Fish Legal

Proposed Swansea Bay Tidal Lagoon hydropower development – independent expert fisheries analysis

REPORT

February 2014

APEM REF: 413196

CLIENT: **Fish Legal**

PROJECT No: **413196**

DATE OF ISSUE: **February 2014**

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1 AUTHORS QUALIFICATIONS

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BSc Hons2.1, Zoology, Swansea University College Swansea, 1970. PhD University of East Anglia, 1976. The distribution and toxicity of zinc in juvenile flatfish. (in receipt of NERC Fisheries Research Studentship). Five years (1975-80) as Research Associate for University of Wales Institute of Science and Technology, Cardiff (UWIST) working on reservoir impacts on salmonid ecology. Joined Welsh Water Authority 1980; led various multidisciplinary environmental teams in water industry and regulators (Welsh Water 1980 - 1979; National Rivers Authority 1979-1989, Environment Agency 1989 – 2007). Left as Fisheries Science Manager for EA England and Wales. Joined APEM as associate in 2007. Currently honorary Lecturer and Research Fellow at Bangor University, School of Biological Science, Molecular Ecology and Fisheries Genetics Laboratory. Member of Atlantic Salmom Trust Honorary Scientific Advisory Panel. Member of Salmon and Trout Association Science Advisory Panel.

Relevant recent projects

- Severn Tidal Barrage, responsible for salmonid assessment and impact modelling.
- Aberdeen Harbour Development (2008). Impact assessment of quay construction on salmonid passage through estuary and effects on fisheries.
- King Street Gas Storage-Pipelines (2008). Impact assessment of brine discharge on salmonid migration through Mersey estuary and effects on fisheries.
- Co-convener AST conference (York 2010) and workshop (Pitlochry, 2011) on fish and flows, Editor and contributor to various reports Milner et al., 2011) and papers (Milner et al., 2011).
- Burbo Bank Extension: migratory salmonid noise risk assessment (2013). Review of salmonid migration in coastal zones and potential for impact from windfarm development.
- Celtic Sea Trout Project (2009-2013) Management Group member and Task leader for Task 7 "Marine ecology, life histories and modelling for Management". Report in preparation.
- Co-Chair of ICES Working Group on Sea Trout (WKTRUTTA), November 2013), report writing in progress.

Some Publications relevant to Swansea Bay Tidal Lagoon EIA

1. Milner , N.J., Elliott, J.M., Armstrong, J.D., Gardiner, R., Welton, J.S. and Ladle, M. (2003) The natural control of salmon and trout populations in streams. Fisheries Research **62**,11-125.
2. Milner, N.J. and Evans, R. (2003) The incidence of escaped Irish farmed salmon in English and Welsh rivers. Fisheries Management and Ecology **10**, 403-406.
3. Armstrong, J.D., Kemp, P.S., Kennedy, G.J.A., Ladle, M. and Milner, N.J. (2003) Habitat requirements of Atlantic salmon and brown trout in streams. Fisheries Research **62**, 143-170.
4. Milner, N.J., Karlsson, L., Degerman, E., Jholander, A., MacLean, J.C & Hansen, L-P. (2006). Sea trout (*Salmo trutta* L.) in Atlantic salmon (*Salmo salar* L.) rivers in

Scandinavia and Europe. *In* G.S. Harris and N.J. Milner. *Sea Trout: Biology, Conservation and Management*. Proceedings of First International Sea Trout Symposium, Cardiff, July 2004. Blackwell Scientific Publications, Oxford, 139-153.

5. Milner, N.J., Harris, G.S., Gargan, P., Beveridge, M., Pawson, M.G., Walker, A. and Whelan,K. (2006) Perspectives on sea trout science and management *In* G.S. Harris and N.J. Milner. *Sea Trout: Biology, Conservation and Management*. Proceedings of First International Sea Trout Symposium, Cardiff, July 2004. Blackwell Scientific Publications, Oxford, 480-489.
6. Evans, M., Milner, N.J. and Aprahamian, M. (2008) Life in Welsh Rivers: Fishes. In: D.D. Williams and C.A. Duigan, (Eds) Rivers of Wales: A Natural Resource of International and Historical Significance, Backhuys Publishers, Leiden.
7. G.S. Harris and N.J. Milner (2006) *Sea Trout: Biology, Conservation and Management*. Proceedings of First International Sea Trout Symposium, Cardiff, July 2004. Blackwell Scientific Publications, Oxford, 499pp.
8. Milner N.J., Solomon D.J. & Smith G.W. (2012) The role of river flow in the migration of adult Atlantic salmon, *Salmo salar*, through estuaries and rivers. Fisheries Management and Ecology **19**, 537-547.
9. Milner N.J., Cowx, I.G & Whelan, K.F. (2012) Salmonids and flows: a perspective on the state of the science and its application. Fisheries Management and Ecology **19**, 445-450.

1.2 Nicola Teague (nee O'Keeffe)

Nicola has a bachelors degree in Zoology from the University of Sheffield and achieved a distinction in her MSc in Marine Resource Development and Protection from Herriot-Watt University. She is a Chartered Biologist with the Society of Biology as well as being a member. She is also a member of the Institute of Fisheries Management and is actively involved with the Institute being both on its Council and Training committees as well as deputising on the Executive Committee on behalf of APEM Managing Director, Keith Hendry. Nicola is an Associate Director at APEM Aquatic Scientists and heads up the Marine Ecology and Fisheries Engineering teams. She has specialised in migratory fish and fisheries engineering throughout her career and has been actively involved in the tidal power generation sector. She was lead migratory and estuarine fisheries advisor to DECC for the Severn Tidal Power study and lead marine ecology advisor to Peel Energy for the Mersey Tidal Power study. One of her specialist skills is the assessment of fish passage through hydropower turbines which has included the development of a bespoke compound mortality model for the passage of fish through the proposed Severn tidal power turbines.

2 SUMMARY OF KEY POINTS

1. Due to extensive movement of migratory salmonids along the South Wales coast there is potential for populations of more rivers to be impacted than currently included within the far-field zone.
2. Migratory salmonids could approach from any seaward direction rather than the currently predominantly assumed oceanic westerly direction.
3. The fish characterisation could be improved by looking at longer term data and referring to conservation limit assessment information.
4. The main migratory periods reported are questionable for adult salmonids in general and more crucially for sea trout which may be present within the area for feeding throughout the year, if their principal prey species are present.
5. There are large elements of uncertainty in the modelling approaches and their input data which are not currently sufficiently discussed or their potential implications acknowledged.
6. The presence of the Tawe barrage and its potential influence on migratory fish behaviour has not been discussed or incorporated into the encounter modelling which could result in underestimates of delay to passage and the potential for multiple returns to the estuarine/coastal environment before entering freshwater.
7. There does not appear to be any mechanism for incorporating environmental conditions in particular river flows into the encounter modelling which may be an important factor in relation to passage past the Tawe barrage.
8. The fish size distribution data used for the encounter model and STRIKER estimates are not fully appropriate to the local river populations of adult salmon and sea trout.
9. The fish turbine passage modelling is currently based on a deterministic model however, due to the uncertainty in input parameters a stochastic model may be more appropriate to allow interpretation of the potential range of model outputs.
10. There should be some acknowledgement within the assessment that the turbine passage compound mortality estimates cannot be considered as complete mortality rates as it is not possible to quantify a number of the impacts such as predation risk and sluice passage.
11. It is understood that the EIA in general has adopted a Rochdale Envelope approach. It s not clear however, how a worse case approach has been implemented for fish.
12. Population effects are not estimated. Even if direct fish number losses (at least from turbine M) are small, there are additional potential mortality effects (e.g.predation). The eventual effects on populations would give added confidence about the impacts. There is precedent for this for salmon on the DECC Severn Tidal Power SEA study.
13. In absence of population modelling. Life time egg deposition offers an improved way to estimate impacts giving a more realistic representation of the importance of larger fish.

14. Given the inherent uncertainty in fully quantitatively assessing impacts, qualitative magnitudes of effects focusing on effects upon the species or population may be more appropriate than the quantitative thresholds used within the assessment.
15. There is discussion in the assessment chapter regarding modelling impacts upon Wye and Usk fish however, there is no presentation of the modelling outputs and no discussion of this further within the assessment.
16. The summary tables of impacts are incomplete for increased predation and entrainment and injury from turbines. It is not therefore possible to comment on the final assessment conclusions at this time.
17. There is limited discussion of mitigation measures within chapter 9, the main one for fish being the use of an Acoustic Fish Deterrent. There is however, some uncertainty regarding the proven effectiveness of this technique for this specific application.
18. There are further potential mitigation options that could be considered which are discussed within this document.
19. In the absence of monitoring methods being provided within the assessment, some potential options are discussed within this document.

3 BASELINE (APPENDIX 9.1, SECTION 9.5 MIGRATORY FISH)

3.1 Section 9.5.2 Methodology

Study Area

Migratory salmonids, salmon and sea trout, are likely to move extensively along the South Wales coast, such that the stocks likely to be exposed to the Swansea Bay Tidal Lagoon (SBTL) will include those from the Taf in Carmarthen Bay to the Rivers Wye and Severn.

The target rivers nominated in the draft EIA (Tawe, Neath and Afan) represent only small parts of the South Wales origin migrating salmonids. Based on EA rod catch statistics (2009-2011) these three rivers contribute 10% of salmon and 19% of sea trout abundance between the Taf and the Wye. Rod catches are here taken to be approximate indices (NB without correction for rod exploitation rate or catch reporting) of adults of both species returning to spawn and sea trout in marine feeding phase (Table 3.1).

Table 3.1 Relative abundance (based on in-river rod catches) of salmon and sea trout referred to in the SBTL draft EIA as percentage of fish in all South Wales Rivers from the Taf to the Wye. 2009-2011 averages. (Source: EA Catch statistics)

	SALMON		SEA TROUT	
Year	**Tawe+Neath+Afan**	**All Taf-Wye**	**Tawe+Neath+Afan**	**All Taf-Wye**
2009	191	1,983	854	5,046
2010	324	2,601	1,031	4,468
2011	196	2,548	782	4,851
mean	237	2,377	889	4,788
%	10		19	

Because coastal movements appear to be extensive more fish will be potentially exposed to Lagoon encounters than suggested in the Report. These potential effects may not be trivial collectively, because although proportionally far fewer salmon from say the river Wye will be exposed than Tawe or Neath fish, the abundance of salmon and sea trout in some of the South Wales rivers is much higher than in the nominal target rivers; the Wye, Usk and Tywi being notable(Figure 3.1).

