Tidal Power Fish Encounter and Collision Modelling

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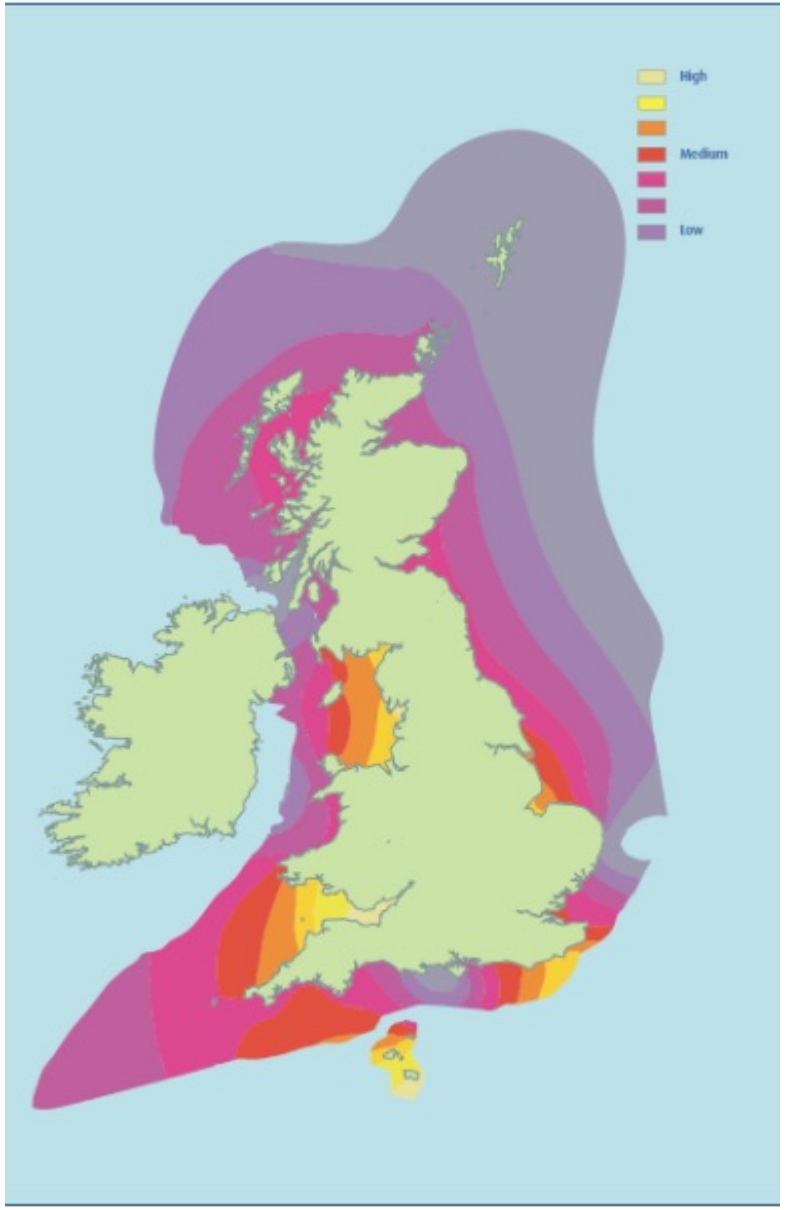
Tidal Power in the UK

- Tidal power has potential to be a significant contributor to UK's Renewable Energy Commitment
- Estuaries where energy generation potential is greatest and therefore economically feasible are unique and dynamic environments afforded environmental protection
- Imperative to determine whether the positive energy benefits outweigh any negative environmental impacts
- A number of fish species that are resident within or pass through estuaries during their migration are included within international and national designations
- Both barrage and lagoon schemes have the potential to encompass river mouths and interact with fish passageways
- Potential risks to highly mobile migratory, estuarine and marine fish species is set to be a key determinant in successful tidal power consenting



