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# Impact Assessment: Predictive Modelling of Collision Risk

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# Collision Risk

- How often will animals **collide with** turbines?
  - Use Encounter Models adapted from behavioural ecology to predict encounter rate **Z**
- But animals may detect and avoid encounter (at some distance), evade collision (at close range) or even be attracted
- Is the passive encounter rate sufficient to have to consider animal behaviour?
- Can we **predict avoidance A** and **evasion E**?
- **Collision Rate = Z (1-E) (1-A)**

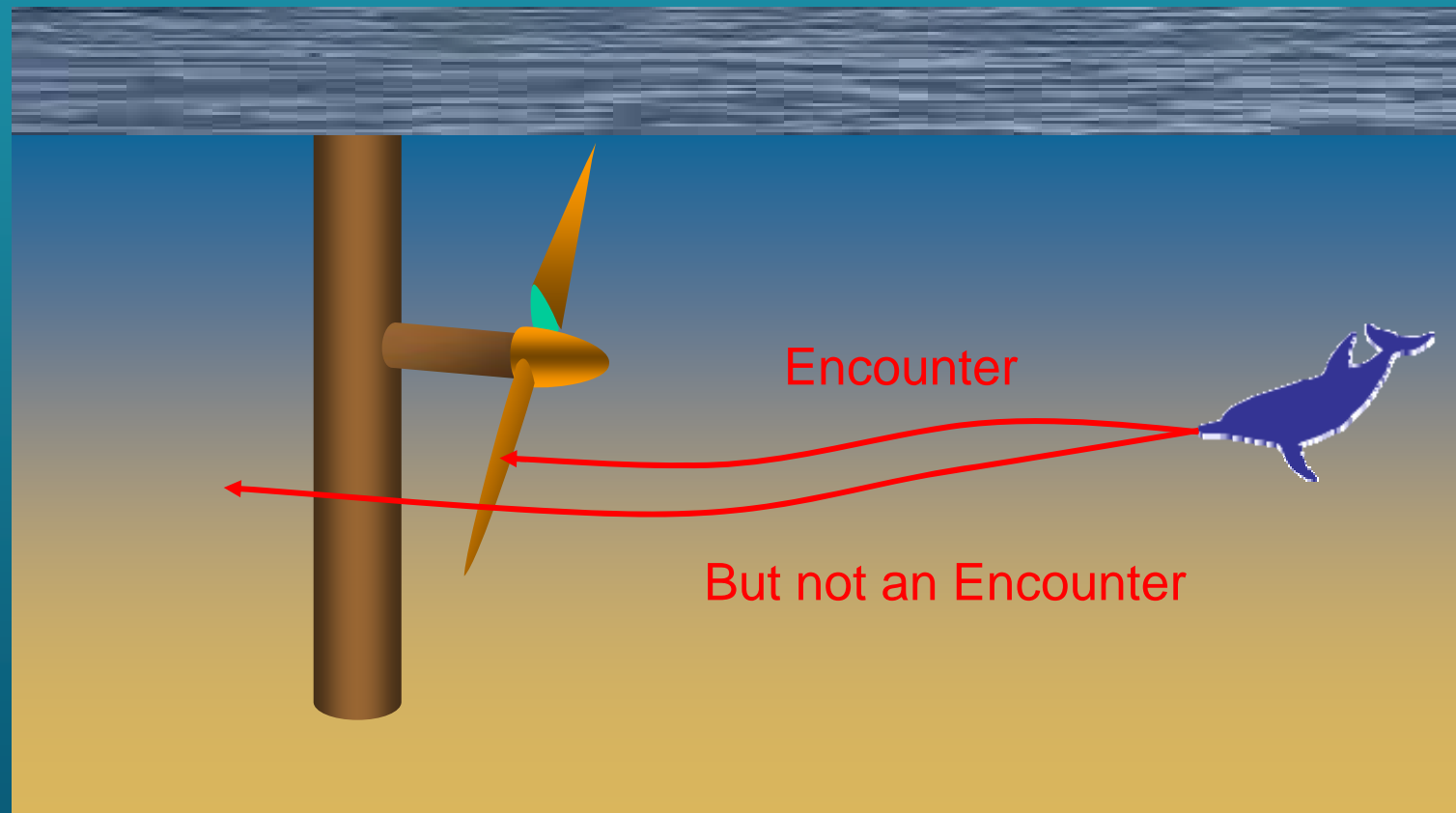


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# Encounter



At SAMS, encounter models developed for behavioural ecology have been adapted to predict encounter rates between animals and turbines.