While the direction of error is clear the amount however, is not. It is not possible to predict with any certainty what proportion of say Wye salmon or Tywi sea trout will be exposed. It is likely however, that repeat encounters will arise, especially in the case of sea trout which are multiple spawners (they spawn and re-migrate to sea several times in their life time) and their migrations are more coastal that salmon, involving feeding on coastally abundant pelagic prey species. Recent genetic and microchemistry studies (from the Celtic Sea Trout Project. www.Celticseatrout.com) on sea trout exchange in the Irish Sea (which extended only to the Tywi) suggest that movements maybe extensive.

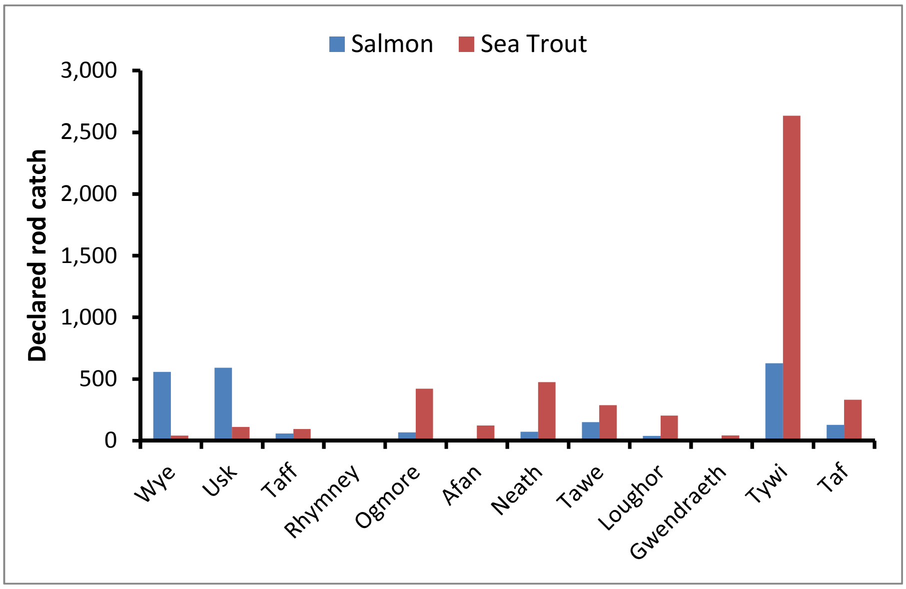


Figure 3.1 Annual rod catches (mean, unadjusted, 2009-2011) of salmon and sea trout in rivers immediately adjacent to the lagoon and further along the South Wales coast. (Source EA Catch statistics)

3.2 Section 9.5.3 Migratory Fish Populations and River Quality Status

The provenance of the freshwater fish population data is unclear. The data are given as NFC classifications for one year, but if these are the same data as used for the EA's WFD reporting they should represent electric fishing surveys for up to six previous years. A full evaluation of the river fish population status is not feasible given the time restrictions on this review; moreover it is impossible to form a view on the populations from the WFD reported status because they cannot be related to specific locations around the catchments (particularly making a distinction between accessible and inaccessible areas) or to types of environmental impacts. While this information is not critical for estimating the potential impacts of the lagoon, they are relevant for proposing realistic, targeted and effective mitigation and future monitoring. A full review would consider the historical Salmon Action Plans (SAPs) and contemporary River Basin Management Plans (RBMPs) in particular whether the rivers are considered to be in good ecological status/potential for the fish aspect of the biological quality element.

The catch data reported are accurate, but the status (see 9.5.5 below) is more completely described by longer term analysis. This could reasonably extend back to 1994 (when effort data began to be collected and second reminders used for the catch returns), or even to 1976 when the national data collection began with some regional consistency. It depends on the purpose. Mitigation should be set in the context of the overall carrying capacities of the affected rivers, informed by knowledge of environmental quality changes, and this is better described over the long term.

3.3 Section 9.5.4 Migratory Fish Characterisation

The migratory salmonid (salmon and sea trout) characterisation is generally accurate, but the Conservation status (9.5.4.3) would be improved by (a) looking at the longer term data

(Figure 3.2 and see also 9.5.3 comments) and (b) referring to the Conservation Limit assessment as reported annually by Cefas/ EA (e.g. Cefas/EA, 2013) and also used as an index for conservation status in SACs (Cowx and Fraser, 2004).

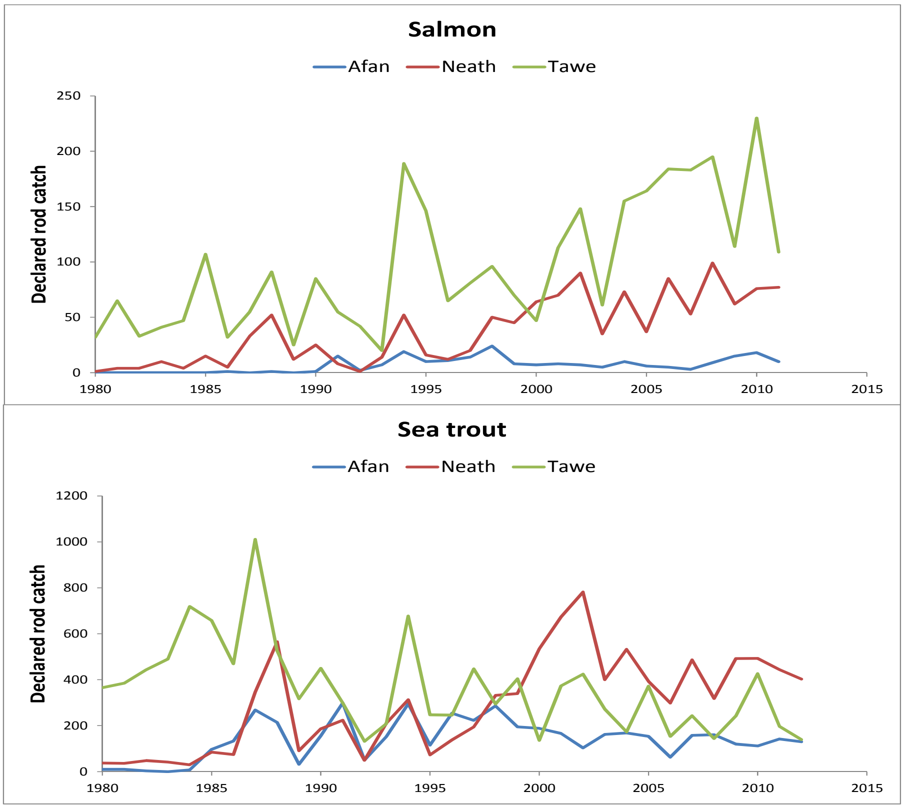


Figure 3.2 Long term trends in salmon and sea trout rod catches for the Afan, Neath and Tawe

While rod catches do have significant constraints on their interpretation, which should not be ignored, the comment (9.5.5.6) that rod catches are poor indicator of numbers is probably over-stating the case. Indeed rod catches are the basis of the Cefas/EA annual assessment to NASCO. The trends and status are different for the species and between the rivers. Thus:

- All three rivers have history of former polluted status and low stocks, with now recovered stocks that are subject to more recent pressures.
- For salmon, the Tawe and Neath catches have increased since 1980s, but the Afan still has low catches (Figure 3.2).
- Salmon CL compliance is poor on the Tawe, the only one of the rivers for which this type of assessment is reported (Figure 3.3), and is currently (2012) judged to be “At Risk” and “Probably at Risk” of failing in 2017 (Cefas/EA, 2013).
- For sea trout, the Tawe catches, having recovered from pollution (Solomon, 1994), have shown gradual decline. Similarly, the Neath (although recovering later) has increased catches which are now (since 1999) greater than the Tawe. However, sea trout catches in all three rivers show recent decline, in contrast to salmon (Figure 3.2).

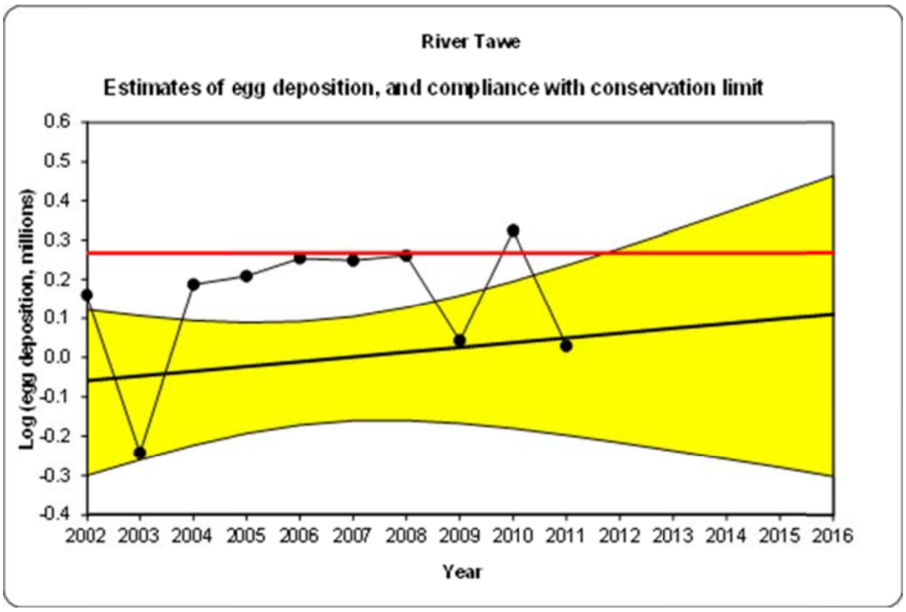


Figure 3.3 Salmon Conservation Limit Compliance assessment for the Tawe. Red line shows the Conservation Limit (total egg deposition), the black line is the trend in the 20%ile observed egg deposition and the yellow band is the 95% probability boundaries of that trend.

