Association of Tissue Damage Assessment in Fish from Underwater Noise

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DOE MHK Webinar – Acoustic Impacts
December 14, 2011

Underwater Noise - Anthropogenic

Impulsive Sounds

- Pile driving
- Seismic exploration
- Explosions

Intermittent and Continuous Sounds

- Low- and mid-frequency sonar
- Shipping
- Wave turbines
- Tidal turbines
- Wind farms

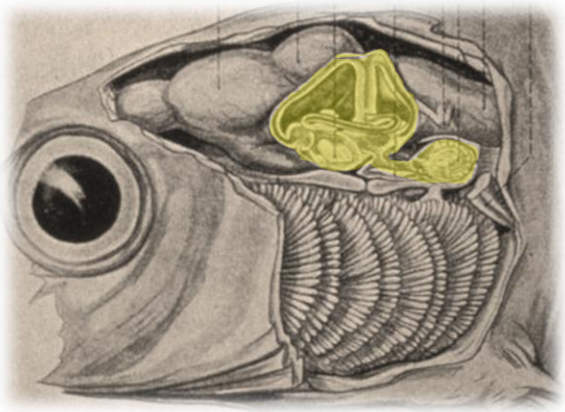
Underwater Noise - Components

- Sound is energy that can do work – thus, it can cause damage
  - Frequency
  - Intensity
  - Spectrum
- Two components of any sound wave
  - Pressure (in air and in water)
  - Particle motion (most notably in water)
- Near field (pressure & particle motion)
- Far field (mostly pressure, but some motion)

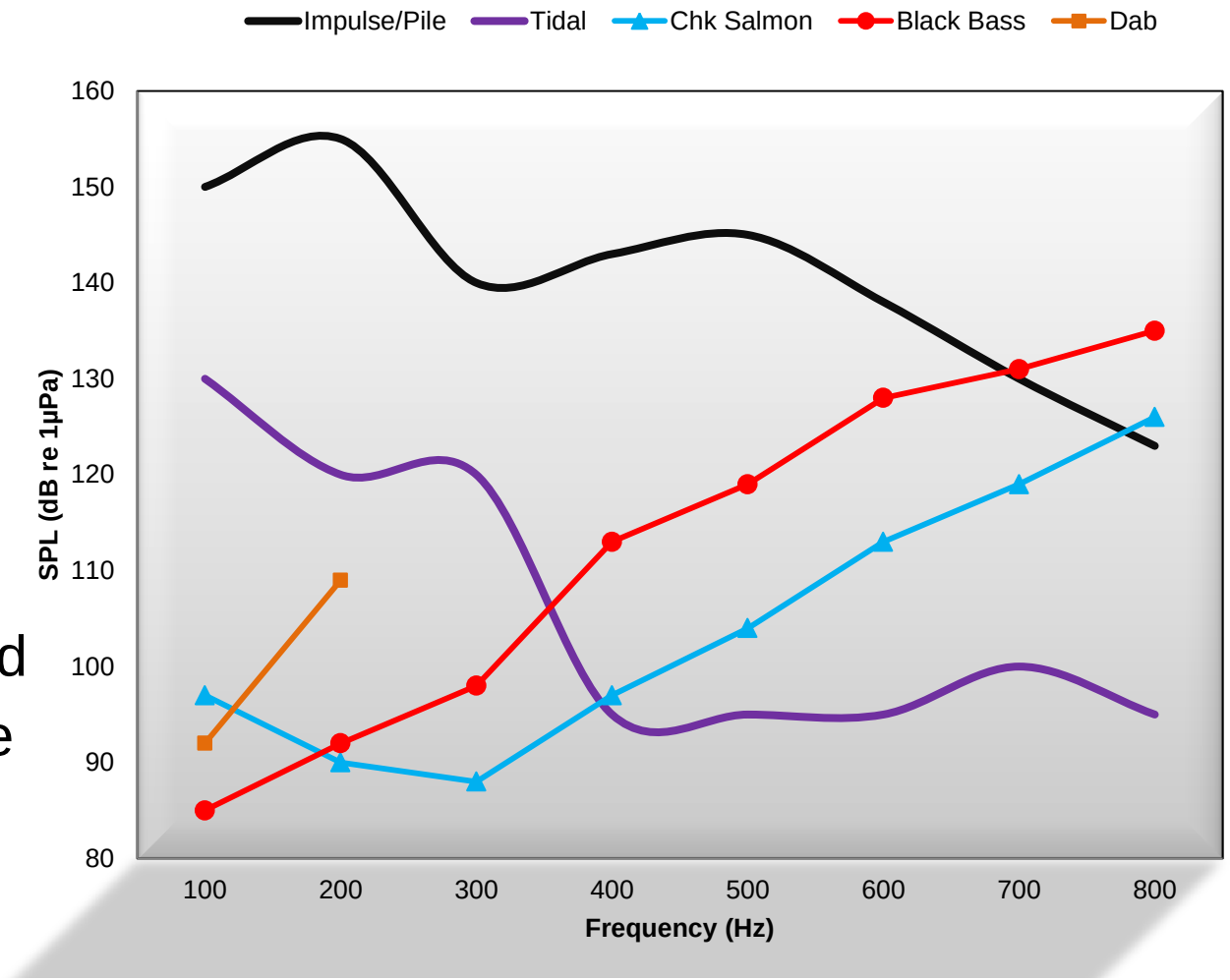
Underwater Noise Effects

- Concerns from renewable energy development in marine environments
  - Concerns include impacts on fish
  - Typical assessments are
    - Auditory
    - Barotrauma