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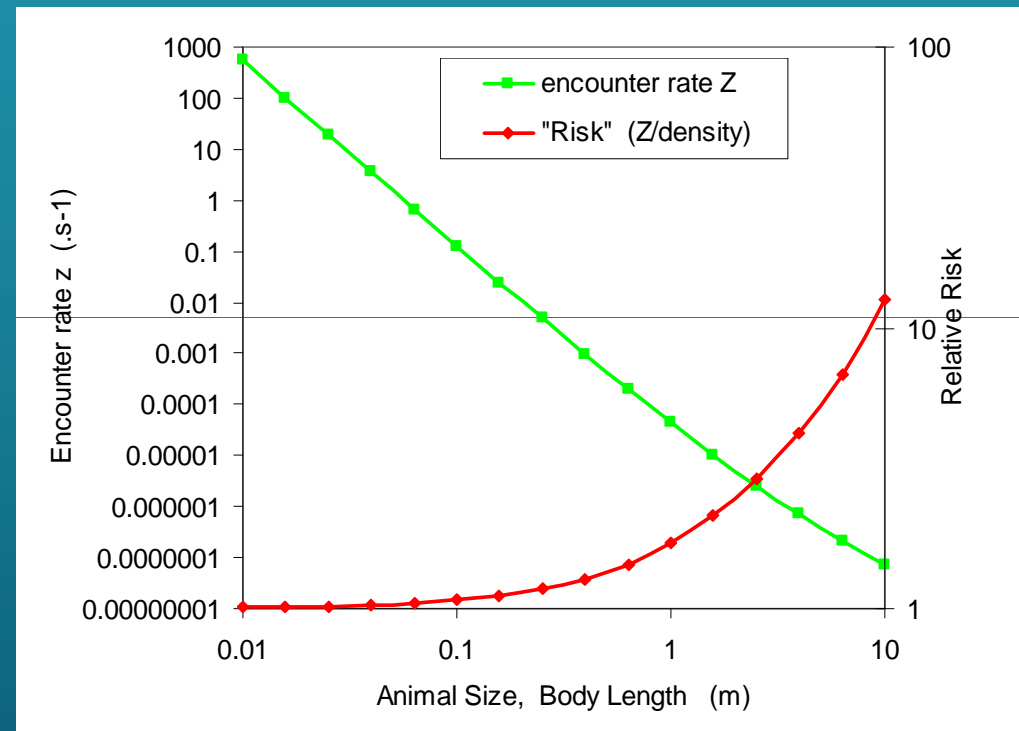


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# Encounter Rate/Risk and Animal Size

Expected encounter rate declines with increasing body size – fewer larger animals.

But as a proportion of the population encounters are much greater: a relative “Risk” estimate.



100 turbines 20 m in diameter to the west of Scotland could result in encounters with 2% of the herring population and 10% of the harbour porpoise population per annum.

Real values will be less due to **AVOIDANCE** or greater due to **ATTRACTION** And **EVASION** will reduce collisions during encounters.