These river-specific conservation and environmental observations are relevant to assessing the likely cumulative effects of the scheme and mitigation options (see below). It is likely that all three rivers (and others that might be impacted in South Wales, see Table 3.1 and Figure 3.1) have capacity for increase in their stocks and fisheries which could potentially be compromised by the project (albeit probably at notionally "Minor" level, but see later comments on impact).

3.4 Section 9.5.5 Presence of Migratory Fish Species, Spawning and Nursery Areas

Table 9.13 (p39 baseline report) is a little unclear for migratory salmonids on the copy received. Is this the origin of tables 9.7 and 9.8 in the EIA draft? The main migratory periods appear to be shown as September to January, which is not correct. Adult presence can be characterised from the rod catch data (Figure 3.4), which are constrained by the angling season (e.g. March 3rd to October 17th for Wye and Usk; March 2th to October 17th for the Tywi and 1st April to 17th October for the others). Salmon are caught on average about 3 weeks after river entry (Davidson *et al*., 1996; Shelton, 2001); therefore fish might be present in coastal waters for about a month prior to the start of recorded seasonal catch. Sea trout have a high proportion of fish of age .1+ (and some at .2+); that is they have passed their first post-smolt winter at sea before first return to the rivers. On the nearby River Tywi 47% of returning sea trout adult sampled in the rod catch (1996-98) were found to be .1+ maidens or older (Harris 2002). Their exact location in the winter is unknown, but sea trout in the Irish Sea feed and grow during winter months (CSTP, unpublished) and will be present in coastal waters throughout the year, if their principal prey species (mainly sand eel and sprat) are present.

Note however, that Figure 3.4 is based on the three nominally affected rivers only and other rivers some of which have much larger stocks may have fish present beyond these times. The Wye for example is renowned for a significant spring run of salmon (Gee and Milner, 1984; Gough *et al*., 1992), although it is less than formerly and much underrepresented in most recent catches due to fishing season controls.

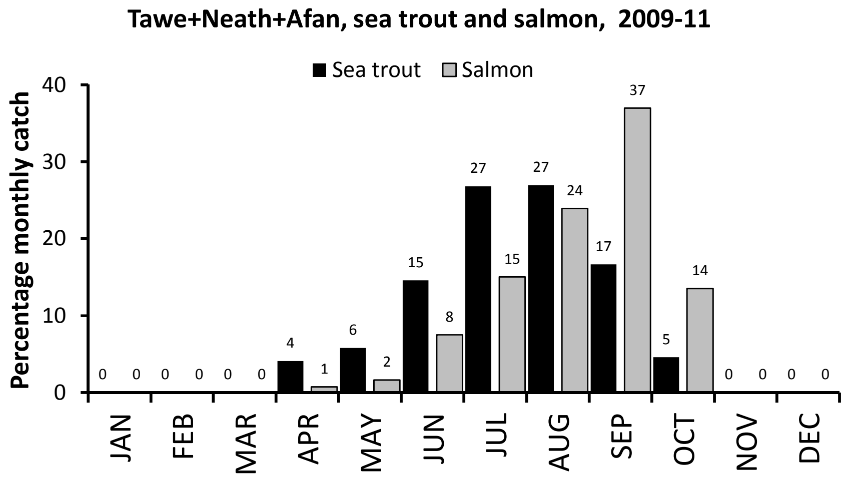


Figure 3.4 Seasonal rod catch of salmon and sea trout in the Tawe, Neath and Afan. (Source EA Catch statistics)

In conclusion, some adult returning salmon are likely to be in Swansea bay coastal waters between January and November, with highest abundance between May and October, and kelts between December and March. Sea trout adults will be present throughout the year, but at highest abundance between April and September, and their kelts will be present between November and March.

4 FISH TURBINE ENCOUNTER MODELLING (APPENDIX 9.3)

4.1 Model appropriateness and general method

Fish encounter with a tidal power scheme is the single biggest factor which sets a tidal scheme apart from a freshwater hydro scheme and likely represents both the greatest determinant of predicting resultant mortality and highest factor of uncertainty within the assessment process. This factor is unique to the individual site and cannot be inferred from any other existing schemes. It will be dependent upon the site location and conditions, the fish populations that may pass through the area and the design and operation of the scheme itself. Modelling through the combination of a hydrodynamic model of the site and species specific Individual Based Model (IBM) is the only means of predicting fish encounter prior to construction. As with any modelling approach however, it is based on theoretical information often backed up with limited or uncertain data and as such is fraught with uncertainty and open to challenge and criticism of in particular the input data.

Although uncertainty in the model technique and calibration are discussed in the upfront sections of this appendix, there is limited discussion of the uncertainty and limitations of the input data in particular and how these may have influenced the model outputs and ultimately the predicted impacts from turbine passage.

There is no mention in this appendix of the presence of the Tawe barrage and how it may influence the behaviour of migratory fish or consideration or reference to the various studies that have been undertaken since it was constructed on this issue. It is not clear from the appendix whether the release point of fish within the Tawe was above or below the barrage but it is assumed to be below as no mention has been made of the delay of entry and exit resulting from the impoundment structure. The lack of consideration of this key factor on fish behaviour upon entering and exiting the Tawe may have affected the model running and resultant outputs which could potentially be falsifying the results of the assessment in either direction.

It is not clear from the reporting as to what rivers are included within the modelling and the final turbine passes within the overview results. All of the video capture figures appear to be for the Tawe only. The appendix would benefit from clearer discussion on the rivers included.

4.2 Model parameterisation and calibration

Salmon smolt model

The input parameters for salmon smolts appear to be predominantly based on a tracking study reported by Moore *et al*., 1998 undertaken in Southampton Water. Given the potential impacts of the Tawe barrage upon salmon smolt movement into and within the estuary in particular however, it is recommended that data from a more locally based study is considered to determine if differing input parameters have any bearing on the outputs of the model. A suitable study would be that reported by Moore in 1997 on 'The movements of Atlantic salmon and sea trout smolts in the impounded estuary of the R. Tawe, South Wales'. Part of the study includes reporting on a single salmon smolt 145 mm in length which was tracked both above the impoundment and below it through the lower estuary and into Swansea Bay for a period of 6 hours and 8 minutes over a distance of 12.6Km. The track shown in Figure 6 within the report shows time of transit and route which appears to move close along the wall of the proposed barrage. Oranges were also released at the time of tracking the individual to represent random drifting particles. It is reported that tracking the oranges had to be abandoned to keep up with the smolt. Speed over the ground was reported as 57 cms^{-1} which could be compared with data in the hydrodynamic model to give an indication of swimming speed for this individual.

The Moore (1997) study also indicated that due to delays resulting from the Tawe Barrage entry into the lower estuary can be during any state of tide as smolts are largely unable to detect the state of tide below the barrage unless it is overtopping. It may therefore be necessary to look at other release times to determine if this factor has any bearing on the number of passes into the barrage. Although only for a single individual the information presented from this study could provide useful local input parameters for the model.

Adult salmon model

The report assumes rather strong directional swimming towards natal rivers as soon as they enter coastal waters. At some stage immediately prior to eventual river entry, that must be so. However, there is strong evidence for temporary straying by salmon, in addition to the true (reproductive) straying referred to by Quinn (1993) and others and noted in this Report. The key reference (Davidsen, *et al*.,2013) describes behaviour of fish well inside a fiord system with a comparatively constrained coast. In the open coastal zone, more representative of Gower and Swansea, one might expect salmon to make more extensive search patterns, influenced in part by tidal direction. This has been shown for salmon on the Aberdeen coast (Hawkins *et al*., 1979). Conventional tagging (Swain, 1982) and micro-tagging (Jones, 1994) of salmon in the South Wales rivers have shown extensive recaptures of non-natal fish in rivers along the North Bristol Channel coast. The strong tidal currents of the Bristol Channel may enhance this effect. The recapture of tagged smolts from the rivers Usk, Wye and Severn (Swain, 1982) indicate that around 4% of recaptured fish in the vicinity of their home river were recorded in the non-tidal reaches of non-home rivers and a further 48% in tidal waters of the Severn estuary and Bristol Channel. In addition to 'overshooting' to nearby rivers, a number were also recaptured in the River Parrett on the south coast of the Bristol channel. It is unknown whether these fish would have later returned to their home river had they not been captured or would have remained as 'stray' fish.

Jones (1994) undertook a review of the microtagging programme of salmon and sea trout in Wales between 1984 and 1993 investigating the return of tagged stocked salmon in particular. The review determined that some returning adults were regularly captured in non-natal rivers both east and west of their natal river. Tagged smolts released in the Afan were recorded to the East in the neighbouring Ogmore. Those in the Ebbw were recorded in its westerly neighbouring Taff. Loughor, Ogmore, Rhymney, Taff and Tawe releases were recorded to the east in the Severn estuary fishery. In addition to the Severn estuary fishery Tawe fish were recorded in the eastern rivers Ogmore and Usk. As above it is not possible to say whether these fish would have returned to their natal rivers had they not been captured or would have remained 'strays'. There is a possibility however, that they indicate that adult salmon could be presented to the Tawe and other impacted rivers not just from the West as modelled but also from the East. Additionally, it further indicates that fish from other rivers than those identified within the assessment may also interact with the scheme and potentially be impacted by it.

There is however, still much uncertainty over return migration behaviour to South wales coast and regional behaviours are likely to vary depending upon how salmon return from oceanic residence (Malcolm *et al*., 2010). Nevertheless, there is a good case for proposing that coastal wandering is more than assumed in the report and from that come two consequences: (1) Tawe and Neath fish might be expected to experience more repeat turbine encounters, and (2) the salmon exposed to the scheme may include fish from other rivers, similarly making coastal migrations.

Sea trout smolts

There are no detailed notes on the calibration model input parameters for sea trout smolts within this appendix. There are however, brief output notes on p 28. Again the Moore (1997) study may provide insight for the calibration for this species life stage. A single sea trout smolt was tracked as part of the study both above and below the barrage. The smolt was detected moving through the barrage lock into the lower estuary where the track was subsequently lost for a period of 4 days. It was then again detected below the barrage before moving back into the lock and finally detected above the barrage for the last time. The 4 day period over which it was not detected in the lower estuary before returning suggests that at least some sea trout smolts could remain in the estuary and coastal environment for a prolonged period and make returns into the freshwater environment. This behaviour could have a significant impact upon the risk of the barrage and its turbine structures to this species lifestage which is otherwise assumed to swim continuously towards the ocean.