Underwater Noise Effects - Auditory



- Auditory
  - Changes in hearing threshold
  - Hair cell damage



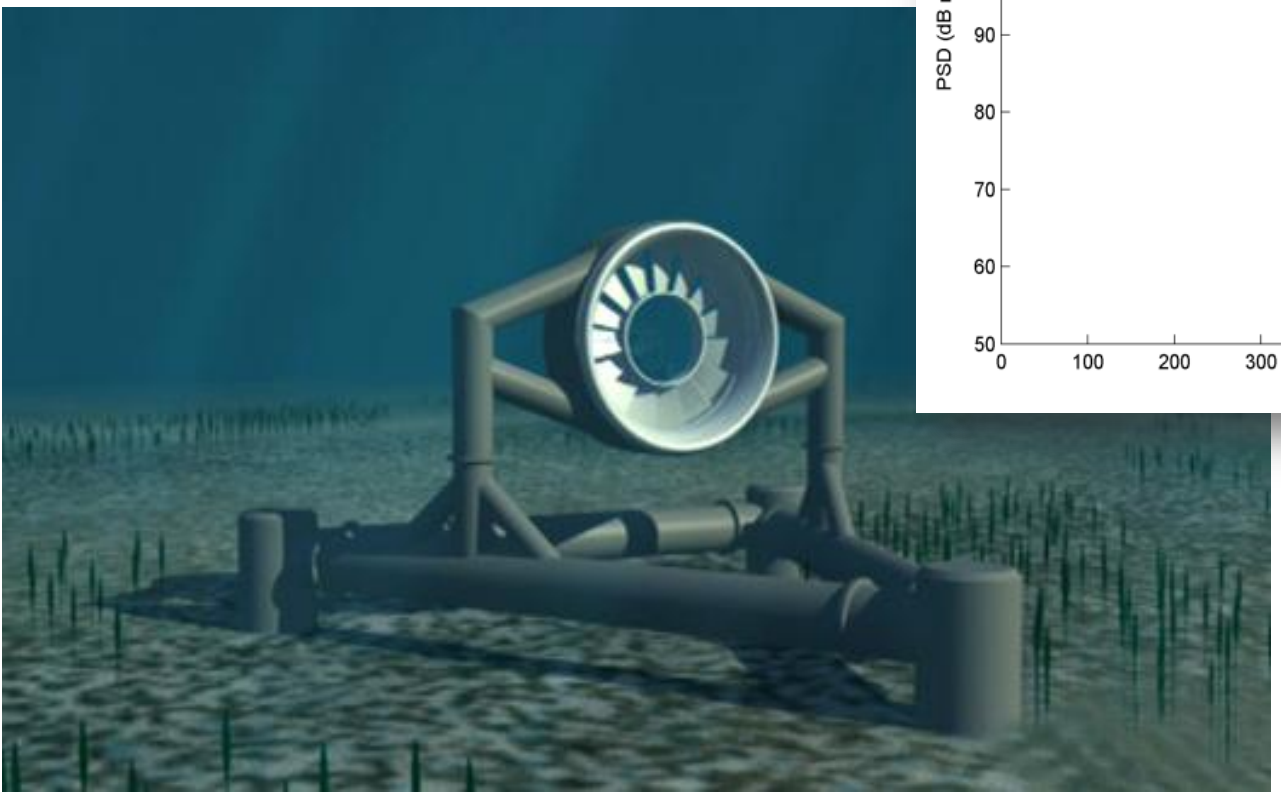
Salmon: Halvorsen et.al., 2009; Bass: Holt et.al., 2010;
Dab: Chapman & Sand 1973; Karl von Frisch- ear