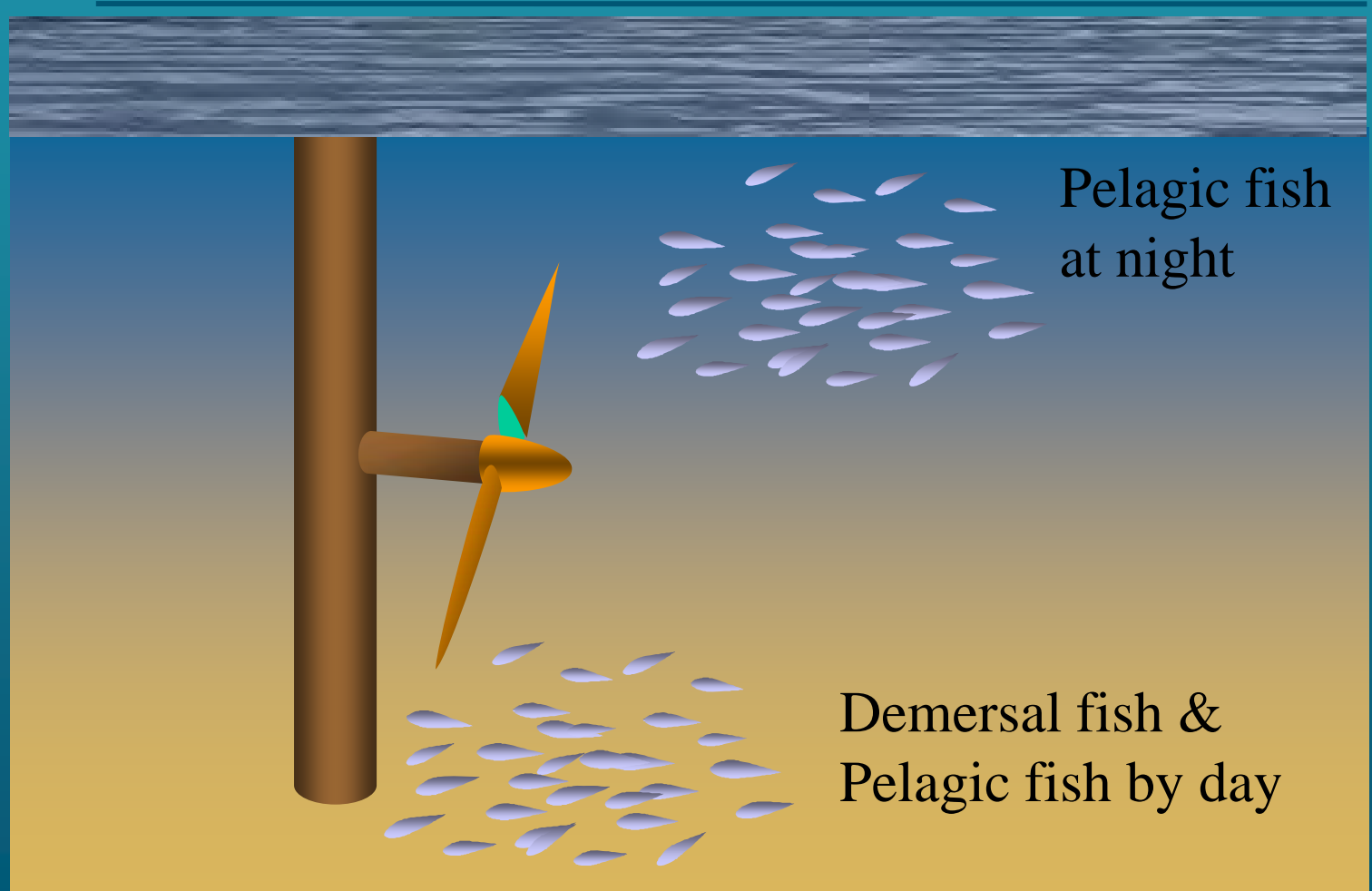


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# Considering Depth Distribution of Marine Animals