The output notes also indicate that a 4 hour release time each side of spring high tide was adopted. The Moore (1997) study however, suggests that they may in fact enter the lower estuary during any state of the tide due to the presence of the Tawe barrage.

Adult sea trout

There are greater concerns over the post-smolt sea trout encounter modelling due to their use of the estuarine and coastal environment as discussed below.

Sea trout will be feeding in the area for much of the year (including the winter, see above, if suitable prey species are present) and as such repeat encounters are therefore likely. The model currently assumes that as with salmon they will only appear in the area prior to entry into the freshwater system and will make directed movement from the oceanic environment into the estuary and ultimately river. This is however, less likely to be the case for sea trout which if possible needs to be represented within the model to give a more realistic worse case of impacts upon the population.

Swimming speeds of more resident individuals may not match those of kelts (the fish studied on the key reference). It would be beneficial to try alternative assumptions of swim speed and orientation etc. to see if they alter the model outputs.

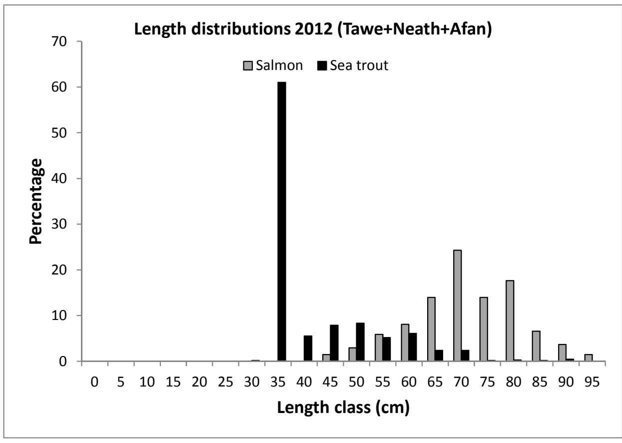
Sea trout will probably approach the scheme from all seaward directions and as for salmon include fish from other rivers. The preliminary genetic stock identification studies of the Celtic Sea Trout Project (CSTP) (reports in preparation) demonstrate extensive straying of sea trout (including The Tywi and Tawe) around the Irish Sea. The prevalence of sea trout in coastal net fisheries (when such fisheries were operating – EA catch statistics) and studies of sea trout elsewhere (Malcolm *et al.*, 2010) suggest that their migrations are primarily coastal and driven by feeding and availability of prey species, typically sand eel and sprat. Sea trout from other natal rivers may therefore also frequent this area and interact with the scheme.

It is not clear from the reporting what model parameters for navigation and orientation were used for sea trout kelts. The reporting would benefit from more detailed notes on this for clarity and to ensure that the most appropriate information has been used.

It is likely that whitling especially may make return forays to the rivers, prior to a spawning migration, based on scale reading from the CSTP which would increase their potential to interact with the scheme.

For adults of both species

Size frequency data for 2012 for the 3 target rivers from the EA statistics are shown (Figure 4.1) and the means and SDs correspond with the chosen stats for the species in the Report (sea trout are slightly larger). It should be noted that a wt/length regression for sea trout had to be used for the translation of the original weight distributions for salmon in view of limited time. This will be approximately correct because the two species have similar shapes; but ideally salmon data, which are available, would be used.



	Salmon	Sea trout
n	136	672
min	43.1	29.4
max	93.2	89.6
mean	68.8	38.6
SD	10.0	11.3
25%Q	*62*	31
75%Q	*77*	45
av-1sd	59	27
av+1sd	79	50

Figure 4.1 Size-frequency data and statistics for the three rivers from EA statistics 2012

It would be informative to model contrasting groups of small and large salmon and sea trout to see if there is any effect of swimming speed if this is not already included in the modelling approach (Figure 4.1).
There may be an impact of temperature upon the model results in particular resulting from likely lower swimming speeds in spring and winter. It would be good to include this factor within the modelling if it is not already.

In Report Table 5 adult salmon "encounters" is 603 vs 2,044 for sea trout. It is not clear what creates this difference in outputs within the model.

Also and related, sea trout turbine passes are proportionally even higher than salmon (3,906 vs 997) compared with encounters. Is this a function of size and swimming speed, and /or some imposed behaviour in the model? The ratios (seatrout/salmon) of passes and encounters are close to the relative abundance of the two species (if the catches can be taken as indices of abundance (see Table 1 and text above). But given their migratory behaviours it is likely that sea trout will be disproportionately prevalent in the area (to their true abundance), and thus even higher proportionate lagoon encounters and turbine passes might be expected.

There does not appear to be any mechanism of factoring environmental conditions in to the model such as river flows. This condition is likely to influence time of entry and potentially residence time and movement within the estuary and bay especially due to the presence of the Tawe barrage which is known to cause delay to river entry. Mee *et al.* (1996) determined from tracking studies of adult salmon in the Tawe estuary in 1993 and 1994 that individuals were only detected traversing the barrage at flows between 1.9 and 9.6 m^3s^{-1}. Over the two study years of the 81 adult salmon tracked 38 (46.9%) were last detected in the estuary and were not observed to pass the barrage. Of the 46 sea trout adults tracked 15 (32.6%) were last detected in the estuary. Those fish that did traverse the barrage took between 8 days and 15 weeks to do so. The 64 fish attempting to pass the barrage made a total of 222 approaches with 41 fish succeeding. Russell *et* al. (1998) reported on a tracking study of adult salmon in the Tawe estuary in relation to the barrage. A total of 68% of the salmon adults successfully tracked and observed to approach the barrage were not recorded as passing upstream within the period of tag life (3 to 35 days) indicating that they moved back out of the estuary or away from the sonar buoys. A study of the movement of adult Atlantic salmon in the Usk estuary tracked 56 adult salmon (Aprahamian *et al*., 1998). 23 of the fish moved into freshwater of which 7 then returned to sea, 20 were recorded migrating out of the estuary and 11 were last detected in the inner estuary although 2 of these were later detected outside of the estuary; one in the Severn Estuary and the other in the River Wye. This study demonstrates that adult salmon upon entering the inner estuary of a river can regularly (over 50% in this study) migrate back out of the estuary. They may therefore come into contact with the scheme multiple times. This behavioural trait does not seem to have been factored into the model.

Attraction to turbines during generation (both species)

Regarding the effect of freshwater flow *per se* as an attractant to migrating salmon entering rivers from the sea, the evidence is usually confounded by the likely role of chemical cues (e.g. pheromonal or geochemical origin). Thorstad *et al*.(2003) reported that freshwater HEP discharge into a Norwegian fiord had minimal effect on salmon homing to a nearby river. It is difficult however, to extrapolate this result to the Swansea Bay situation because the environment and local topography are very different. Moreover the salinity of the generating flow is predicted to be virtually the same as the sea, so this mechanism is unlikely be a problem. While chemical attractants are undoubtedly important cues for coastal and in-river orientation, the roles of water volume flow, turbulence and velocity should not be forgotten. These hydraulic variables are important and in rivers HEP releases have been demonstrated frequently to attract salmon and cause significant migration delays (Thorstad *et al*., 2008), with salmon being preferentially attracted to areas of high velocity (Karpinnen *et al*., 2004). The Swansea Bay lagoon ebb generating discharge might therefore present locally important attraction to migratory fish and cause deviation from a migration route located by chemical cues. This effect will be related to the size of generating flow, its configuration and attenuation in the sea, which will be partly influenced by the tidal cycle.

It is not clear from the reporting what determined the olfaction strength upon release. In reality this is likely to alter seasonally in particular in relation to river discharge. Changes in olfaction strength may alter the navigation time and route made by adult salmonids returning to their natal river and could influence the potential for them to pass into the lagoon.

4.3 Model outputs and conclusions

Were re-modelling to be undertaken on the basis of some or all of the points detailed above then this is likely to result in changes to the modelling results in the following ways:

- Adult salmon and sea trout populations from other Rivers along the Welsh coast may come into contact with the scheme and potentially be impacted by it increasing the number of rivers to be assessed.
- As a result of 'straying' salmon and particularly sea trout adults may approach the scheme from potentially any seaward direction rather than just the west which is the situation currently modelled. This could result in changes to the model outputs in either direction.
- Sea trout are likely to be resident within the area for longer periods than currently modelled and as such have greater potential to interact with the scheme.
- The influence of Tawe barrage is likely to result in delayed adult entry into the freshwater environment and potentially increased 'straying' back into the estuary and coastal environment. It may also result in random entry into the estuary in relation to tidal state. These factors if incorporated into the model may influence the outputs.
- Factoring environmental conditions into the model in particular in relation to passage over the Tawe barrage may influence the outputs.

- Amending the input parameters for salmon and sea trout smolts from alternative local tracking studies may influence their route of passage within the Bay.
- Incorporating different swimming speeds in relation to size frequency and environmental conditions in particular temperature in to the model may influence the rate and route of passage through the Bay.

5 FISH TURBINE PASSAGE MODELLING (APPENDIX 9.4)

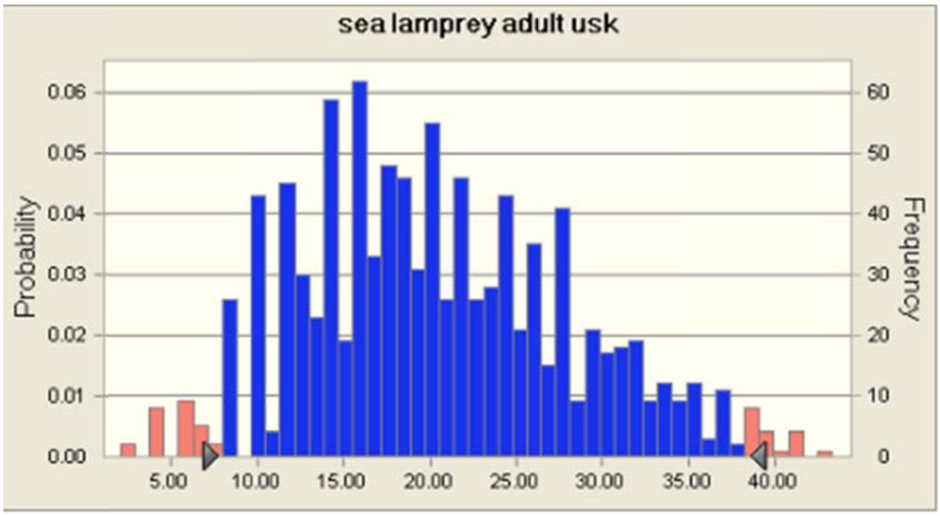
5.1 Model appropriateness and general method

The STRIKER fish turbine passage modelling approach adopted within this assessment is generally an appropriate technique for predicting quantitative estimates of fish mortality for a tidal power scheme. It is a similar modelling approach based on the original Von Raben method to that used for other tidal power scheme assessments including the operating Annapolis Royal development and the DECC Severn Tidal Power Scheme study options. Specific comments regarding the model parameters and setup are discussed in detail below.