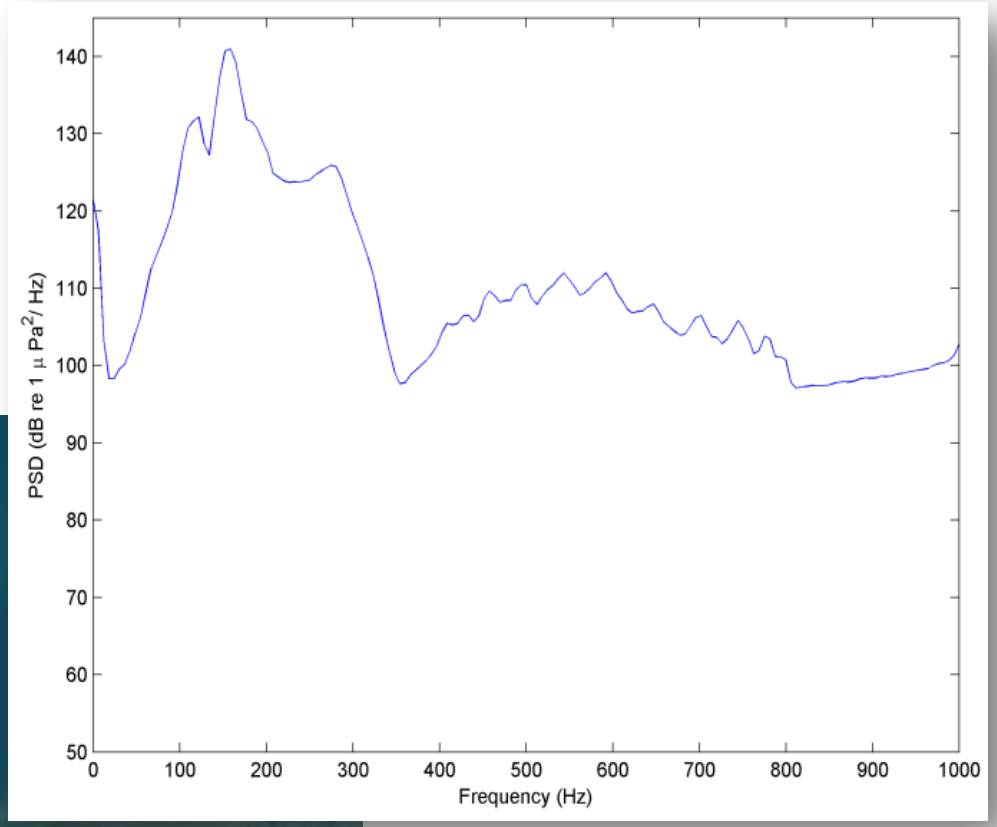
Underwater Noise Effects - Barotrauma

- Contraction and expansion of free gas in body
- Change in state of gas from soluble to free-form
- Swim bladder – (buoyancy state, hearing)
  - Rupture
  - Damage surrounding tissues
- Natural blood-gases
  - Solubility changes
  - Gas comes out of solution
    - Bubbles form in blood and tissues
    - Damage to tissues, vessels, organs
- Equilibration state is very important
  - Neutrally buoyant fish
  - Tissue-gas equilibration with surrounding water
  - Physiological state of fish at exposure is critical
    - Must mimic state of wild fish

Tidal Turbine Exposure

- Tidal Power
  - Continuous noise exposure
  - Physiological response of fish to sound exposure