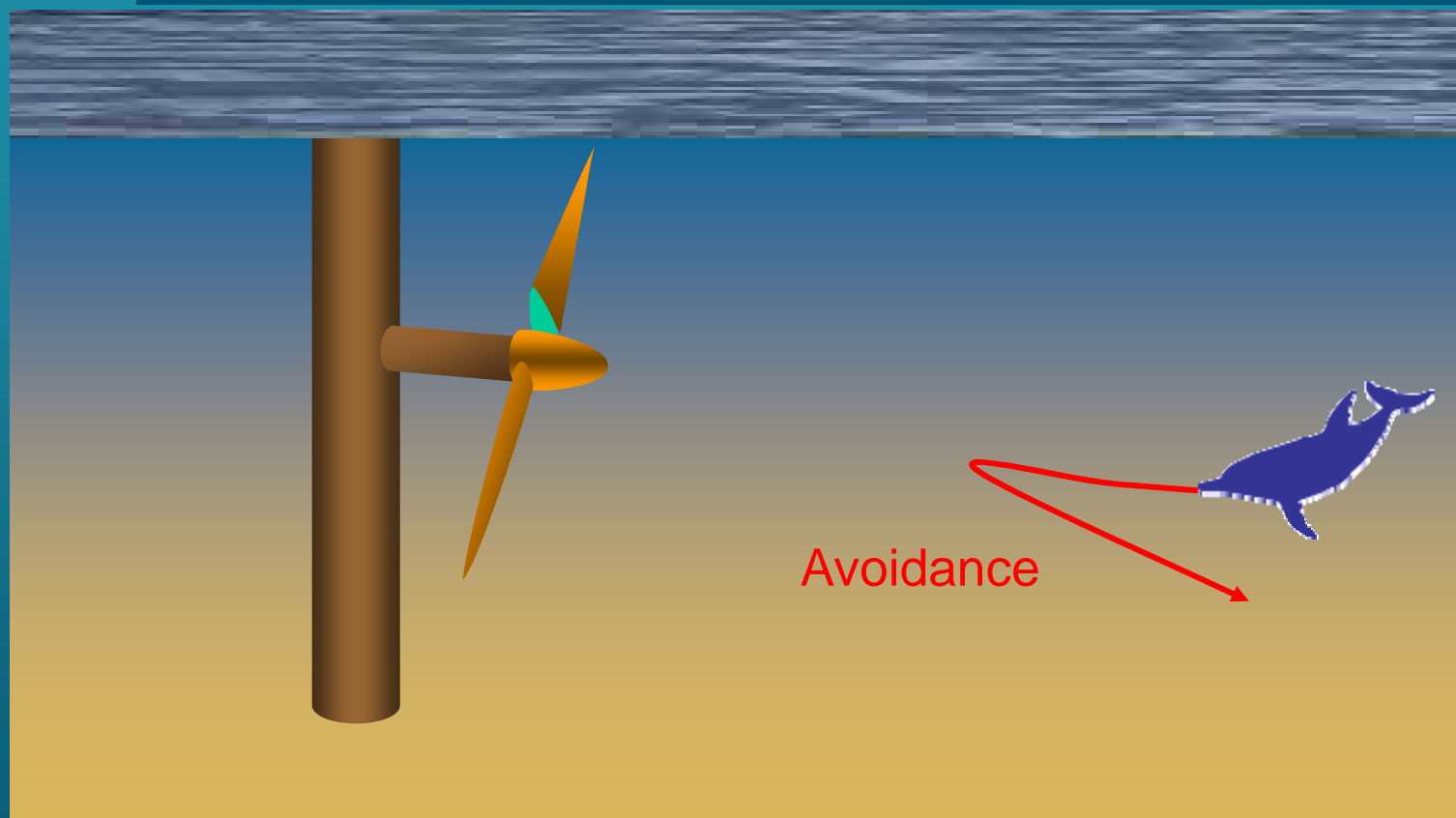


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# Avoidance



SAMS has developed an acoustic detection model to predict the distance upstream at which species may detect a device above background noise levels and also developed equipment to measure background noise level.

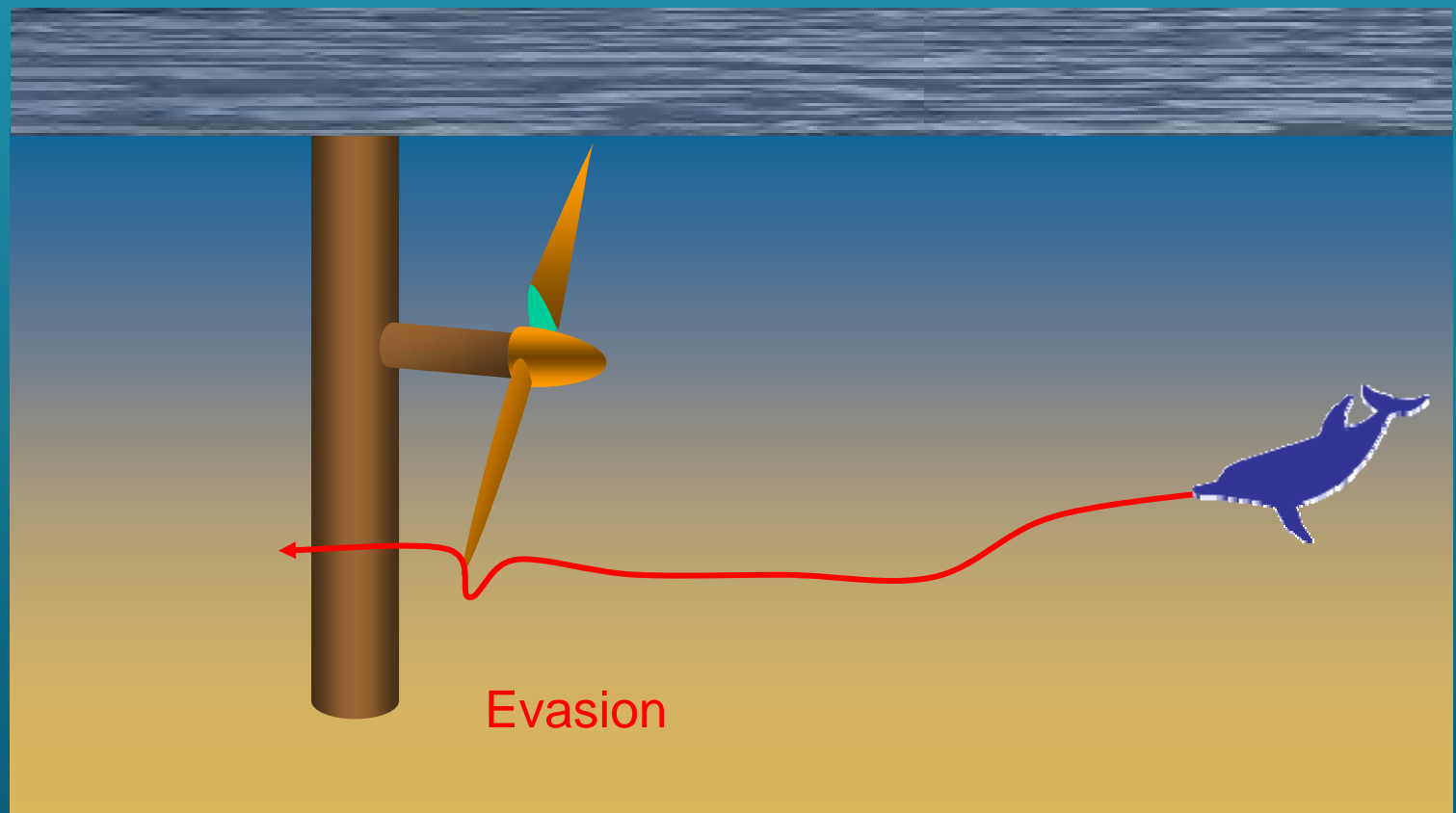


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# Evasion



A visual stimulus evasion model has been developed at SAMS for fish. An acoustic model can be developed. Both may be extended to include mammals.