Other relevant studies
Within the introduction, studies in relation to tidal barrages are discussed and a list of references given. Studies undertaken for DECC in relation to the Severn Tidal Power Scheme however, are notable exceptions which included a review of Fish Passage through Tidal Power Turbines (APEM, 2010a) and the development and running of a stochastic compound mortality model (APEM, 2010a & b). It should be noted that Andy Turnpenny of THA was a peer reviewer for the former document.

There is also no mention of the Annapolis Royal scheme in the Bay of Fundy, Canada. Although this scheme only has a single STRAFLO unit it has been generating since 1984 and a number of studies have been undertaken to monitor fish passage and mortality through the turbines, sluices and fishways including pre and post generation population estimates for some species. This site represents the best available information for an operating tidal turbine. It should be noted however, that comparison opportunities are limited as it has a differing turbine type, the turbine was a test unit and is not optimally sized for the physical characteristics of the location and has relatively inefficient operation due to its manual operation. Due to it being the only monitored operating site it does however, warrant some note in the Swansea scheme assessment.

Deterministic vs stochastic modelling approaches
The model used for the assessment is the STRIKER v.4 Turbine Fish Passage Model which is a version of the model specifically developed for tidal hydropower applications. It is a deterministic model with fixed input parameters per run of the model. A review of blade strike models as part of the Severn Tidal Power Scheme (APEM, 2010a) included consideration of both deterministic and stochastic models and where possible comparison of the results against empirical site specific data. A stochastic model operates within a Monte Carlo platform to enable variation of numerous parameters such as discharge, net head, flow, guide vane angle, fish orientation, fish behaviour, mutilation ratios, fish length and the number of potential passes over a specified range. When run over a series of iterations (usually 1,000) a range of potential predicted mortality rates can be provided to take account of inherent uncertainties and give indications of different levels of probability of a situation occurring (see Figure 5.1). Rather than just obtaining a single mortality probability figure this therefore takes account of inherent uncertainty in the modelling approach and its input parameters to provide a minimum and maximum mortality rate as well as a mean, to give an indication of the range of potential outcomes upon the populations.



Statistics:	Forecast values
Trials	1,000
Mean	20.68
Median	19.83
Mode	---
Standard Deviation	8.09
Variance	65.38
Skewness	0.5352
Kurtosis	3.18
Coeff. of Variability	0.3910
Minimum	2.05
Maximum	52.80
Range Width	50.75
Mean Std. Error	0.26

Percentiles:	Forecast values
0%	2.05
10%	11.32
20%	13.89
30%	15.79
40%	17.71
50%	19.82
60%	22.03
70%	24.25
80%	27.56
90%	31.73
100%	52.80

Figure 5.1 Example output from the stochastic blade strike model for the Severn Tidal Power Scheme (APEM, 2010b)

Ploskey and Carlson (2004) undertook a study to compare the predictions of a deterministic and stochastic version of Turnpenny's (2002) blade strike model with empirical field based experimental data from Powerhouse 1 of Bonneville Dam. This comparison concluded that stochastic modelling was deemed to result in closer outputs to empirical data than the deterministic model. It should be noted however, that the deterministic model was considered to overestimate predictions on average by 2 to 5 times. Deng *et al.* (2005) undertook a similar comparison between the two modelling approaches and bead trajectory and severity of collisions data from a 1:25 scale McNary Dam turbine model. Again the stochastic model was considered to more closely match the bead trial data and the deterministic model outputs were higher. In both cases the deterministic model overestimated strike probability at the hub zone. Although both of these studies were undertaken on freshwater hydropower developments they are large scale examples and as such provide a useful insight to a tidal turbine assessment.

Uncertainty and limitations

There are inherent limitations and uncertainty with any modelling assessment approach. For turbine passage modelling for a tidal power scheme this is enhanced by the fact that there are very few operating schemes and for those that do exist there is little empirical data. The behaviour of migratory fish in estuarine and bay environments is also not well known in addition to their potential interaction with a tidal power impoundment and its turbine and sluice structures. This appendix would benefit from text discussing uncertainty and limitations to allow the outputs of the modelling to be viewed in this context. The use of a more stochastic model to provide a range of potential probabilities would also assist with understanding the uncertainty and potential range of outcomes.

5.2 Mechanical injury

Fish orientation

The model assumes random orientation of fish as it passes through the turbine through the use of an average ‘apparent’ length and a factor of 0.67. An alternative method for accounting for this factor would be to have this input value as a variable function within a stochastic version of the model which would result in a range of final outputs. Although providing a range of outputs to assist with the assessment of uncertainty in the modelling approach it is unlikely however, to make a significant difference in the mean model output.

Vertical fish position

It is unclear from the information provided how the vertical position of the fish as it approaches the turbine and passes the blades has been accounted for within the model. It would appear from the model description however, that it is accounted for. This is a key factor which can be influenced by fish species and life stage and their swimming behaviour. In general higher mortality rates are observed for fish passing at the tip of the blade. It is noted however that the design being assessed here is a Minimum Gap Runner technology which has been documented to reduce the mortality of tip passing fish by up to 3% (Normandeau *et al*, 2000 cited in Ploskey *et al*., 2007) compared to a standard Kaplan design. For a horizontal turbine there is also the potential for swirl and as a result random orientation reducing the influence of species specific behaviour.

Abrasion, grinding and collision with fixed structures

It is agreed that it is not possible to quantitatively assess the potential injury and mortality rates resulting from abrasion, grinding or collision with fixed structures such as the guide vanes and draft piers. Collision with fixed structures however, is considered likely to increase as turbulence within the turbine increased. As the turbine moves away from optimal efficiency such as during flood tide generation the risk of this injury mechanism may therefore increase. The potential for injuries to be sustained may also be increased in a tidal power turbine than a riverine scheme due to the potential for biofouling and a resultant abrasive surface as can be observed at the La Rance scheme.

Figure 5.2 Evidence of biofouling and a resultant abrasive surface on the draft tube of a La Rance turbine (photo: Nicola Teague)

5.3 Pressure change

The formulae used within the STRIKER model to predict mortality rates from pressure change are appropriate for a study of this type. It is not however, clear what acclimation pressures were used within the assessment. It is assumed that the exposure pressures were taken from Figure 5 within this appendix from Turnpenny, 1998 which are again appropriate model parameters in the absence of specific Computational Fluid Dynamic (CFD) profiles for the turbine units proposed for this development.

5.4 Shear stress and turbulence

It is not specifically stated within this appendix what formulae or other values were used within the STRIKER model to predict mortality from shear stress. The experimental trials undertaken by Turnpenny *et al*., 1992 are however mentioned and as such it is assumed that the mortality formulae calculated from these trials was used (Turnpenny *et al*., 2000). If so, this is a suitable technique for predicting mortality from this factor of turbine passage in the absence of dedicated CFD modelling.

5.5 Cavitation

It is agreed that it is not possible to quantitatively predict mortality rates resulting from cavitation and that if designed and operated efficiently that mortality rates from this cause should be minimal.

5.6 Post Passage Effects

Although not specifically stated it would appear that potential mortality rates from post passage effects have not been quantitatively assessed within the STRIKER model. It is agreed that mortality rates cannot be predicted from this cause but should be acknowledged within the overall assessment of effects.

5.7 Model technical input data

Rotation rate

There appears to be an inconsistency in the document as to the rotation rate (rpm) of the turbines which is reported as 67rpm (maximum) on page 5 and 60rpm on page 18. This may however, just be due to a reporting of maximum and average. It is generally considered that the probability of a fish being struck by a blade increases as rotation rate increases. If the value of 67rpm is correct then this could result in an increased strike probability than those reported.

Operating performance

The operating performance of the turbines was considered within the model in relation to net head, flow rate and guide vane angle under both ebb and flood generation modes and the frequency of occurrence of each scenario. Although not built in as variable functions within the model this adds a stochastic feature to the otherwise deterministic model design.

5.8 Model biological input data

The conclusion that there are no size data for adult salmon and sea trout returning to the rivers is incorrect. The Panteg trap on the Tawe has produced salmon and sea trout size data that should be available through Natural Resources Wales (NRW). NRW (formerly Environment Agency Wales) annually collects individual size data on catches of both species declared through the rod catch return system. Such data for 2012 were used to produce Figure 4.1 above (2012 was used because it was the only set of data immediately to hand that covers both species). These size distribution data can be obtained from NRW. Note that data for the smallest sea trout category is gathered in a slightly different way from larger fish (the anglers are asked for a seasonal total, which is likely to be less accurate than the individual records for larger fish). Some caution is therefore needed to consider and if necessary adjust for size selective reporting. For that the modellers should refer to the NRW trap data from the Rivers Dee and Tamar. This need not be a major issue however: it depends on the application.