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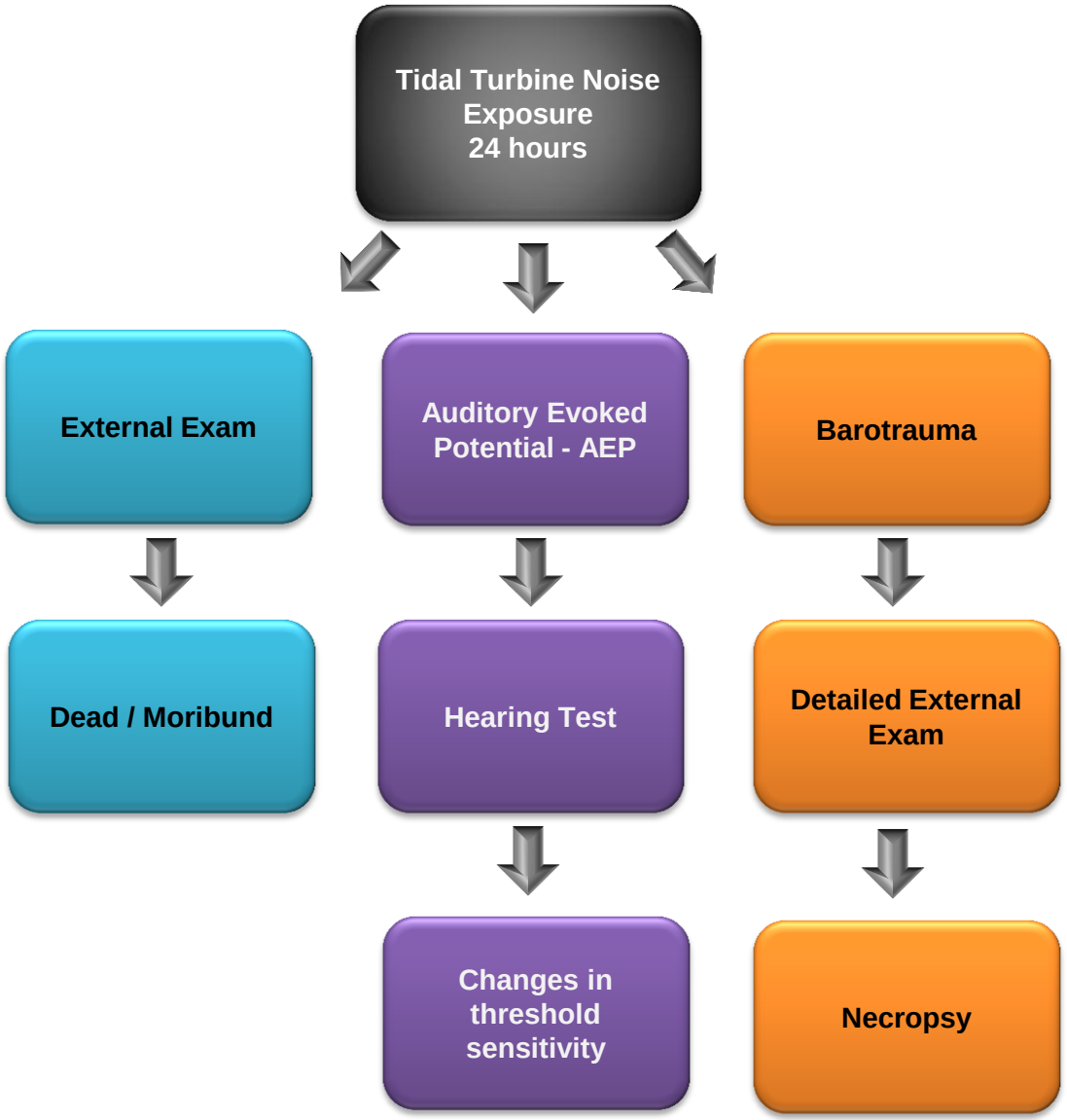
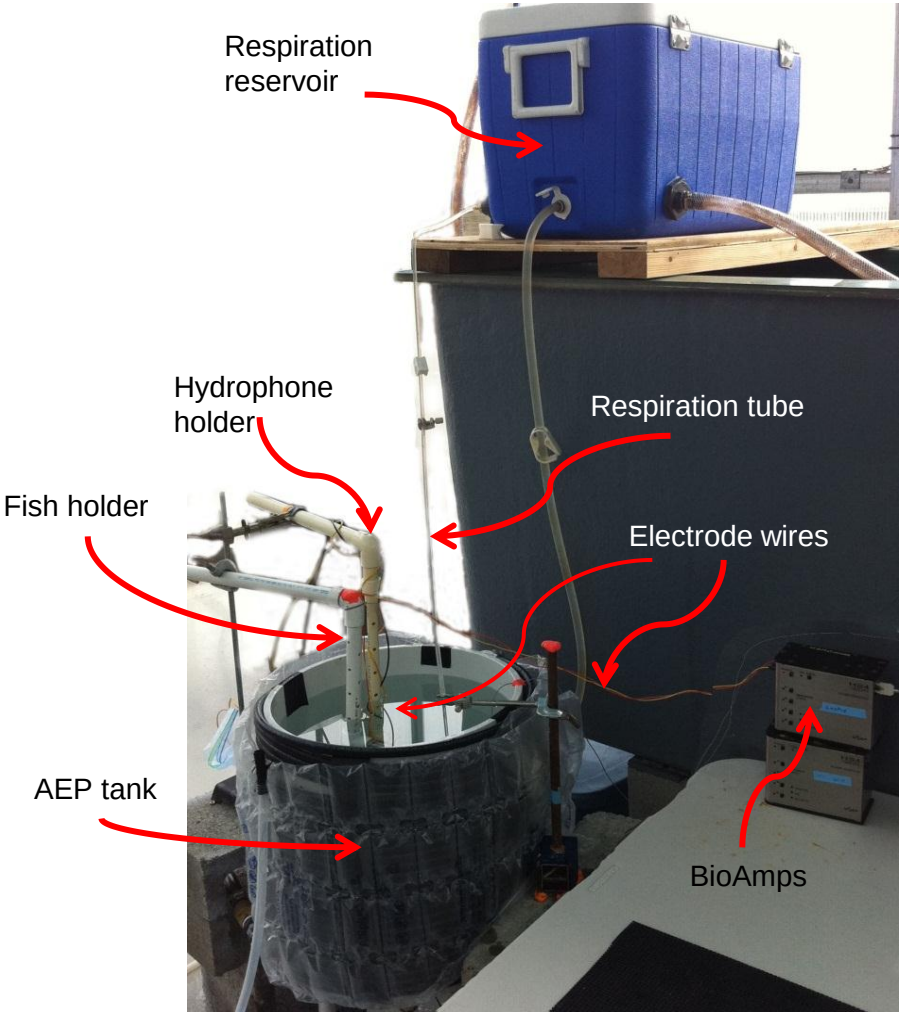
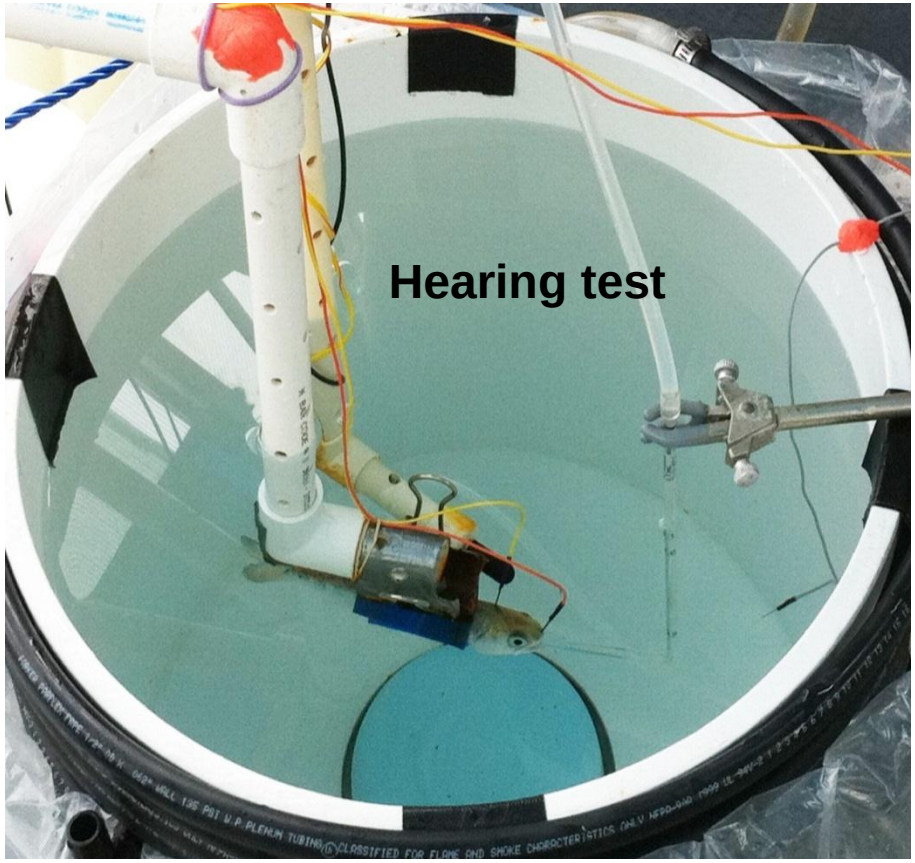
Tidal Turbine – Exposure Response