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# Collision Evasion Visual Looming Objects

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Detection.

When the looming rate exceeds a threshold, animals make an escape response.

Looming rate depends on size and velocity and increases as the object gets nearer.

Fish anti-predator behaviour research is being applied to develop a model to understand and predict collision evasion.



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# Evasion - Visual Response

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- Ability to evade collision depends on:
  - Looming rate of turbine blade and True Looming Threshold (TLT)
  - Latency
  - C-start escape orientation distribution
  - Burst swimming performance
    - animal length
    - temperature (for fish and invertebrates only)



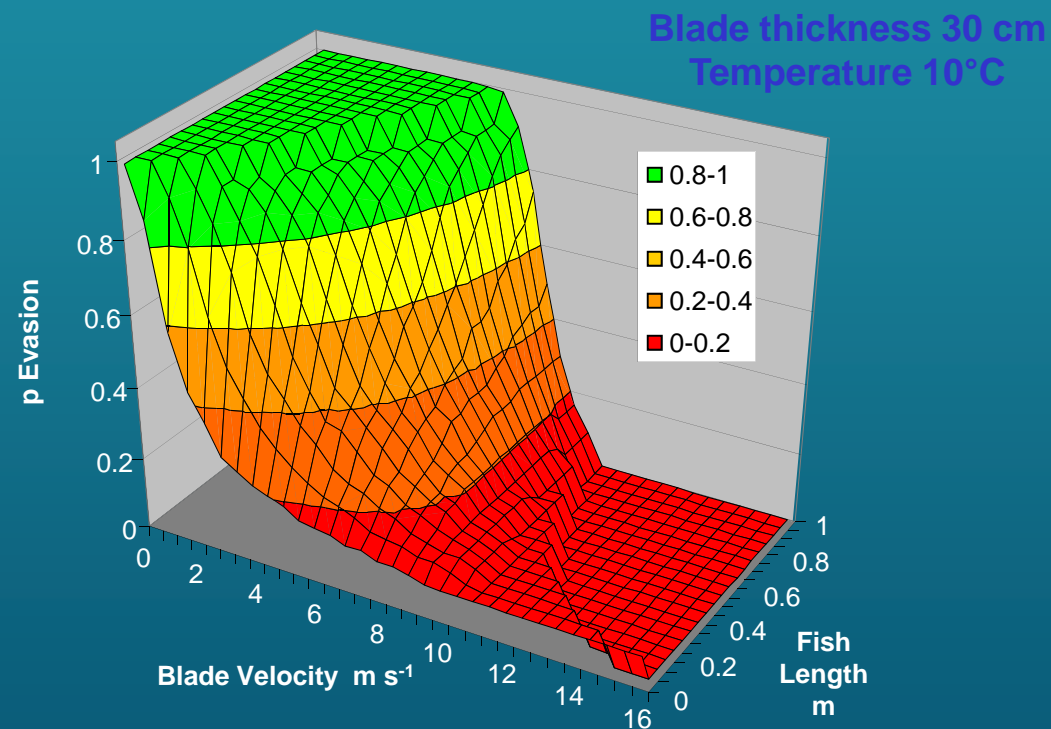
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# Evasion - Visual Response

## The Effect of Fish Size on evasion



Evasion depends on fish size, temperature and blade thickness.  
Evasion by fish and invertebrates less likely at lower temperature  
– a seasonal and location effect.



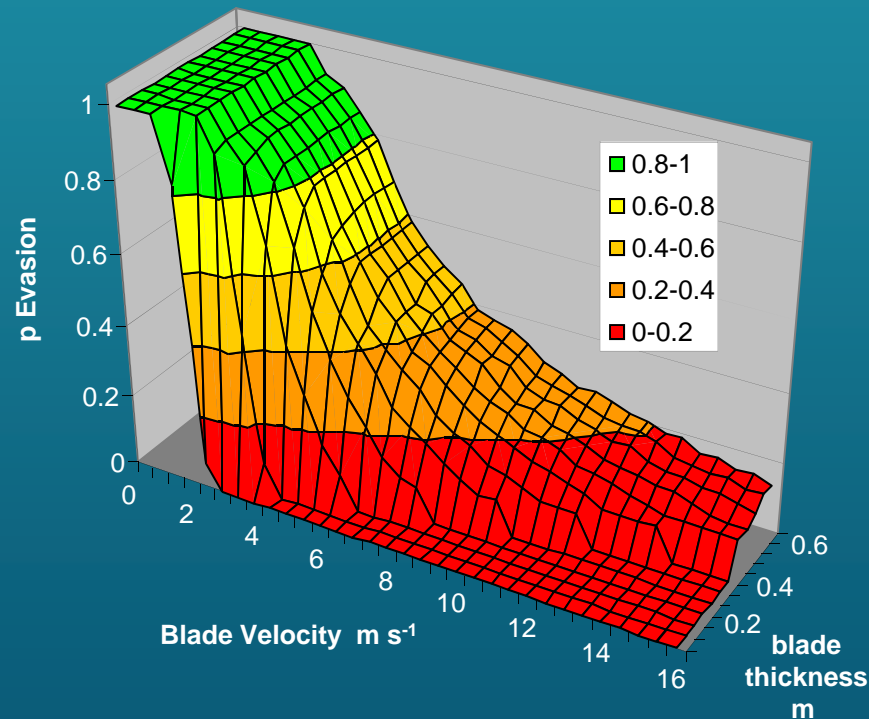
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# Blade Thickness and Velocity

For a fish with a total length of 30 cm at 10°C



but thinner blades are not better!

