Title: Swansea Tidal Lagoon: Fish Entrainment Monitoring

Technical Note

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1 Introduction

The Adaptive Environmental Monitoring Plan (AEMP) for Swansea Tidal Lagoon, "Objective F1 - To assess fish passage through the turbines", proposes a combination of hydroacoustic techniques (e.g. DIDSON™/ARIS™/BlueView™ cameras) to enumerate fish entrainment rates and turbine outflow netting to provide a breakdown of catch into species/lifestages. This Technical Note sets out in more detail how these measures will be used in practice. Where the name DIDSON (Dual-frequency Identification Sonar) is used below, it should be interpreted as the generic camera type, which could be any of the three listed above, or alternatives that come onto the market.

2 Hydroacoustic Technology

2.1 Description

(*This section is taken from AEMP Rev. 1 dated 050814*).

The technology uses high resolution imaging sonar cameras which can give near video quality images even in turbid waters. Specialist fisheries software supplied with the units (see Figure 1 below) can be used for:

i. Quantification of fish entrainment,

ii. Conducting fish counts,

iii. Monitoring fish behaviour,

iv. Monitoring temporal and special distribution of fish, and

v. Identifying fish species/types.

The software is user friendly and can allow remote 24hr data collection and data analysis tools. There are also a number of specialist software packages available such as HTI Echoshape and Sonarpro.

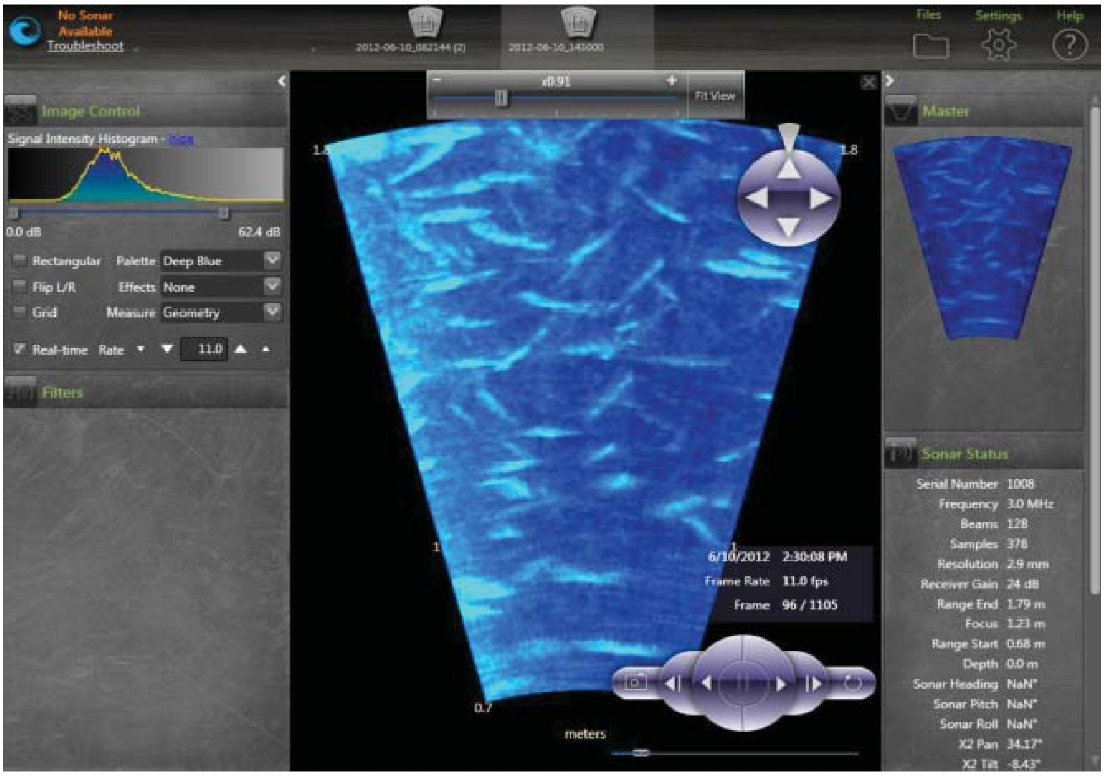

Figure 1 Image from ARIS software

There are two main types of device commonly used (including by the Environment Agency and Natural Resources Wales): High definition sonar DIDSON (Dual Frequency identification Sonar) 1.8MHz and the more recent ARIS (Adaptive Resolution Imaging Sonar) Explorer 1800 1.8MHz (see Figure 2 below).

