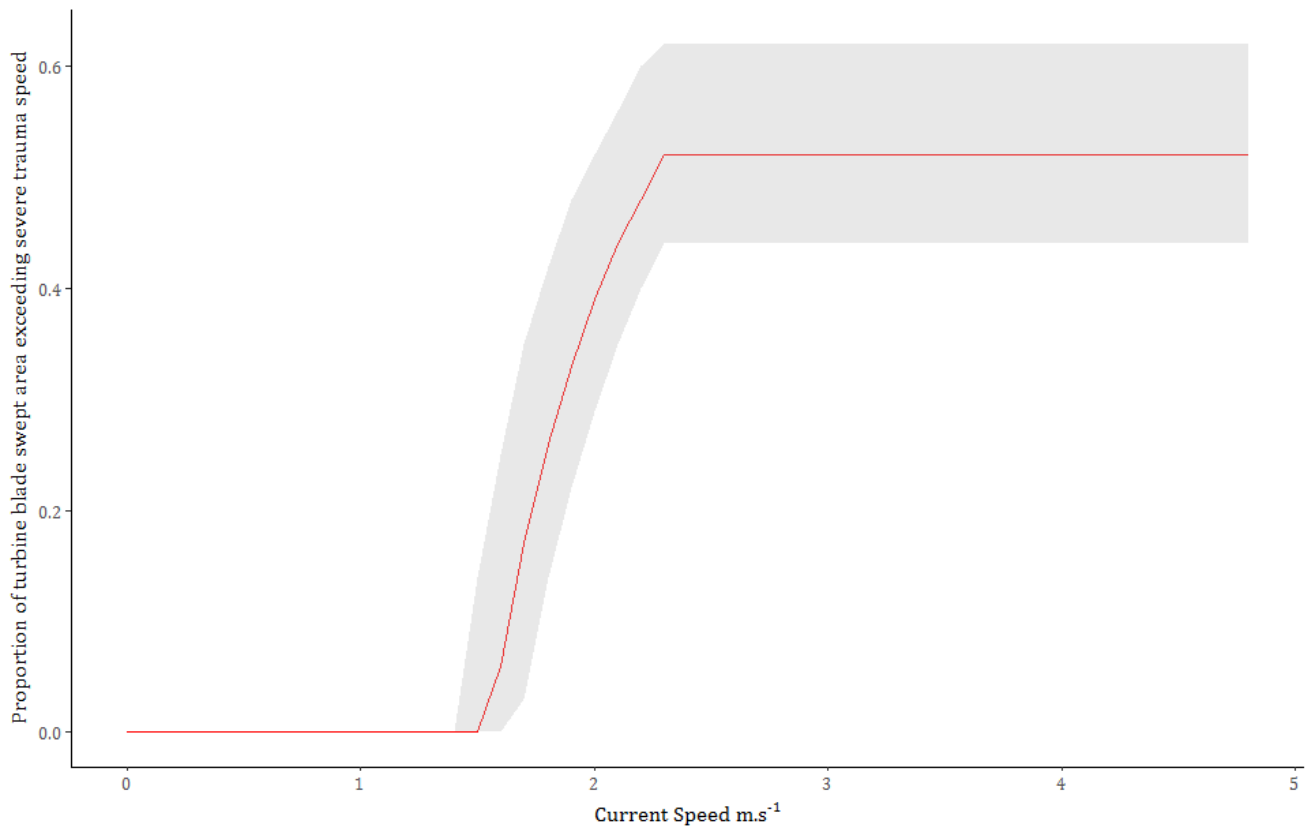
Point estimate of likelihood of severe trauma being greater than a benign impact at 5.1 $m.s^{-1}$

Predictions



Seems fitness of the seal may play a role in their ability to withstand trauma however signal too weak to say for certain…