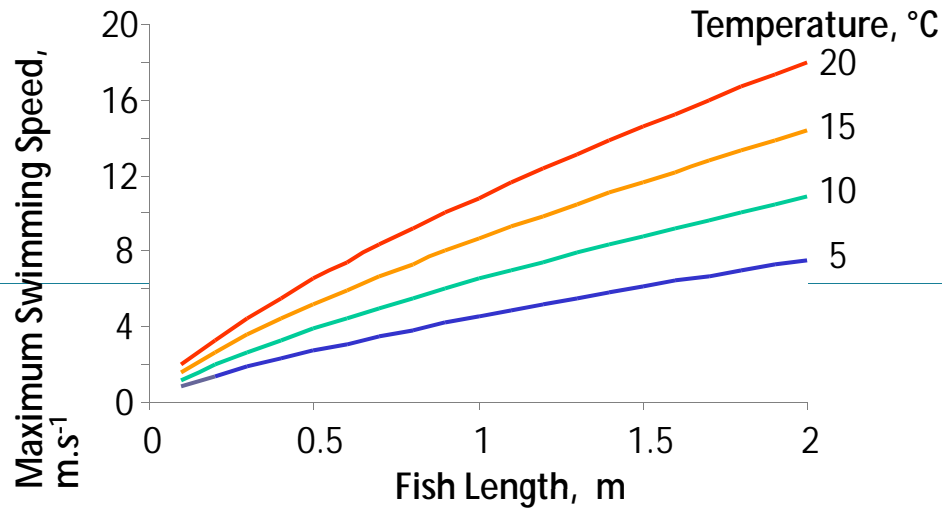


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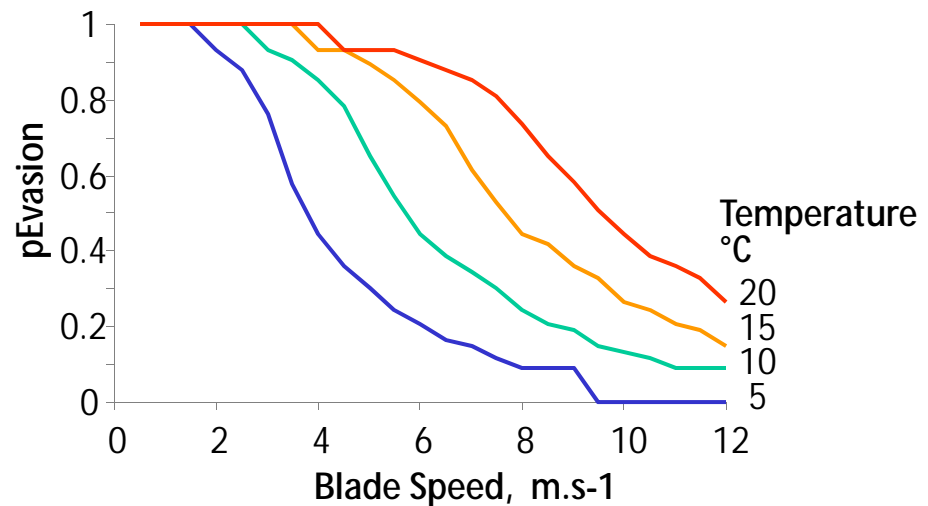
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# Fish Maximum Escape Speed and Temperature



Maximum swimming speed is temperature dependent.

The Probability of Evasion is, therefore, strongly influenced by water temperature.





