Coping with the physics of Acoustic Fish Deflection Systems

Dr J R Nedwell and Dr A W H Turnpenny

Fish Guidance Systems
Bishops Waltham, Hampshire, UK

Innovative Solutions for Fish Deflection and Protection
Why design an Acoustic Fish Deterrent System?

- Large system may comprise 100 or more projectors.
- Cost from £10k to £10M.
- Pre-emptive, detailed and objective engineering design usually essential to ensure system appropriate and effective.
- Experience may allow selection of small systems but in all cases “let’s give it a try, it may work” is not an option!
Design considerations when planning an Acoustic Fish Deterrent System

Consideration of five key areas is required:

- The source: what is the level of sound stimulus generated by the transducer?

- The hearing sensitivity of key fish species; how sensitive is their hearing, and over what frequencies can they hear?

- A criterion for effectiveness – level (objective) *versus* “loudness” (subjective)

- Acoustic modelling: establishes the field generated by the system, the level or “loudness” encountered by fish, and hence estimated effectiveness

- Optimisation: select signal for appropriate frequencies and greatest or best effect, optimise design, evaluate redundancy & confinement of sound field, and hence define optimum system
Making noise: The FGS 30-600 series

- Rugged and reliable projector; many hundreds made already
- Linear – reproduces signal
- Matched to hearing of fish - infrasonic to sonic frequencies
- 1 year service life
- Stable well defined acoustic output ideal for modelling purposes
Hearing

Defined by audiogram, lowest level of sound that can be perceived by species as function of frequency.
Measuring hearing

- Electrode manipulator arm
- Shielded electrode leads
- Left transducer
- Electrode tip insulator
- Right transducer
- Sturgeon
Auditory Brainstem Response

- Audiogram established by playing repetitive “pings” to fish at particular frequency and level and averaging results
- Threshold of hearing where level of sound at which the brainstem auditory response just appears above noise.
“Loudness” of a sound to fish

- Illustration of perceived sound level (dB$_{ht}$) for representative fish and marine mammal species, plotted over spectrum produced by transducer.

- Degree noise can be heard by each species (“loudness”) is represented by ‘hatched’ region.
The $\text{dB}_{ht}$ ($Species$) metric

- Measure of “loudness” for a species
- Generalisation of $\text{dB}(A)$ used for human noise exposure; even criteria are same (90 $\text{dB}_{ht}$ for avoidance; “powerful hifi in small room”)
- Incorporates weighting function based on hearing ability defined by audiogram
- Unacceptable loudness = avoidance
- Allows objective engineering evaluation of “avoidance”
As any given sound is perceived differently by different species (since they have differing hearing abilities) the species name must be appended when specifying a level.

For example, an AFD system might produce a level of $70\text{dB}_{ht}(\text{Salmo salar})$ for a salmon, and $110\text{dB}_{ht}(\text{Clupea harengus})$ for a herring.

The perceived noise levels of sources measured in $\text{dB}_{ht}(\text{species})$ are usually much lower than the unweighted levels because sound contains frequency components species cannot detect, and because most species that live in underwater environment are relatively insensitive to sound.
The $dB_{ht}(\text{species})$ Metric

- Can be used for estimating wide range of behavioural effects (e.g. avoidance of windfarm piling).

- $0dB_{ht}(\text{species})$ represents sound at hearing threshold for that species.

- If the level of sound is sufficiently high on the $dB_{ht}(\text{species})$ scale an avoidance reaction occurs.
Acoustic modelling of AFD systems

Given the criterion (typ. > 90 dB$_{ht}$($species$) for critical species) acoustic design is required to determine -

- Extent of sound field required for effectiveness
- Impact of tidal variation
- Optimum location for Sound Projectors
- Optimum number of Sound Projectors required to screen intake
- “Sensitivity analysis” - required redundancy for system?
- Extent of sound field; side effects on non target species
Example: Pembroke Power Station

PrI SM Modelling

- Salmon - critical species (others expected to react more strongly)
- Based upon dB$_{ht}$ criteria, sound field should have:
  - A high level of sound in front of intake of $90$dB$_{ht}$ ($Salmo salar$) - absolute minimum
  - $100+dB_{ht}$ ($Salmo salar$) - preferred level
  - A rapid change in sound level as intake is approached
  - An absence of low sound pressure areas or “funnels” near the intake
Prl SM Modelling

Modelling based upon assumptions -

- Sound Projectors will be located on buttresses between intakes
- Maximum intake velocity <0.3 m/s
- Water level drops below top of intake gates at extreme low tide
Prl SM Modelling

- Prl SM – Predictive Image Source Model estimates the sound field from projectors
- Allows “nearfield” calculation of sound level, also complex interaction between water surface and sea/river bed.
- Automatically generates dB\text{ht} values from audiogram
- e.g. Pembroke; indicated optimum system of 72 Sound Projectors
PrI SM
Modelling

Modelling of other species, using dBht metric -

- Herring more sensitive to acoustic signal
Modelling of other species, using dBht metric -

*Seal less sensitive but notice “beaming”*
Conclusions

- Acoustic fish deterrent systems, like any other engineering structure, must be carefully designed in accordance with objective engineering design criteria in order to achieve maximum effectiveness for minimum cost.

- The process of design requires a knowledge of fish hearing acuity, the level of sound generated by the transducer, the consequent sound field (propagation of the sound to the point where it is received by the fish), and a criterion by which the effect of the sound field may be judged.