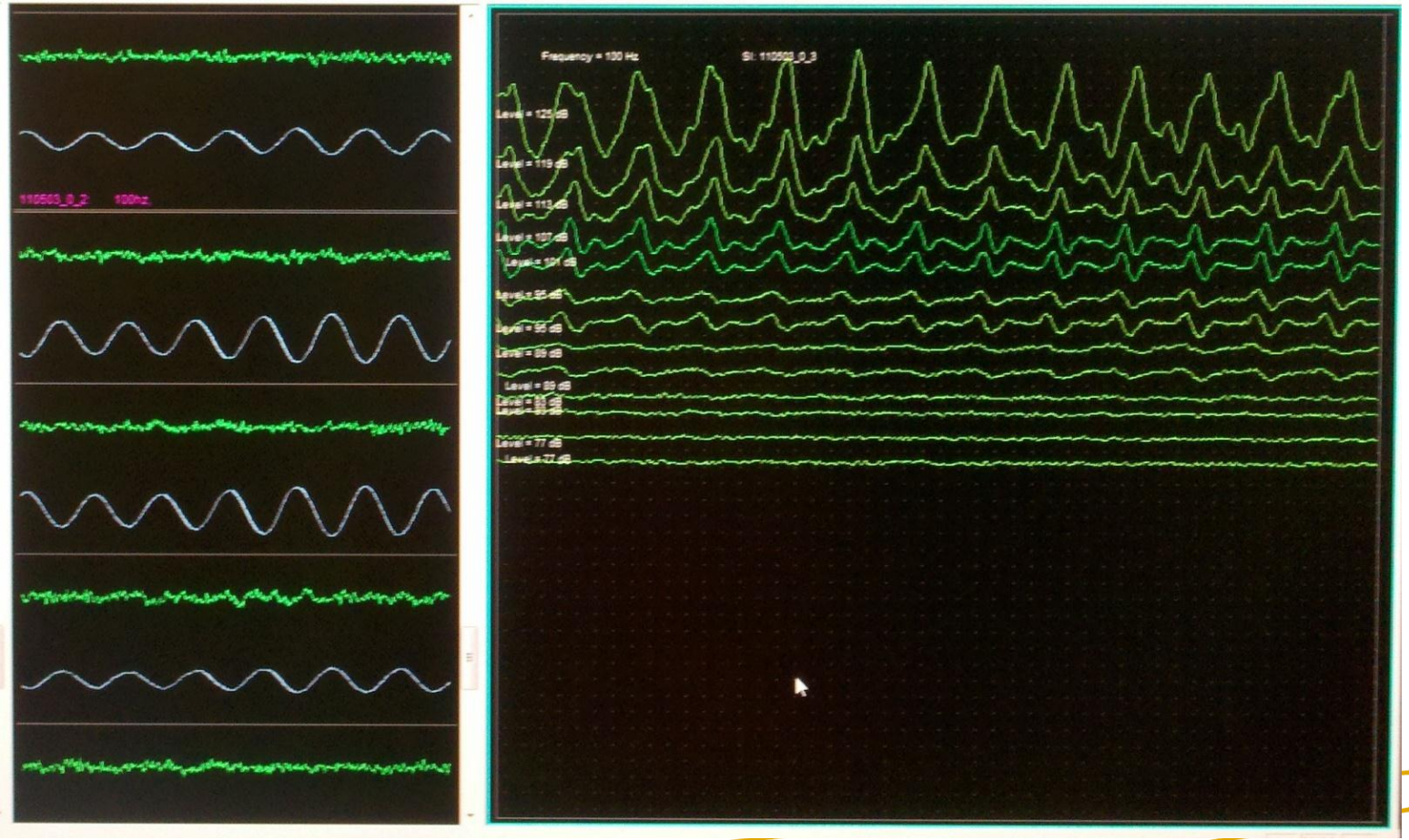


Tidal Turbine- Hearing Tests

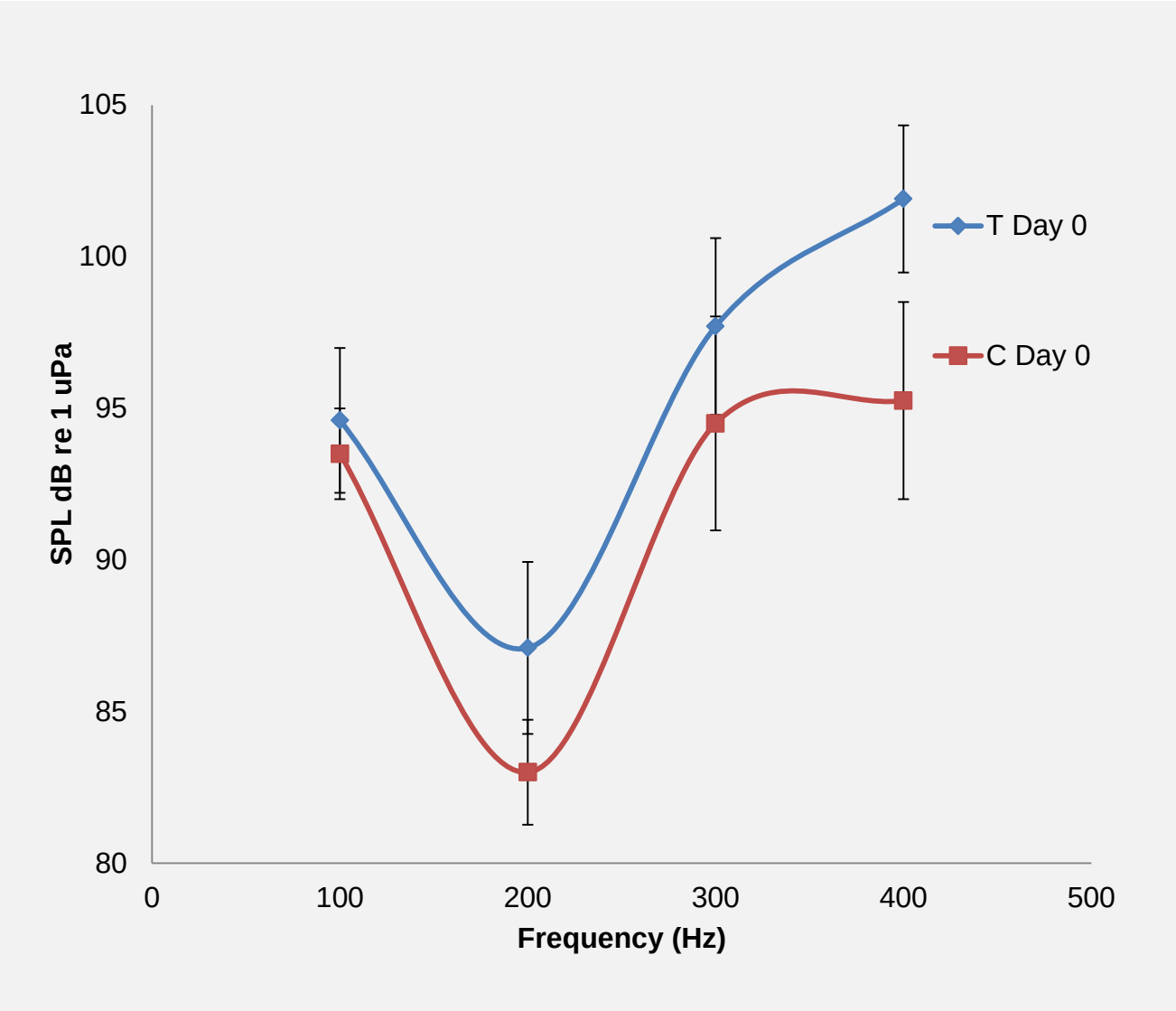




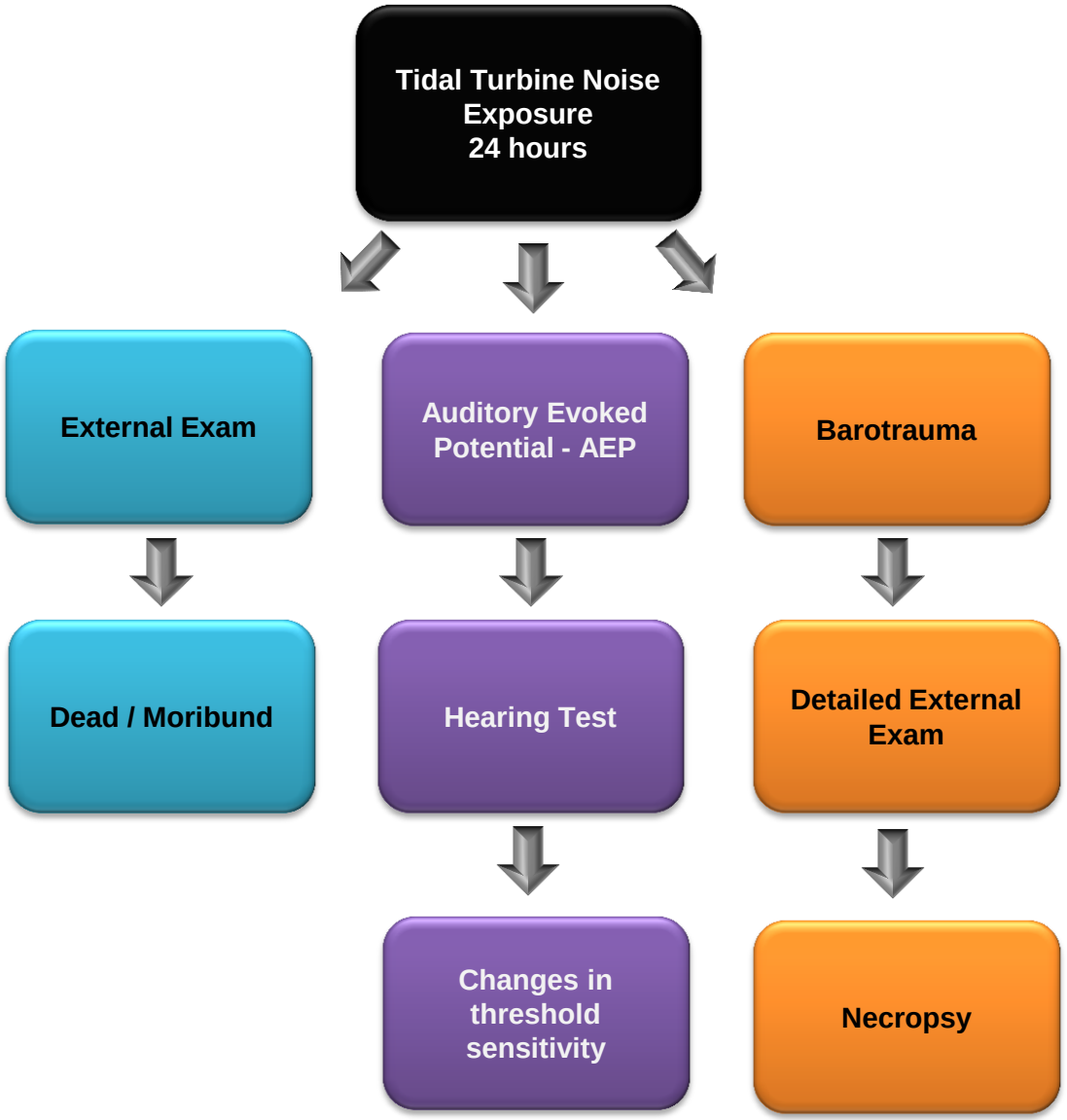
Tidal Turbine- Auditory Evoked Potentials



Tidal Turbine – Hearing Results



Tidal Turbine – Exposure Response



Barotrauma Exposure Response

- Barotrauma
  - Used panel of 72 injuries
  - Assessment of the biological effects
  - Quantifies a qualitative assessment
  - Addresses ‘meaning’ of injuries

- Fish Index Trauma (FIT Model)

what does ‘x’ number of injuries mean to fish?