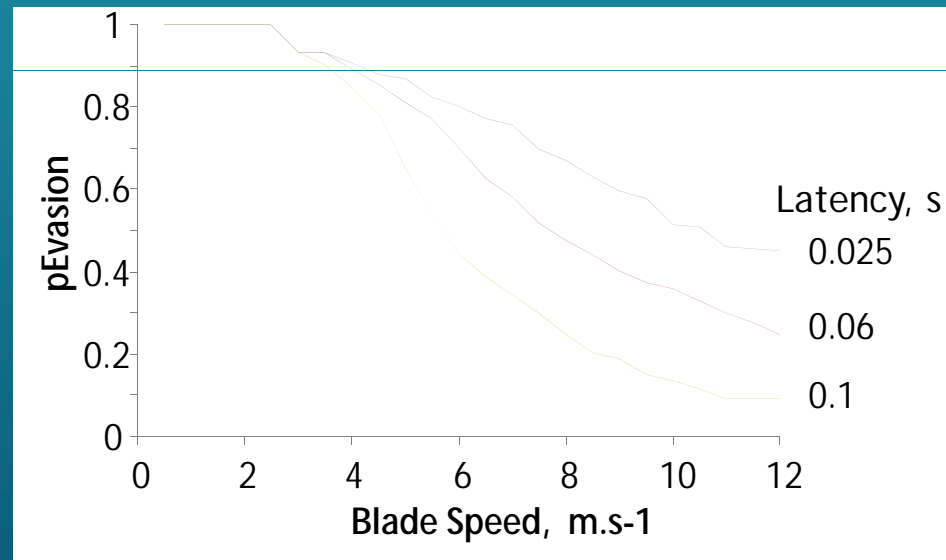
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# Effect of Response Latency

The problem with thin blades is that fish just can't react fast enough. Looming threshold will only be exceeded at close range with insufficient time to react.



Latency to sound stimuli are shorter: as little as 25 ms.  
Performance may be better with transient sounds.



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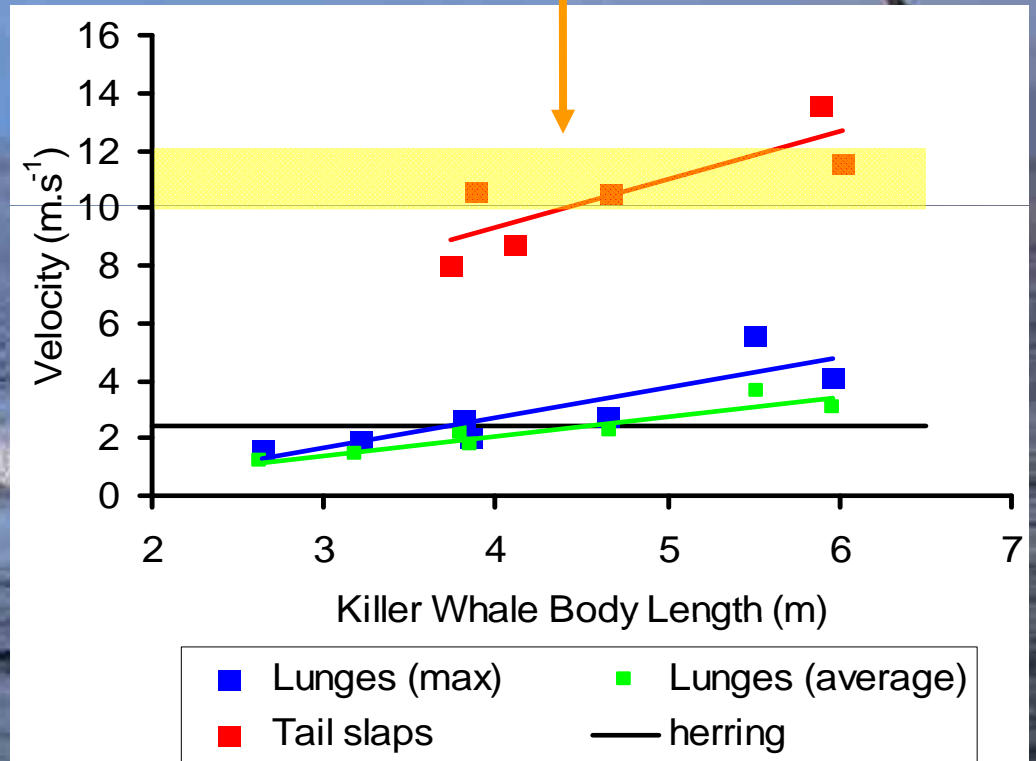
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# Killer Whale “Carousel feeding” on herring Fits model predictions well

Domenici, Batty, Simila, Ogam (2000). *Journal of Experimental Biology*, **203**, 283-294.



Maximum blade velocity



Evasion not possible at similar fluke velocities to  
maximum turbine blade tip velocities of some turbines