Predictions

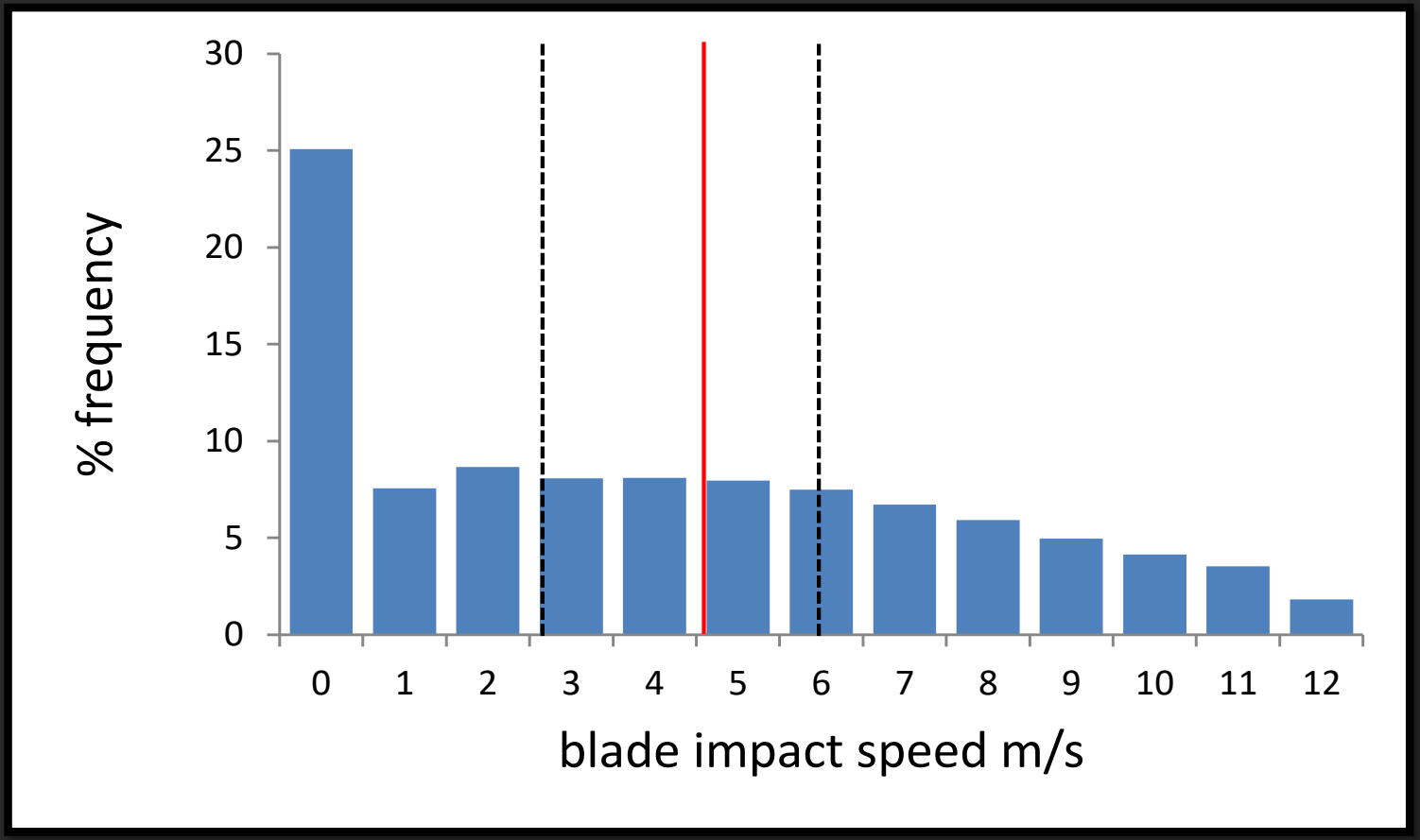


Proportion of a blade swept area estimated to cause severe trauma. Maximum proportion reaches asymptote at ~0.5.

This highlights the requirement for adjustment to various devices and environments.

Implications

Threshold for severe skeletal trauma suggests that at least 39% of collisions would be fatal



Summary

- Collisions between seals and tidal turbines can be lethal
  - The speeds at which fatality is guaranteed are not likely to be enduring over a typical tidal cycle

- We can use these data to refine collision risk models to identify the population level consequences of direct interactions with tidal turbines

- A better understanding of less dramatic injuries are required to provide a more robust estimate.

- Need to resolve the issue of concussion