Figure 2 High resolution sonar cameras

The ARIS 1800 has an effective range of 35 m and can be mounted to the external wall of the turbine housing (see Figure 8.3), on a frame. Alternatively, a specially designed slot for the cameras could be incorporated into the turbine housing design for each turbine (or sluice gate) to minimise blind spots. Incorporating slots in the design would mean cameras could be easily moved between turbine or sluice gate units and would minimise interference in the water passage.

Figure 3 Mounting at Arzal dam, France

2.2 Deployment on Turbines

All 16 turbine units will be fitted with fixing rails for the DIDSON/ ARIS camera in the optimum position to maximise coverage of the intake and exit areas so these can easily be transferred between units. The turbine position to be monitored at any one time will be selected using a randomised timetable.

2.3 DIDSON Set-Up

The DIDSON field of view is typically 29 degrees (this may vary according to type but 29 degrees will be assumed here). It is proposed to mount the DIDSON at the top of the turbine openings pointing vertically downwards (Figure 4), although optimum positioning will be determined by experimentation. The turbine opening height/width is

~13.4 x 13.4 m square (180 m²). A 29 degree beam of 13.4 m height will scan an area of 46.4m², equivalent to 25.8% of the intake open area. It may be necessary to be able to deploy the DIDSON from more than one vantage point on each turbine to avoid distributional bias, particularly with respect to vertical coverage (e.g. looking up from bed also). The Teledyne BlueView M900-130 imaging sonar ('BlueView') field of view may be up to 130 degrees, which would increase coverage. This system has been used successfully in marine fisheries application and merits further investigation for Swansea (Wolff and Badri-Hoeher, 2014).

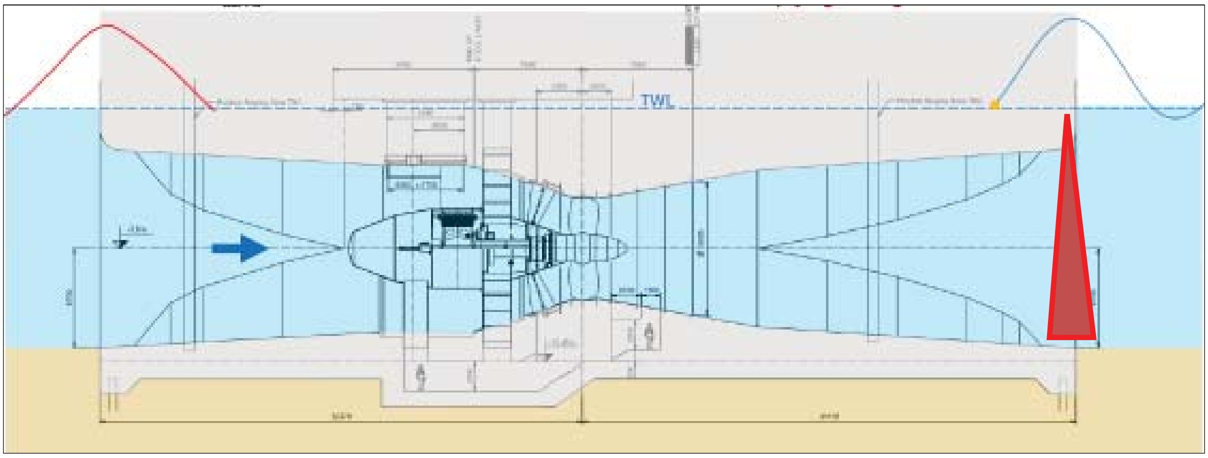

Figure 4 Section through turbine, showing proposed vertical direction of DIDSON beam

For high resolution monitoring of eels, DIDSON operating at 1.8 MHz and a maximum range of 15 m is recommended, with a frame rate of 5 frames per second (Environment Agency, 2011). Field trials will be conducted prior to commissioning at a site where fish will be present in water velocities of 1-2 m/s, comparable to turbine entrance conditions, to establish whether this frame rate is suitable.

2.4 Number of DIDSON Units to be Deployed

This being the first tidal lagoon system for which turbine monitoring has been proposed, there is no existing example of good practice from this type of application to inform survey design. However, the application proposed in this technical note is broadly similar to fish impingement monitoring at cooling water intakes of coastal power stations, for which there is a long history of monitoring design.