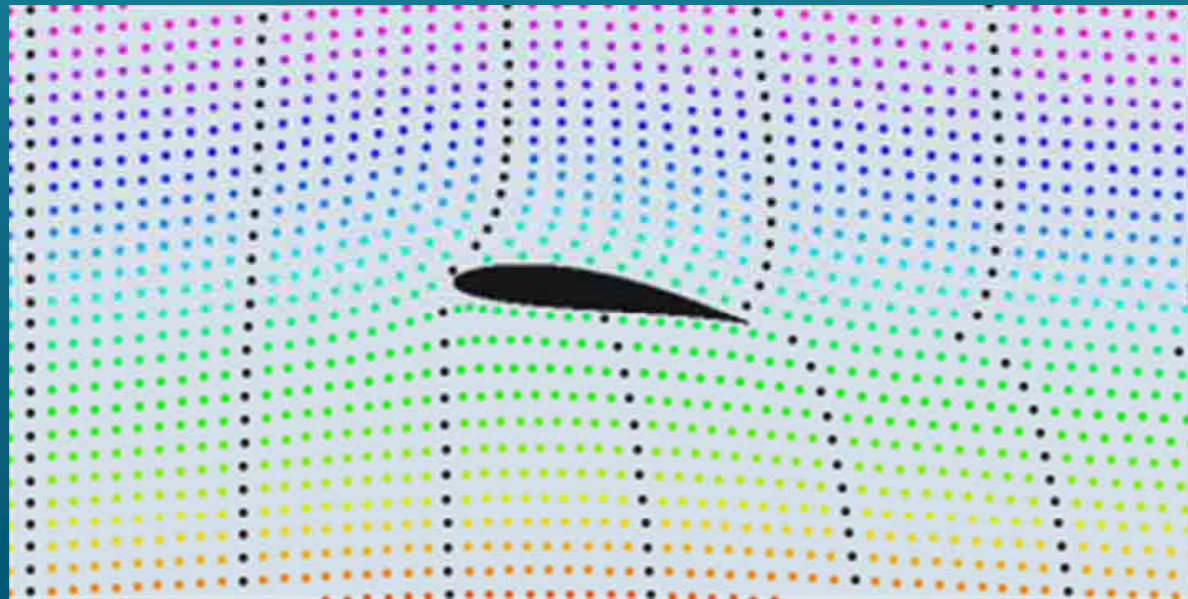
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# Pressures Around Turbine Blade Surfaces

- Can the increasing pressure ahead of a turbine blade be detected as a transient pulse of sound?
- Fish respond to the leading edge of low frequency transient sounds.
- They respond to the “bow wave” of an approaching predator.



Kraaiennest - Wikipedia



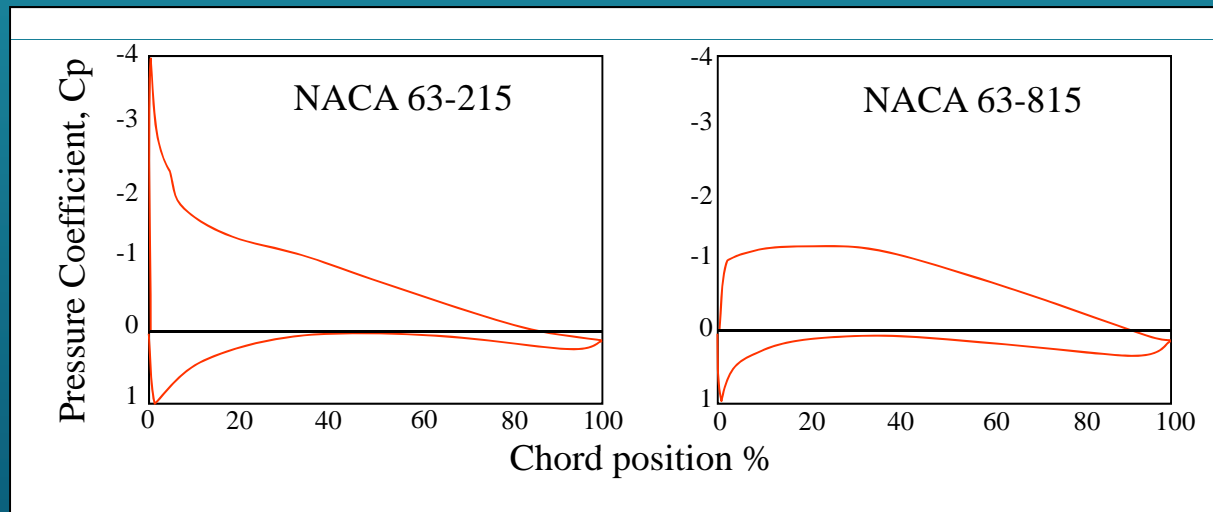
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# Pressures on Turbine Blade Surfaces

Pressure coefficient  $C_p = \frac{p - p_\infty}{1/2 \rho_\infty V_\infty^2}$



after Batten *et al* Renewable Energy 31 (2006) 249-256



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# Pressures...

	Pressure Coefficient	Velocity  m s <sup>-1</sup>	Pressure Difference		Rise time	frequency
			Pa	dB		
lethal			275000	229	<1 ms	
burst herring bulla			300000	230	<1 s	
escape response threshold			7	137		>50 Hz
NACA 63-215 upper surface	-4	12	-295200	229		
NACA 63-215 lower surface	1	12	73800	217		
NACA 63-815 upper surface	-1.2	12	-88560	219		
NACA 63-815 lower surface	1	12	73800	217		



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# Further Issues to Consider

Scale, including:  
Schooling



Device  
Arrays  
vs.  
single  
installations

Constrained  
areas