In Figure 5.3 the STRIKER size distributions are overlaid on the catch size distributions of Figure 4.1. The salmon distribution clearly under represents larger fish. For sea trout, the smallest size class is under represented and the middle sizes are over represented. In sea trout rod catch data from all rivers in Wales and North West Region the smaller size category are the most abundant. Notwithstanding some deviations through the age-related time of first maturation and return, this is to be expected in populations with stable recruitment. This is not seen in the STRIKER distribution, which looks more like a symmetrical distribution around some predetermined mean. That may have been the intention, but it does not mimic a returning sea trout population, which is usually more like that seen in the sea trout catch data (

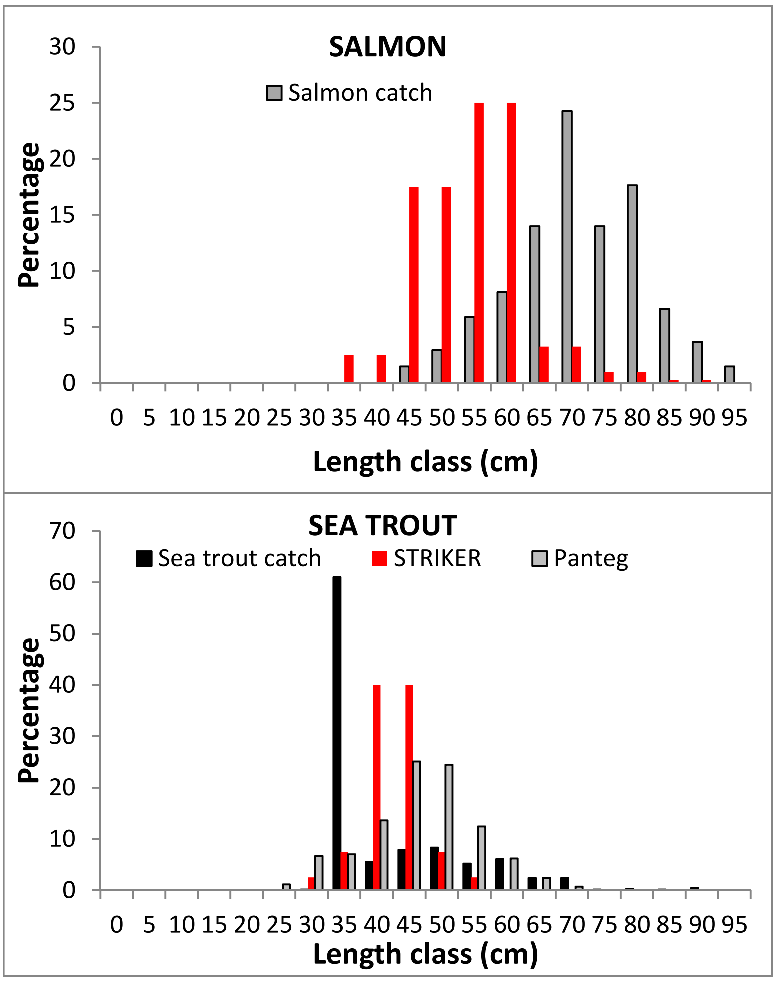


Figure **5.3**). Since the draft EIA was prepared the Panteg trap data (EA, 2002) have been made available with a NRW recommendation to use those instead of the original STRIKER data. These are shown for sea trout in Fig 5.3 and convey a distribution for fish >35cm similar to the catch data, but like the STRIKER data have a symmetrical structure. This suggests that the Panteg trap may be under-sampling the smaller whitling. This might be due to the location of the trap which is 18kms upstream of the Barrage, coupled with the generality that smaller sea trout tend to spawn in the lower reaches of rivers (Jonsson and Jonsson, 2006).

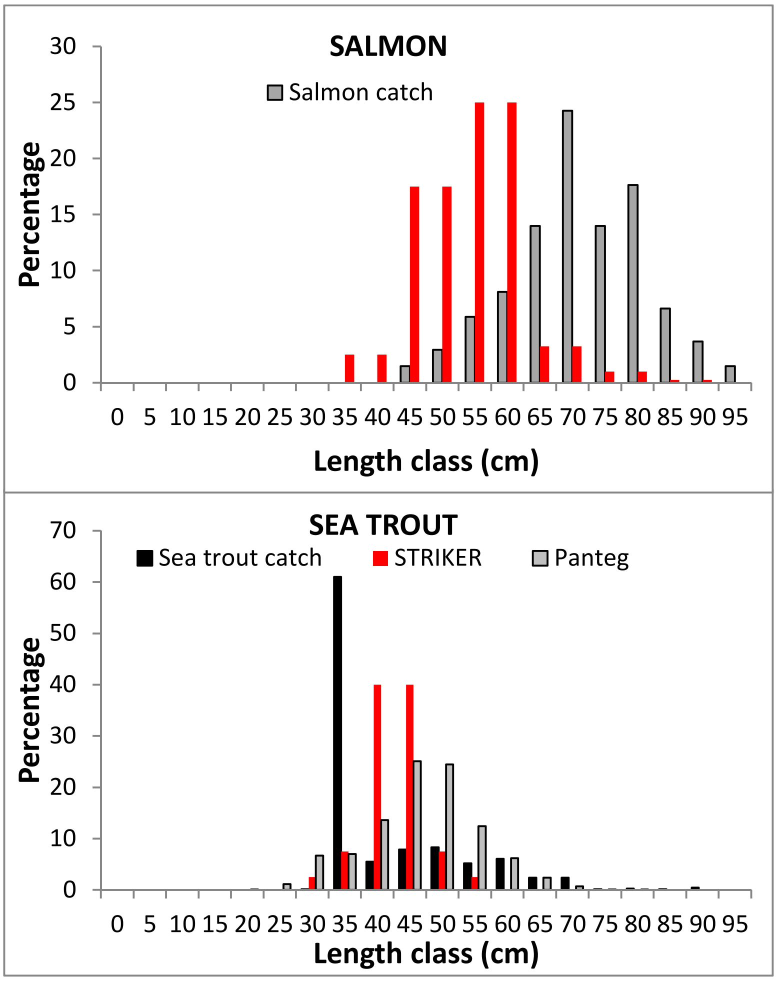


Figure 5.3 Size distribution data from observed 2012 rod catch returns (source EA), pooled for the Tawe, Neath and Afan (see also Fig 5) compared with the size distributions used in the STRIKER model (Table A2.1) and the Panteg data for sea trout

Smolt data are harder to find, but Cefas have recently assembled data for ICES and NASCO on life histories of salmon in English and Welsh rivers which might be informative.

For sea trout smolts, size data have been gathered from sites around the Irish Sea as part of the CSTP and showed that the average sea trout smolt length is around 180mm. Smolt age and size varies with latitude (age and size tending to with latitude (e.g. Jonson and Jonsson, 2006); but the data cover France and Spain (Harris and Milner, 2006) so it should be possible to establish realistic distribution statistics for the Swansea rivers. A salmon smolt size (presumed fork length?) range of 83-164mm is reported (p21) and seems about right (although 83mm is very small), however no sea trout smolt size data are reported. Note that salmon smolts are smaller than sea trout smolts of the same age. The STRIKER smolt size distribution was assumed to be the same for salmon and sea trout. The overall range (10-25cm) will cover all the smolts, but the distribution will have under-represented the larger sea trout.

Under representing larger size classes will have reduced the predicted mortality rates for mechanical injury in particular as mortality increases with increasing length. It is not possible however, without re-running the model to determine what level of effect altering the size classes would have on mortality predictions.

5.9 Model outputs and conclusions

All predictions of fish injury from the modelling outputs have been taken to represent mortality events, which is a recommended approach for modelling of this type. The main comments regarding the model outputs and conclusions mirror those discussed in section 5.1 in that the limitations and uncertainty in the modelling approach and data inputs are not discussed at all within the document. Furthermore, that the model is deterministic presenting single mortality rates for each species/lifestage only rather than a range of potential rates borne from the uncertainty in the modelling approach. Presenting a range of rates would provide a better indication of the uncertainty in the approach and allow a more informed interpretation of how the impacts upon the populations could in fact vary especially when combined with the further uncertainty within the outputs of the turbine encounter model.

There should be some acknowledgment within the conclusions that the predicted mortalities cannot be considered as complete compound mortalities due to the aspects discussed above for which it is not possible to quantitatively assess risk in particular cavitation and post passage effects and sluice passage discussed below. The predicted mortality rates should therefore be considered as minimum estimates as post passage effects in particular predation resulting from disorientation may well increase the observed mortality rates.

5.10 Sluice passage and injuries

There is no empirical information available from which to quantitatively inform the prediction of mortality rates from sluice passage. Any assessment could therefore only be qualitative.

6 FISH, INCLUDING RECREATIONAL AND COMMERCIAL FISHERIES (CHAPTER 9.0)

It is understood that the assessment in general has adopted a Rochdale Envelope approach whereby it is acknowledged that the design of the scheme and the assessment of environmental impacts is an iterative process and the exact design is still evolving. In this situation the EIA usually therefore adopts a cautions worse case approach to the assessment. This is often complex with differing scenarios having different implications for the different groups of receptors under consideration.

It is not clear from the information to date how a worse case approach has been adopted in relation to the assessment of the design of the scheme upon fish. In the absence of this information it is therefore assumed that the alignment, design and operation of the turbines in particular will not alter for the final scheme in a way that could potentially result in greater impact upon migratory fish populations.

It is recommended that the final EIA details how the scheme assessed represents the worse case for the fish receptors for clarity.

6.1 Section 9.4.3 Study area

See section 3.1 above for text relating to study area and the rivers included within the far-field zone.

6.2 Section 9.4.8 Assessment of the significance of fish mortality through tidal turbines

There is a precedent in the UK for assessment of tidal range power schemes on fish, including, migratory salmonids in particular the DECC Severn Tidal Power Scheme (APEM 2010c). In that assessment matrix projection models were used to model the effects of turbines on salmon populations, in addition taking into account the long term effects of climate change to explore those cumulative effects during the lifetime of the scheme. Leslie matrix projection models were used based on the approach used for turbine strike mortality in a freshwater HEP context (Ferguson *et al*.,2008; Lundqvist *et al*., 2008), but incorporating density-dependent freshwater mortality and parameterised realistically for the Severn estuary salmon stocks. Such an approach should be possible for salmon in relation to this scheme. Sea trout may be more problematic because of the complexity of their life cycle and the difficulty of parameterisation (Ferguson *et al*., 2008).

The application of life history-based models would recognise that the actual effect on stocks is not a function of just the number of fish killed, but of the number of eggs lost and the translation of that into the longer term rate population increase. Numbers alone may underestimate effects if mortality is positively size selective.