A good practice guide for power station sampling design was prepared by the BEEMS (British Energy Estuarine & Marine Studies) Expert Panel, a group of specialists in this field including Environment Agency and SEPA representatives (BEEMS, 2010). Based on variability of estuarine and coastal fish populations and consequent impingement rates, the guide proposes that sampling intensity (percentage of recorded time processed) for power stations should be equivalent to 11% of the time over a year. It is proposed that this figure is used as a basis for turbine fish passage monitoring over the first year, with scope for adjustment thereafter, once variability has been established. The sampling intensity will be adjusted after the first survey year according to measured variance in total fish numbers using statistical power analysis.

In terms of coverage, since a single DIDSON unit will monitor 25.8% of the turbine inlet area for a single turbine, this equates to 1.61% of the combined total turbine inlet area. To achieve the required 11% sampling rate would require 11/1.61 =6.8 DIDSON equivalents. Therefore it is proposed to deploy seven DIDSON units simultaneously, each one randomly allocated to a different turbine unit.

2.5 Data Sampling

The intention is to run the DIDSON cameras more or less continuously (notwithstanding downtime whilst switching between turbine units and for maintenance of camera/recording system or turbines), recording and archiving all the data. The data may then be subsampled for processing, ensuring uniform coverage with respect to:

- Time of day
- Tidal state
- Turbines 1-16.

The sampling rate (percentage of recorded time processed) will be adjusted once surveys are under way according to measured variance in total fish numbers using statistical power analysis.

2.6 Data Processing

Data storage for DIDSON is demanding, around 1.8 gigabytes per hour per camera, or around 15 terabytes per year (Myounghee Kang, 2011); however, hard drive storage is now inexpensive (around £40 per terabyte) and therefore storage cost *per se* is not significant.

Initially, 'off-the-shelf' fisheries processing software such as Echoview™ (DIDSON) or ProViewer (BlueView) will be used to analyse DIDSON data. Post-processing data using these products is at best semi-automated (Myounghee Kang, 2011) and Natural Resources Wales (NRW) estimate that it takes around 1 man-day to process five days' data for fish counting purposes.

A number of groups are currently developing automated software, with Kiel University, Germany developing software for BlueView which may be commercialised. Kiel University (Lars Wolff, pers.comm.) have indicated that they believe BlueView would be suitable for the turbine application, provided that wave action is not allowed to interfere with the beam. This can be achieved by pointing the beam down towards the bed. It is anticipated that bespoke software will be developed for the tidal lagoon application so that processing can be speeded up and made less labour-intensive.

The following outputs will be generated:

- Number of fish passing per hour
- Diurnal/tidal variations in fish numbers passing
- Size distribution of fish (including diurnal, tidal and seasonal variations)
- Speed and direction of fish travel relative to water movement

- Vertical distribution of fish (which will be used to revise STRIKER v.4 input data if necessary)

From the data, annual numbers and size distributions of fish passing through the turbines on all operational states (ebb and flood generation, pumping, turbine sluicing) will be calculated based on percent of generating flow sampled. These figures will then be allocated to species based on proportions estimated from tailrace netting data.

2.7 Accuracy of Data

It is not clear at this stage what the accuracy of count data would be for the wide range of fish species found in Swansea Bay but in a large-scale evaluation of DIDSON cameras reported by Cronkite *et al.* (2006) for Pacific salmon a 95% C.I. of ± 14% for a total population of approximately 645,000 was estimated.

3 Turbine Tailrace Netting

3.1 Purpose of Tailrace Netting

Netting of the turbine outflow ('tailrace') will be used to 'ground-truth' the DIDSON observations. By collecting fish emerging from the turbine flow, it will be possible to make the following observations (Turnpenny *et al.,* 1992):

- Species and sizes of fish passing through the turbines; these will be matched against the DIDSON observations for the same sampling period.
- Frequencies of injury types in turbine-passed fish, including:
    - Scale loss, fin-damage and other minor external lesions
    - Severance of bodies, spinal injuries or torsional damage
    - Eye injuries such as haemorrhages or gas embolisms

3.2 Tailrace Netting Frequency

During the first year, tailrace netting will be carried out on five turbines (selected at random from 16) each over a day per month. Samples will be removed at hourly intervals.