Barotrauma Effects Response Model

Fish Index Trauma - FIT

Response Severity Weighted Index (RSWI)

$$RSWI = \sum (W \times T_i)$$

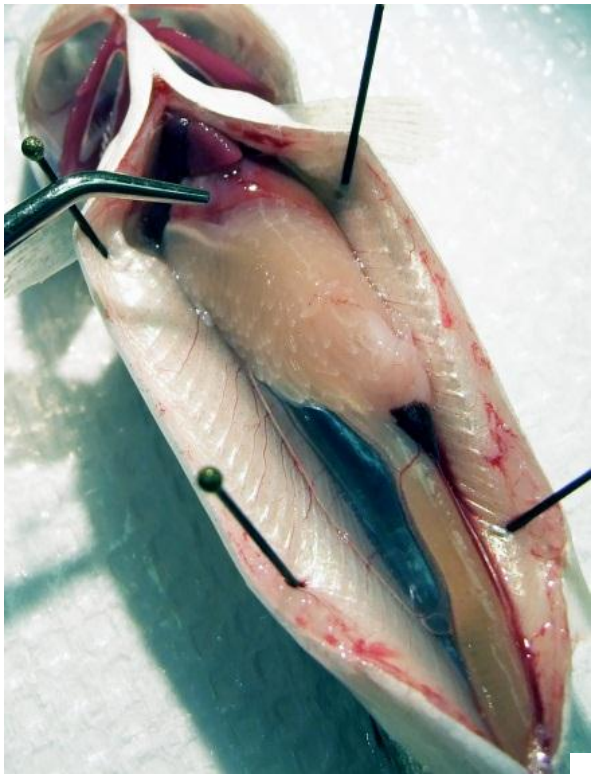
Mortal Injury	Wt
Dead within 1 hr	5
Hemorrhage: heart	5

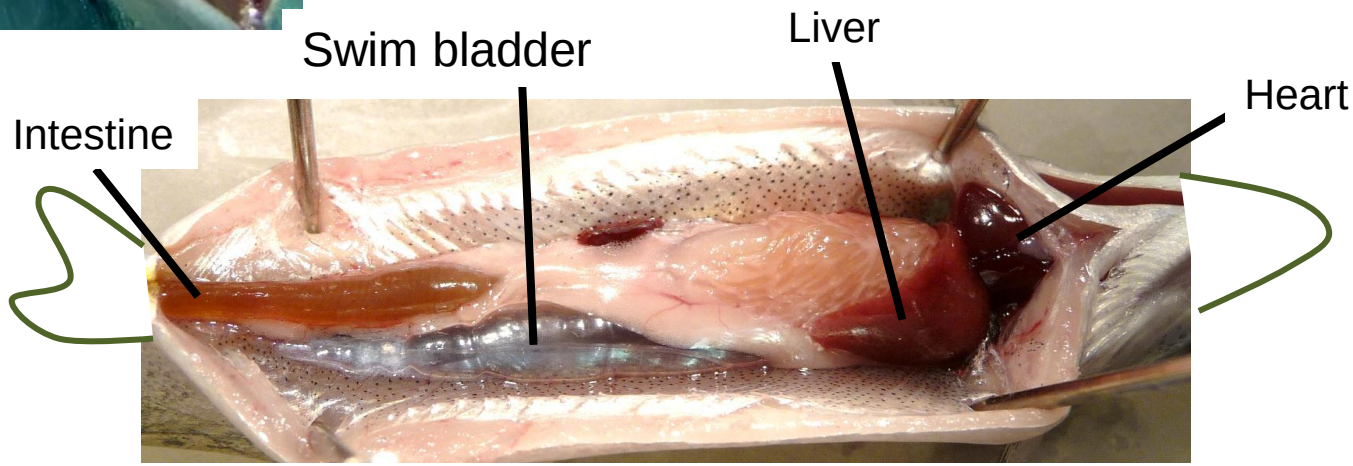
Moderate Injury	Wt
Hemorrhage: intestine	3
Hemorrhage: wall capillaries	3