For sea trout a simpler approach may help in which the losses are enumerated not by numbers but by future life time egg losses of killed fish. Larger sea trout tend to be predominantly female, and thus to carry more eggs than smaller fish. An example of how this might be done for sea trout is shown below, using data from the Celtic Sea Trout Project. In this case the rod catch size distribution data for 2012 (Fig 6) were used. Loss estimates were reworked using data summarised in the Report Table A2.1, in which the total turbine-related loss was 7.6%. The % mortality rate (%M) was extended to the wider size distribution of the catch data by the equation %M = 0.2069. length (cm) - 0.6914 (established from the reported %M data in Table A2.1). Future lifetime egg deposition (LTEGGS) estimates were available for the River Tywi (based on survival, sex ratio and maturation derived through the CSTP) using the equation: LTEGGS = $(-70.523.X^2)+(1867.5.X) -1879$, where X = mean wt(lbs).

The estimates of *total* % loss were surprisingly similar for the two approaches (length weighted vs egg weighted loss), and for the two size distributions (catch vs STRIKER). The egg weighted method gave marginally higher losses as expected (10.8% vs 8.5%for the 2012 size data for example (Figure 6.1). The spread of losses over the size ranges were however, different due to the combined effects of the initial size distributions, inflated by the LTEGG-size relationship (Figure 6.1) and the size selective turbine mortality. The potential is for the impact on the recruitment potential from larger fish to be underestimated by the STRIKER model, using just size frequency data and with the assumed distribution.

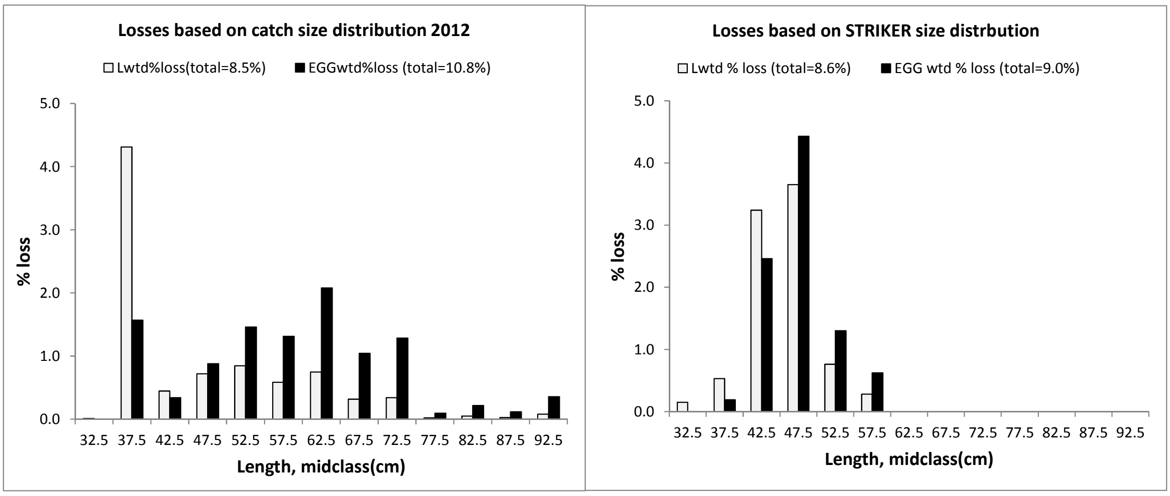


Figure 6.1 % loss due to turbine related mortality, based on observed catch data (left) and STRIKER assumed size distributions (right). While the total losses were similar (range 8.5-10.8%) the EGG weighted approach resulted in losses being distributed more across the larger fish of both size distributions

The significance of such size-bias effects is not however, known. When combined with the encounter rates (assuming those are accurate) the final losses are still small and not, on their own, likely to cause detectable long term changes in the salmonid stocks. The losses however, need to be set alongside effects of potentially increased predation and there is considerable uncertainty in all these estimates. It is in the area of the encounter rates in particular where there is most uncertainty and even if it may not be possible to model the uncertainty some greater recognition of this is advised.

In light of the discussions above and given the inherent uncertainty in quantitatively assessing impacts where multiple modelling approaches are required with uncertain input parameters and a number of impacts that can only be qualitatively assessed such as predation, a more qualitative assessment criteria may be more appropriate in this instance than the qualitative magnitudes used. An example of such parameters used within the DECC Severn Tidal Power Scheme study are provided within Table 6.1 as an example.

Table 6.1 Thresholds for magnitude of effects from DECC Severn Tidal Power Scheme

Magnitude	Definition
High	A permanent or long-term effect on the extent/integrity of a species population or assemblage. If adverse, this is likely to threaten its sustainability/favourable conservation status; if beneficial, this is likely to enhance its conservation status
Medium	A permanent or long-term effect on the integrity of a species population or assemblage. If adverse, this is unlikely to threaten its sustainability/favourable conservation status; if beneficial, this is likely to be sustainable but is unlikely to enhance its conservation status
Low	A permanent or long-term reversible effect on the integrity of a species population or assemblage whose magnitude is detectable but will not threaten or enhance its integrity
Very Low	A short-term but reversible effect on the integrity of a species population or assemblage that is within the normal range

6.3 Section 9.5.3 Operational phase effects

Increased predation

There is discussion regarding potential increased predation upon smolts from bass which is ruled out on the basis of limited seasonal overlap with bass. There is however, no discussion of potential predation from other species upon all life stages including marine mammals known to use the area such as harbour porpoise and grey seals. There is also no consideration of avian predators especially those that could utilise the lagoon wall as an attack point. This impact upon disoriented fish passing out of the turbines requires further consideration and at present may have been under estimated.

IBM fish encounter modelling

Detailed discussion of this modelling approach is contained within section 4 above. Only additional information contained within this chapter not included within appendix 9.3 is discussed below.

Table 9.13 provides information on the behaviours modelled within the IBM for each of the fish species/groups. This indicates that the ontogenic target of the model for all life stages of salmon and sea trout was migration in and out of the rivers Tawe and Neath, Wye, Usk and Severn. There is no indication however, within appendix 9.3 of this being the case. The model does not appear to go outside of Swansea Bay to encompass the Wye and Usk for instance other than a brief mention of an additional olfactory cue from east to west. There is however, no presentation of the outputs of this addition of conclusions from them in terms of potential impacts upon the populations.

It is considered unlikely that the distinct split between adults homing to the Tawe and Neath as demonstrated by Figure 9.15 in this chapter would occur in reality without some element of searching and 'straying' behaviour. A less distinctive splitting behaviour could result in increased interaction with the turbines and resultant impacts.

It is acknowledged in 9.5.3.37 that Tawe Barrage is likely to have a significant effect on migratory fish movement but no further comment is given to how if at all this was considered within the model or the model outputs and resultant impact assessment.

Fish modelling for designated sites

There is no mention of the Severn Estuary European designated sites (SAC and Ramsar) within the list of designated sites.

Fish injury mechanisms in tidal power turbines

The results in table 9.18 represent those impacts from passage through the turbines that can be quantified and forms the basis of the impact assessment judgements. It is recommended that this section also contain some discussion of the fact that these are effectively minimum estimates of mortality as they do not take account of other impacts for which it is not possible to determine a quantitative assessment of impact such as sluice passage, predation etc.

Summary of impacts on fish and shellfish

In the tables summarising the potential environmental effects on salmon and sea trout some information is not yet complete within the version reviewed. In particular information is missing for significance, confidence, mitigation and residual significance and confidence level for a number of operational phase impacts such as; Increased predation and entrainment and injury from turbines.

Presumably on the basis of the assessment criteria detailed in table 9.5 of the chapter with all mortality rates coming out as less than 1% impacts for entrainment and injury from turbines has been classed as Low magnitude. As discussed above it is recommended that where possible these impacts are assessed in the context of impacts upon the populations.

7 MITIGATION (OFFSETTING)

7.1 Chapter 9

There are a number of mitigation measures identified within chapter 9 of the draft EIA. Those suitable for mitigating impacts upon salmon and sea trout are as follows:

- Waterborne noise – measures to reduce the impact of underwater noise and vibration during construction are discussed in particular low-noise piling techniques where feasible and 'soft-start' procedures. These are both valid techniques for reducing impacts upon fish. In addition however, other options could also be considered such as using sound absorption/reflection techniques such as bubble screens. The most appropriate techniques would however, have to be researched further for the specific techniques to be used for this scheme.
- Behavioural fish guidance – The use of an Acoustic Fish Deterrent (AFD) has been proposed for the scheme and fish mortality calculated on the basis of its use which it is assumed are the mortality rates that will be taken forward for the residual impacts assessment. It is agreed that in some circumstances high deflection efficiencies can be observed for salmonids with appropriately designed and operated acoustic deterrent systems. There is no discussion however, of how the examples provided in the text relate to such a large and likely unprecedented situation as is likely to be experienced for the Swansea lagoon. Consideration would need to be given to the approach velocities at the point at which the acoustic deterrents could be realistically operated in front of the turbines. Approach velocities will have to be kept low to allow fish that respond to the deterrent to alter their behaviour and direction of travel and move away from the deterrent and as a result the turbines. More information would therefore have to be provided on the intended design and operation of the scheme and the approach velocities that would be experienced before expected efficiencies can realistically be applied to the assessment. It is considered likely however, that due to the likely unprecedented scale that would be required in this case and the additional complications resulting from the environmental conditions that efficiencies could be lower than observed elsewhere. Results from any similar case studies with data on salmonids would be beneficial for assessing whether the deflection efficiencies stated could realistically be achieved in this case.
- Suspended sediment and deposition – the measures proposed look to be appropriate for this scheme.
- Increases in light emissions - the measures proposed look to be appropriate for this scheme.

7.2 Potential opportunities

If impacts are deemed to be below moderate and have no significant impact upon the populations then there is no legal requirement to undertake mitigation for the scheme.

If measures are required then options might include activities on “impacted” rivers or offsets elsewhere. In any event the most crucial recommendation is that the associated monitoring is properly designed to detect the effectiveness of the mitigation as well as to evaluate residual impacts of the scheme, with the intention of follow-up adaptive management, as far as the scheme design allows. Further, the mitigation should be planned jointly with the stakeholders because early inclusion and ownership are essential to successful long term delivery.

In principle, mitigation should be designed to compensate for the anticipated unavoidable significant losses from the Lagoon Scheme. These have not yet been estimated satisfactorily; but should be based on population models as far as data and other constraints allow and should be assessed to optimise the spatial distribution of mitigation, within and between catchments.