3.3 Tailrace Netting Method

Tailrace netting has been extensively used around the world to assess fish entrainment and survival through hydropower turbines. The Electric Power Research Institute (EPRI, 1997) undertook a review of tailrace netting methods and protocols from numerous North American studies and produced industry guidelines for this for both enumeration of fish entrainment and estimation of survival rates after turbine passage. The practicalities of this depend on the size of the turbine flow and the amount of debris in the water column. Netting may be full-flow, i.e. capturing everything that passes through a turbine, or partial-flow where full-flow sampling is impractical. EPRI indicate a practical upper limit for full-flow sampling of around 70 m^3s^{-1}; at Swansea, a single turbine will pass in excess of 400 m^3s^{-1} and therefore only partial tailrace netting can be considered.

The tailrace netting method chosen for Swansea is to deploy a trawl net (e.g. bass trawl, 10 mm half-mesh cod-end) from a small fishing or research vessel. This has considerable advantages over fixed tailrace netting:

- No tailrace fixings are required, although it would be advantageous to provide fixed seabed anchorages with buoys at each turbine position
- The vessel will be fitted with a suitable A-frame and net recovery winch
- The vessel can move easily between turbine positions
- Control samples of non-turbine-passed fish can be obtained (see Section 3.4)
- The system can be operated more safely than a fixed net system which has to be serviced by boat, since the net will be bought aboard the vessel for inspection.

Turbines will be netted seven days per month over the first year of operation, netting each of the turbines on which the DIDSON is operating at that time. Six one-hour samples will be collected on each date. The need and scheme for continued monitoring will be reviewed at the end of year one of operation.

For each sample, the following will be recorded:

- Flow through the net during sample
- Species present
- Length distribution for each species
- Injuries (as set out in Section 3.1)

3.4 Net Injury Controls

Distinction between netting-induced injury and turbine passage injury can be difficult to discern if controls are not used. Under fixed tailrace netting procedures (i.e. net attached to turbine draft tube, exposing fish to netting without first passing them through the turbine is problematical, since turbine-passed fish will also be present in samples, so controls are difficult to achieve.

An advantage of using the boat-based netting method proposed for Swansea is that the net can be operated as a trawl in open water, maintaining the same flow speed/volume through the net as in the turbine-passed sample. This is achieved by deploying a tally-type oceanographic flow meter in the mouth of the net, calculating flow velocity and then replicate this during active trawling outside the hydraulic near-field of the lagoon.

3.5 Gut Analysis

It is also proposed to carry out gut-content analysis of piscivorous fish species collected from the tailrace samples to ascertain levels of predation on migratory fish species. This will be reported in terms of frequency of occurrence in samples, species and size of fish prey, where degree of digestion allows.

4 Reporting

An annual report will be prepared presenting all of the above data, putting data into the context of predictions within the Swansea Tidal Lagoon Environmental Statement and making recommendations for ongoing monitoring.

5 Summary

Table 1 below summarises the proposed monitoring methods, sampling intensity and scope of outputs.

Table 1 Summary of turbine monitoring

Method	Deployment	Sampling Intensity	Processing/ Scope of Outputs
DIDSON	7 units deployed on random turbine positions. Change positions on a monthly rota, following a randomised schedule.	25.8% per single turbine, giving 11.3% across 16 turbines, to meet BEEMS (2010) criterion of >11% per annum	No. fish per hour (diurnal/tidal pattern)/ day/year
			Size distribution of fish (including diurnal, tidal and seasonal variations)
			Speed and direction of fish travel relative to water movement
			Vertical distribution of fish (for STRIKER v.4)
Tailrace & Control Netting	Partial tailrace netting to maximum safe/practical (estimated 70 m^3/s based on EPRI ,1997 guidance) using bass trawl, 10 mm cod end, deployed from boat at fixed anchorages. Net injury control using same gear but deployed outside of Swansea Bay	Turbines will be netted seven days per month over the first year of operation, netting each of the turbines on which the DIDSON is operating at that time. Six one-hour samples will be collected on each date. Six control samples will be obtained per month	Flow through the net during sample
			Species present
			Length distribution for each species
			Injuries (as set out in Section 3.1)
			Gut analysis of turbine-caught piscivorous fish to assess predation migratory fish species

6 References

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