Mild Injury	Wt
Hematoma : vent	1
Hematoma: dorsal fin	1

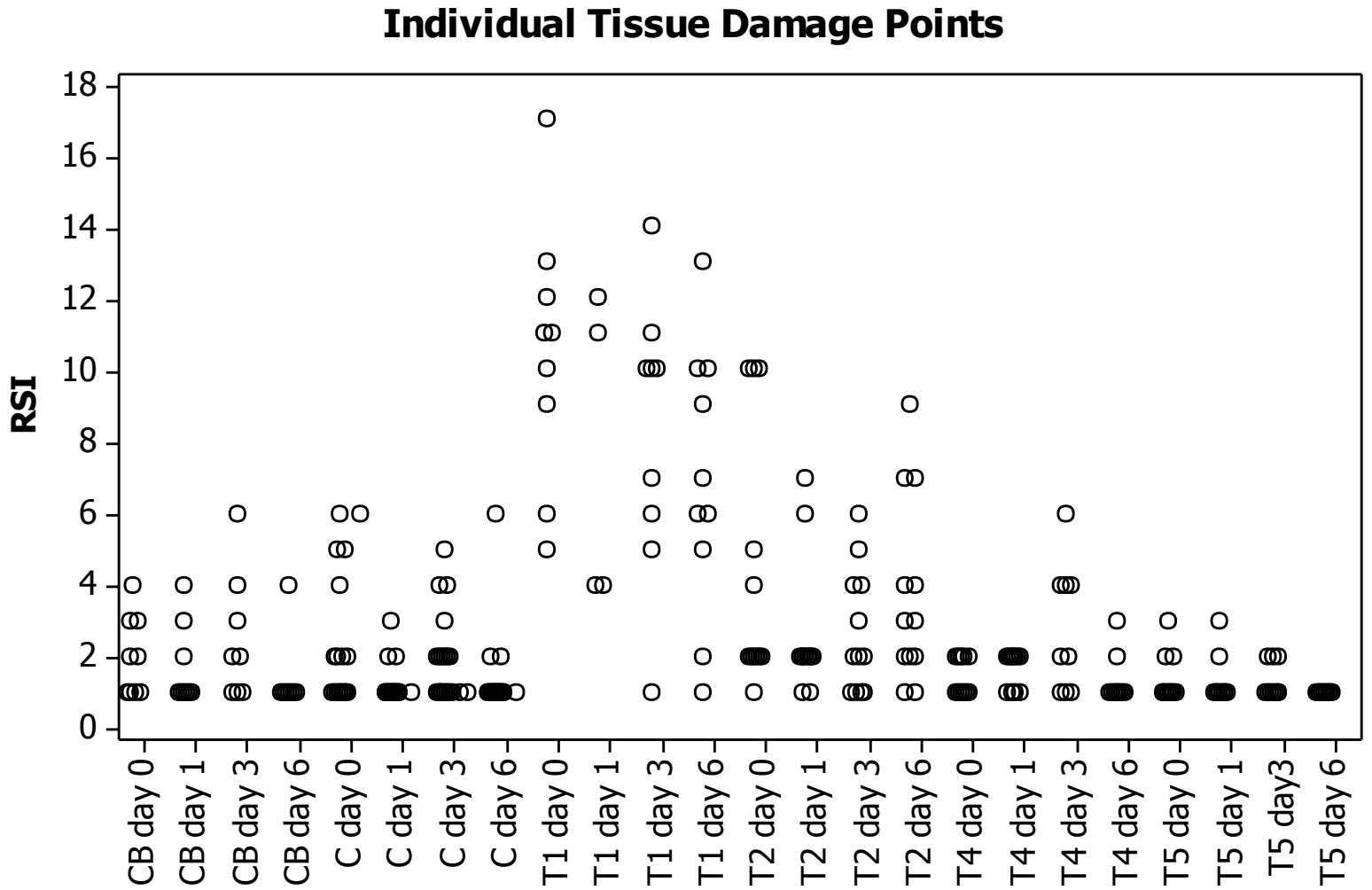
- List of 72 injuries
- Physiological Rank
- 3 Injury classes
- Weight

Tidal Turbine- Barotrauma Results





Underwater Noise – Barotrauma Results



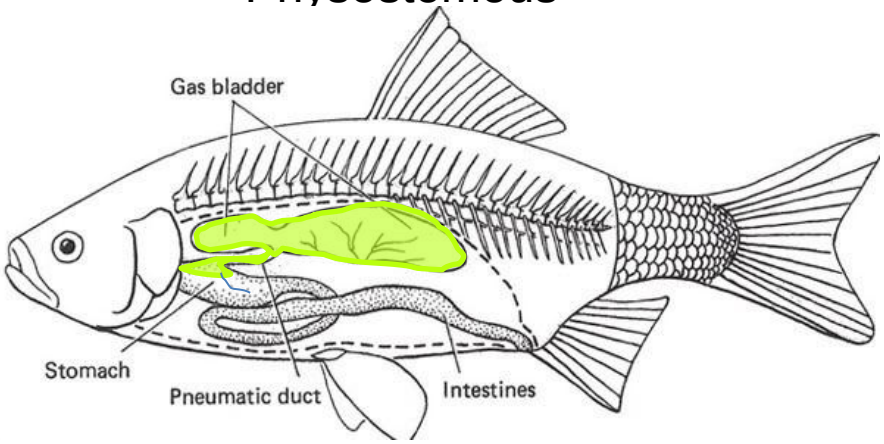
Tidal Turbine – Effects Summary

- Initial findings suggest no auditory system damage
-
- Barotrauma results indicate onset of minor injury at test exposure

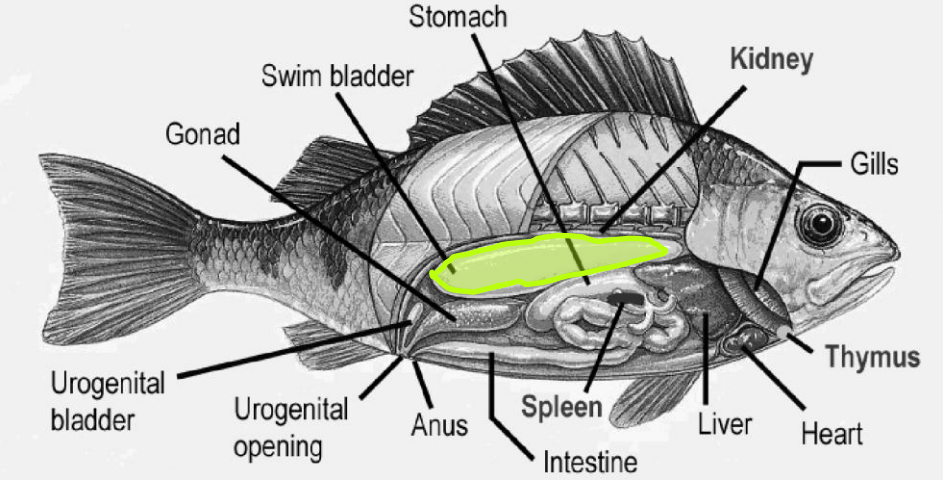
Tidal Turbine – Next Phase

- 2 major groups of fish
  - Threatened or endangered
- Physostomous
  - Connection between gut and swim bladder
  - Gulp air or expel air
  - Need access to air
- Physoclistous
  - Closed swim bladder
  - Rete organ needed to fill swim bladder
  - Need time- hours to days

Physostomous



Physoclistous



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