Appendix 7.1.5

Note: New smolt analysis

TLSB 9-4 Clarification Note Chapter 9

Topic: Tagged smolt analysis for Swansea Bay Tidal Lagoon

1.0 Introduction

1.0.1 This clarification note explains the review and comparison of data recently made available in respect of the track of a single salmon smolt crossing Swansea Bay, in the context of the TLSB fish behaviour model included in the EIA.

2.0 Overview

2.0.1 The document entitled "Proposed Swansea Bay Tidal Lagoon hydropower development – independent expert fisheries analysis. Report. APEM reference 413196" made reference to a MAFF R&D Technical Report W81 (Moore, 1997). Moore, 1997 included a figure representing an acoustic track of a salmon smolt emerging from the River Tawe. Smolt then crossed Swansea Bay towards the main Bristol Channel for a distance of about 12km. This was the first time this figure had been provided to TLSB's expert team. It was considered that it provided an excellent opportunity to confront the TLSB fish behaviour model (IBM) with real data of a salmon smolt in the vicinity of the proposed lagoon during its outward migration, when the chance of interaction with the new lagoon is highest.

2.0.2 Although the consultants (Turnpenny Horsfield Associates - THA) who undertook the Environmental Impact Assessment (EIA) in respect of fish for the Project were aware of this reference as part of their literature review, the title of the paper suggested that the study focused on smolt movements in the impounded river and the executive summary does not mention this external tracking element of the study. As such this specific piece of information and figure regarding the fish outside the Tawe was not identified as germane to the Project in the literature review undertaken.

2.0.3 In any event, it should be noted that had THA been aware of this data, they would not have relied on this information alone to inform the model for the following reasons: 1. it was not in the peer reviewed literature; 2. it shows a single fish; 3. the method of following from a boat with a hand held directional antenna incurs substantial uncertainty; and 4. the original data were unavailable, so only the figure within the paper was available for use. In addition, the timing labels on the figure are indistinct with respect to exact position on the track which leads to some interpretation uncertainty.

2.0.4 Nevertheless the report is from a highly reputable source, and the species and lifestage were an exact match to the TLSB fish model target. Therefore, it was decided to use these new data to calibrate the existing TLSB baseline fish model and then use this new calibration to predict the probability of encounter using the hydrodynamic model including the operational turbines.

2.0.5 The results of this re-calibration (as discussed below) show that had this calibration alone been used in the TLSB fish behaviour model for the EIA, then the prediction of smolt mortality would have been less than 25% of that reported in the ES. The reason for this difference is that within the EIA the assessment has intentionally focused on a plausible (reasonable) worst case. Information used from literature and THA precautionary expert opinion imply that salmon smolt can swim more slowly and in a more undirected way, and, as such, this worst case movement was used. The following sections outline the methods used for calibration from a track such as this.

3.0 Methods

3.0.1 The methods used are straightforward but relatively new in the scientific peer reviewed literature. The most relevant similar example involves the decomposition of a track of a seal crossing the English Channel (Chevaillier et al. 2014).

i. **Digitise the track**. The original figure was digitised into the model domain. This involved cutting and pasting the figure out of a .pdf format document and loading it into the software program that is used to model the fish. It was necessary to scale the original figure. This was done by choosing two cardinal points that were easily identifiable in both figures and writing a short function to convert one to the other, in order to match these points exactly. The original figure had latitude and longitude axes whereas the TLSB fish model was based on the OSGB grid in metres. There are standard converters but THA has found that customisation is required (especially on older figures) and the method of cardinal points is superior. Subsequent to this, the track positions were placed by hand using a Graphic User Interface. These points were placed along the track and enough were placed in order to capture any twists and turns. Points were identified within this set, on the track, which relate exactly to the times noted on the original figure. Since these times were indistinctly placed on the figure, this step required judgement and thus implied some uncertainty. After this step, points were placed on the track, which were linearly interpolated between the specified time points, in order to place a point on the track for every minute of the journey between the start and end time.

ii. **Reset the water model**. The water model was synchronised with the time of the original track. The time of high tide on the day the track (7^{th} May 1995) was retrieved from tide tables (12:00 noon high tide, neap).

iii. **Decomposition of the track**. The tide vector was recorded at each position on the track by running the water model through the track and recording the tidal vector at each minute at each successive point on the track. Then this was subtracted from the vector that was defined by the movement from one point to the next (the ground speed). The result of this subtraction should, in most part, represent the voluntary swimming vector of the fish. It also included uncertainty not captured in this model (including wind, waves, tracking uncertainty mentioned above, interpolation uncertainty from i. above, and turbulence of a size less than the spatial resolution of the water model).

iv. **Voluntary swimming vector of the fish was used to calibrate the model**. The swimming speed and tortuosity was set to match the tagged fish track data. This was cross checked using the baseline water model (with no tidal lagoon) with a combined representation of both the position of the tagged fish as well as the modelled fish at each time step. The model fish include a number of sources of random uncertainty and so the aim here was to broadly capture the movement of the tagged fish with a 'cloud' of model fish.

v. **Calibration was used in the predictive model**. Here the calibration developed in the above methods was used in the water model that included the tidal power lagoon. The mean speed of the fish and the tortuosity value (random bias at each turn) were the only parameters that were changed. All other parameters, including the location of the assumed olfactory path were the same as the original model.

4.0 Results

4.0.1 The calibration to the new scenario implied an increased swimming speed to around 4.8 body lengths per second (originally 1.2 body lengths per second) and a slight increase in directedness (0.3 originally to 0.15 (SE of π radians) for new calibration). The results of the original and new calibration are shown in Table 4.1.

Table 4.1 Overview results

Species	Scenario identifier	No. encountering turbines	Turbine passes (inward)	Difference in/out	Mean mortality %	SE Mortality %
Salmon smolt (re-calibrated)	TEM-J01a (Moore 1997)	55	95	0	0.03	0.02
Salmon smolt (original)	TEM-J01	125	373	0	0.12	0.03

5.0 Discussion

5.0.1 This method of calibration could be improved by an analysis of the uncertainty in the calibration through a Markov Chain resampling of the original track with estimated uncertainty. This would aim to capture the uncertainty in the calibration by resampling the track many thousands of times through the entire range of the uncertainty in measurement (Monte Carlo Methods – combined with above, usually called MCMC). This analysis would not materially alter the primary result in this case as there is only a single track, and the uncertainties (albeit of different components) remain rough estimates.

6.0 Conclusion

6.0.1 The calibration of this smolt track demonstrates that the approach that was originally used within the EIA and reported in the ES focused on a plausible and reasonable worst case. In general the track is very similar in shape to the original predictions used in the EIA. This data, therefore, strongly supports the approach and the resultant worst case predictions. This type of decomposition of track data is a relatively new method of analysis but its value is demonstrated here. It is a technique that will prove very effective in the future for calibration of encounter models. It may also be a technique that improves basic understanding of animal navigation.

7.0 References

7.0.1 Chevaillier, D, Karpytchev, M , Mcconnell, BJ , Moss, S & Vincent, C 2014, ' Can gray seals maintain heading within areas of high tidal current? Preliminary results from numerical modeling and GPS observations ' Marine Mammal Science , vol 30, no. 1, pp. 374-380.

7.0.2 Moore, A. (1997). The Movements of Atlantic salmon (*Salmo salar* L.) and sea trout (*Salmo trutta* L.) smolts in the impounded estuary of the R.Tawe, South Wales. Environment Agency. R & D Technical Report W81.