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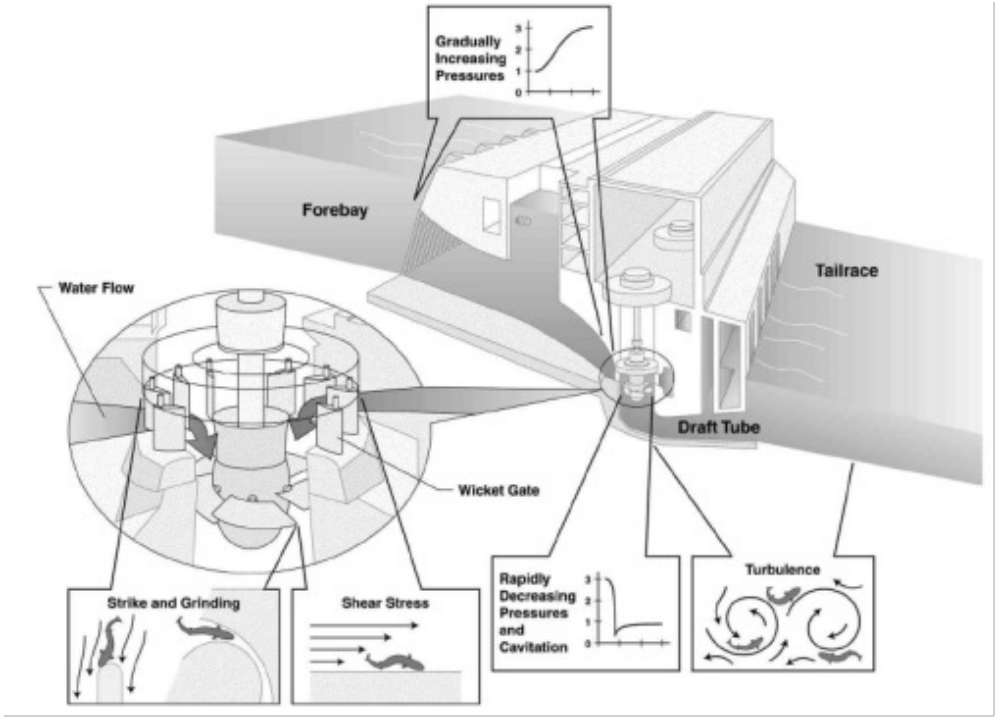
Tidal Power and Fish

- Fish passage through tidal power schemes is likely to be primary source of fish injury and mortality and have the greatest impact upon fish residing within and passing through an estuary
- The mechanisms by which fish injury or mortality can occur are grouped into 4 categories;
  - mechanical (including strike, abrasion and grinding),
  - Pressure
  - shear/turbulence
  - cavitation
- Different injury mechanisms occur at different locations within the turbine & can also occur in the sluices & other structures
- Injury may lead to direct mortality or indirect mortality sometime after passage
- Due to tidal exchange potential for multiple fish interactions with a scheme



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Tidal Power Modelling Needs

- Due to the potential for fish to be impacted by a tidal power scheme there is a need for the assessment of how many fish may interact with the scheme and how many of these interactions could result in injury or mortality
- Assessments are focused on two main modelling types which are applicable not only to tidal range power but also other renewable energy including tidal stream & offshore wind;
  - Encounter Risk Modelling – The potential for fish to have a close encounter with the scheme & the number of potential encounters
  - Collision Risk Modelling – The impact of fish passing through the scheme structures equating to injury/mortality risk (entrainment)
- As with all models, assessment and management of uncertainty is key & must be considered during parameter development
- Understanding of inherent uncertainty key for Adaptive Environmental Management Plans

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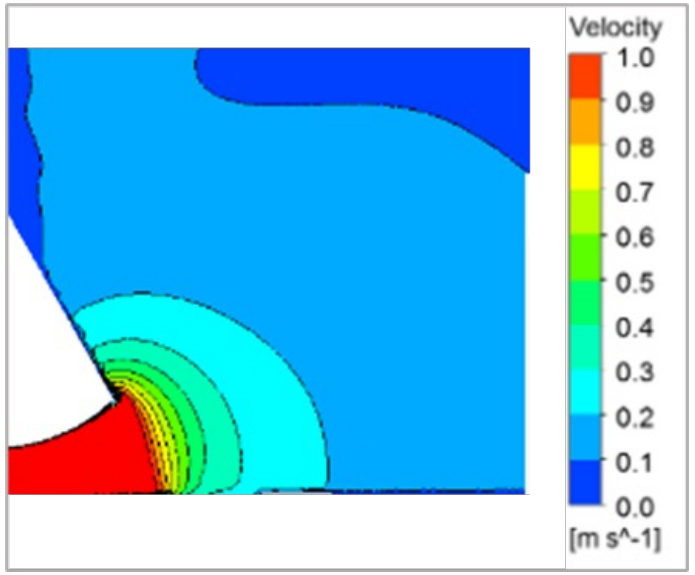
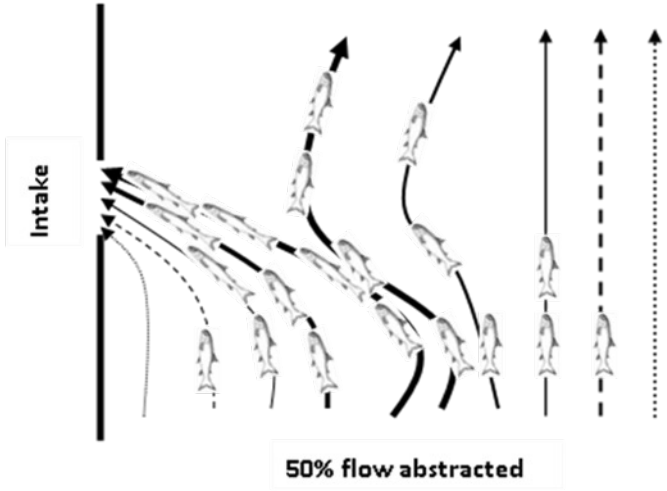
Key Aspects of Model Review

- Is the model suitable for tidal range & fish application?
- Is it suitable for multi-species & life-stages?
- Capability to model multiple passages over time
- Ability to use model openly
- Availability of data & evidence for model parameters
- Requirement for site specific data gathering
- Practicalities of parameter data collection
- Have models been validated in the lab, field or with empirical data?
- Is residual uncertainty recognised and managed by the model?

Encounter Risk Models

- Require complex modelling capabilities & site specific bathymetry & hydrodynamic data
- Entrainment Zone Computational Fluid Dynamic (CFD) Models
  - Model near-field flows surrounding the turbine intakes
  - Flow & acceleration fields & fish swimming speeds to identify entrainment risk zones
  - Identifies risk zones but not fish distribution to determine proportional risk
- Empirical Transport Modelling/Particle Tracking
  - Passive particles in abstraction water streams
  - Mainly used for conventional abstractions not tidal schemes
  - Varying degrees of mathematical or modelling complexity





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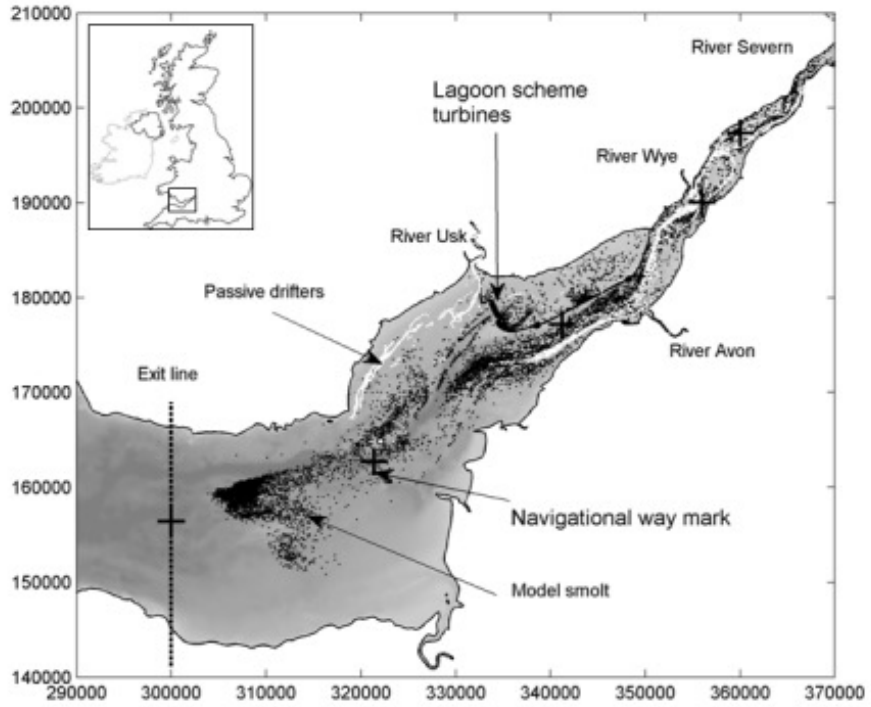
Encounter Risk Models

- Eulerian Lagrangian and Agent based Models (ELAM)/Individual Based Models
  - Hydrodynamic model incorporating complex fish behaviours at a population level
  - Main model used on UK tidal power studies to date
  - High data and modelling requirements
- Alternative Draw Zone Model
  - Combination of entrainment/draw zone model data & excel based fish population, behaviour & presence
  - Stochastic Monte Carlo model effectively dealing with uncertainty management
  - Used for Swansea Tidal Power Scheme assessment



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Collision Risk Models

- Require turbine specific data, CFD modelling, fish behaviour and response but can be run in excel
- Blade strike models
  - First collision risk modelling for hydropower dating back to the 1930's
  - Equation based models considering rate of fish strike from a turbine blade
  - Developed over the years with introduction of CFD model shear stress data and other parameters such as mutilation ratios
  - Adapted in the 2000's to incorporate stochastic functionality
  - Traditional methods for hydropower and tidal power in the UK
  - Strike only models
- STRIKER
  - Turbine CFD and dose response model
  - Incorporates fish behaviour, stress response and species data
  - Compound mortality model considering strike, shear and pressure impacts
  - Recent stochastic model updates

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Collision Risk Models

- Biological Performance Assessment (BioPA) toolkit
  - CFD modelling of turbine flow fields with stream trace sampling ‘fish’ seeds
  - Exposure probability modelling for shear, pressure and collisions
- Fish-Net
  - Bayesian network model combining strike, shear and barotrauma
  - Mathematical accumulation of expert opinion – best & maximum estimates & confidence
  - Uncertainty explicit in the model approach

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What can we learn from other taxa models?

- Encounter Rate Models for tidal stream & offshore wind generally not considered appropriate

Collision Risk Models

- Equation based probability of a marine mammal or bird of a given size & speed occupying the same spatial & temporal extent as rotating turbine blades
- Similar approaches & fundamental equations & principles to fish blade strike models
- Band model most well known originally focusing on birds & offshore wind assessments
- Similar basic principles & adaptations/improvements including height entering rotor swept area & stochastic advancements
- More recently combined with IBM's to incorporate encounter rate
- Other models focusing on marine mammals have adapted predator-prey interaction models replacing predators with turbine blades
- Models fundamentally similar to fish CRM's & could be adapted but don't consider key aspects such as pressure & shear or ducted turbine characteristics. Some potential advancements using 3D modelling & game design software

Next Steps

- Develop a consistent open source model for use across tidal range schemes in the UK
- Fully understand data needs & where possible minimise IP protected data requirements
- Identify data & model build gaps & undertake targeted research to improve future assessments
- Use insight & software developments from other taxa to improve model functionality
- Explore opportunities to combine as far as possible ERM and CRM approaches

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Thanks

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