Potential options that can be considered as ‘mitigation’ or more commonly now ‘offsetting’ include measures to prevent impacts, reduce them or offset them. Measures to prevent and reduce impacts are usually directly connected with the design and operation of the scheme where as offsetting measures are in connection with the population as a whole and may not be at all associated with the scheme itself.

Potential options under each of the categories above are discussed below. It must be noted however, that these are discussed on the basis of the limited information available to date and would need to be assessed in more detail for this specific scheme with greater information on the planned design and operational regime of the scheme.

Options to prevent and reduce impacts

Potential prevent and reduce options in addition to those already identified within chapter 9 may include:

- Timing of construction works – avoiding key migration or residence periods may prevent or reduce any impacts resulting from construction works.

- Timing of operational generation – it may be possible for some schemes to alter the timing of generation to reduce impacts during key sensitive periods. This is unlikely to be realistic for a tidal power scheme however, as there are so many different species and life stages to consider and generation is obviously dictated by the tidal cycle. It is unlikely to be economically acceptable to alter generation in any significant way as to have a true reduction upon impacts.

- Efficiency of operation – As efficiency of the turbines reduces injuries and mortality of fish passing through them tends to also increase. It is therefore recommended that where possible periods of lower efficiency are reduced or avoided to decrease impacts upon fish passing through the turbines.

- Passage easement – in some cases there are advantages to easing passage in and out of the lagoon through measures such as increased permeability and dedicated fish passage structures. The preference for this scheme however, would most likely to be to keep migratory salmonids out and as such this may not be a beneficial measure in this circumstance.

- Fish exclusion and diversion structures – The use of AFD's have been proposed for the scheme and are discussed in section 7.1 above. Alternative fish exclusion measures for migratory salmonids would be the operation of physical screen structures. Further information would be required however, to assess whether this would be a feasible option in relation to the approach velocities likely to be experienced in front of the turbines. Given the scale of the scheme this would likely be a complex and costly (both during construction and ongoing operation) option that may not be practical in terms of effective and safe fish protection.

- Predator control – If predation is considered to be a significant impact upon migratory salmonid populations as a result of the scheme then there may be some benefit in assessing options for predator control where possible. Acceptable long-term options for this are however likely to be limited.

Offsetting options

It may be possible to improve salmonid populations in ways not directly connected with the scheme to effectively mitigate for losses resulting from it. The majority of effective measures are likely to be most feasible within the freshwater environment. It should be noted however, that improvements to freshwater habitats are commonly conducted within river catchments as part of ongoing management programmes implemented by the statutory authorities and others to meet the requirements of national and European legislation such as the Water Framework Directive to meet Good Ecological Status/Potential. Measures proposed as mitigation under this scheme may therefore represent an additionality conflict as there may already be an obligation to undertake them under another driver.

For example the lower reach of the Tawe which is designated as a Heavily Modified Water Body due to flood protection is currently graded as moderate ecological potential although with no specific fish assessment. It is therefore likely that measures will need to be undertaken to reach the intended classification of good ecological potential by 2027 which may include measures to improve fish stocks. Given the presence of Tawe Barrage it is likely that this would include an element of improved fish passage past this structure. There may not however, be funds available to undertake this work. Fish passage easement past this structure as a mitigation measure may therefore have additionality conflict as the measure should be undertaken in the future anyway. Many measures identified as potential mitigation options for this scheme would therefore have to be discussed with NRW to determine if they are realistic options.

Habitat restoration

<u>Barrier removal</u>

The extent and location of these will determine their value in increasing fish production. NRW has a barrier database and doubtless these opportunities will be apparent to them. There is likely to be a lot of scope in the target rivers, which have been subject to human influence for centuries. A key aspect to consider is the ranking of factors limiting fish passage. These might include flow regimes or water quality barriers as well as downstream physical barriers. Cost benefit appraisal is vital and there is Defra guidance on this as well as a functioning EA fish pass/barrier group.

Riparian and in channel works to increase carrying capacity

Evaluation of the potential of the opportunities for in channel works will require a survey of the existing catchments to assess and quantify habitat quality. As for barriers NRW should have a full inventory of the opportunities, but may not have this in a quantified form that allows estimation of the benefits accruing. Note that there are many other, wider ecological benefits from restoring naturalness to banks beyond simply salmonid production.

Habitat enhancement

"Enhancement" takes improvement beyond the notionally pristine natural state of the rivers. This might include increasing in-channel habitat complexity by installing structures, or installation of specific habitat types deemed to be bottle necks such as spawning beds. These can be costly to install and to maintain; therefore the need and cost-effectiveness should be carefully assessed. It is not normally as useful as habitat "restoration".

Stocking

Likely to be a popular option with anglers, because it appears to be simple and effective. It can work and has a place, but has substantial costs and can bring significant ecological and genetic risks. It is essential to seek good objective advice on this and any stocking should be managed as part of an agreed catchment scale stocking programme, and always as a second preferred option after habitat management. Stocking of badly reared fish or of any fish into waters having poor environmental quality from whatever cause is a waste of money. There are very many advisory texts and a recent (2013) AST workshop on this topic.

Fishing quality enhancement

Physical access to angling locations may be limited in some sections and this will require negotiation with the riparian interests, local angling owners, clubs, NRW and river trusts. Caution is needed to avoid over-exploitation (manageable by catch controls) and to minimise conflicts of interests amongst fishery types (e.g. trout *vs* salmon) and other water users.

8 MONITORING

8.1 Monitoring of impacts and a basis for compensation claims

Article 5(3) of the European EIA Directive contains no explicit monitoring requirements, but these are implicit in the identification of "measures to prevent, reduce and where possible offset any significant adverse effects". Predicted impacts should be monitored as well as delivery of commitments in the Environmental Statement. It is likely that the Competent Authorities will also attach monitoring conditions to the scheme consents. Furthermore, best practice for adaptive management necessitates an appropriate, well designed and effective monitoring programme to inform the environmental optimisation of the scheme.

The mitigation measures proposed for this scheme should ensure that no significant impacts arise. Nevertheless residual impacts may arise. Pre-agreed compensation needs to be assessed for its effectiveness (IEEM, 2010). Other factors could lead to changes in fisheries which might lead to unexpected compensation claims and monitoring should be able to disentangle causal factors.

A good monitoring programme is therefore, beneficial at several levels and is integral to the Compensation, Mitigation and Monitoring Agreement (CMMA) (IEEM, 2010) and is particularly desirable in this case, which is the first of such large lagoon schemes in the British Isles.

Potential impacts of the scheme arise in two stages: construction and long term operations. The monitoring of the impacts of the scheme requires:

- Identification of agreed indicators and their geographical extent that reflect the priority receptors, or acceptable surrogates.
- Setting of predetermined performance targets
- A statistically scoped survey programme of performance with predetermined levels of compliance that identify significant change in the face of the inevitable uncertainty.
- A feedback mechanism that unambiguously links monitoring results to changes in operational practice or mitigation.
- A transparent and prompt reporting procedure

These principles apply to construction and operational phases, but the time scale and detail of monitoring would be different and appropriate to each.

Indicators

The salmonid receptors (salmon and sea trout) each have two components:

- The fishery (the exploitation through catch and release or harvest) of the fish stock
- The fish stocks (comprising multiple populations)

Potential indicators with a qualitative ranking of their value for the context of this scheme and likely feasibility are detailed within Table 8.1 below.

Table 8.1 Summary of potential monitoring indicators for salmonid fisheries and stocks. Rankings are based on combination of information value and feasibility (1 High, 2 Medium)

Receptor	Attribute	Indicators	Method / data source	Ranking	Comment
Fisheries	Rod catch (EA stats)	Annual and Monthly catch Size (wt) distribution	EA/NRW catch statistics, using individual fish records	1	For each of the Tawe, Neath, Afan AND local S. Wales rivers as controls (and for other indicators)
	Rod catch per effort CPUE (EA stats)	Annual effort from EA/NRW statistics	EA/NRW annual statistics (see note)	1	At present effort (e.g. angler days) is only collected on annual basis. Monthly or daily would be highly desirable hence log books.
	Catch and CPUE (log books)	Daily to annual		2	Log books were used on Tawe 1988-2002. Hard to sustain, labour intensive but useful.
	Participation	Local and visitor numbers Licence sales Days fished Satisfaction rating	EA/NRW licence sales, Socio-economic survey	2	Need to identify the indicators usefully within scheme impact
Stocks	Adult run	Catch Catch per effort Catch size distribution Panteg trap (Tawe only)		1	Statistical modelling of confounding factors (e.g. effort, exploitation rate, river flow) is essential. NB Panteg trap is high in system (18kms upstream of Swansea) may not cover all returning groups (this needs to be assessed) and cannot be operated at high flows
	Egg deposition	Annual eggs / area	Use EA/Cefas annual statistics	1	Salmon only

	Juvenile populations	Density (N/area) of fish	Timed fry surveys	1	EF surveys must be fully statistically scoped to assess power AND be stratified by a one-off catchment scale habitat survey
	Smolt production	Density of parr (age 1,2,3) Annual (April May) production of pre-smolts	Quantitative electrofishing surveys	2	(ditto, juvenile EF). Data to be reported for stratified sub-catchments and summed
	Smolt output	Annual numbers of smolts from whole river, or proportionally important sub-catchments	Screw traps	2	Valuable when they work; but costly to run and prone to river flow vulnerability
	Smolt mortality	Annual encounters and losses through turbine strike	Netting surveys to assess numbers of fish passing through the turbines and their survival, Video of turbines, Tracking studies, Sensor fish monitoring	1	It may be possible to assess the number of fish passing through the turbines and the subsequent survival and injuries of those individuals through a netting capture technique. Mechanisms for accounting for handling mortalities and injuries would have to be considered within the monitoring design. It is recommended that consideration of how this could be done is incorporated into the design of the scheme to allow necessary net frames etc. to be built into the design rather than having to try and retrofit at a later date. Fish interactions with the turbines could also be monitored through a visual assessment of their presence and behaviour with the use of video or DIDSON type cameras depending on water clarity. Tracking studies could also be undertaken

					to monitor the route of passage of individuals passed or into the scheme. If monitoring of fish passing through the turbines was not possible it may be appropriate to use a surrogate 'sensor fish' which is an electronic device which can be passed through a turbine and detect encounters of blade strike, shear, pressure etc. which could then be compared with biological data to determine if the rates of injury/mortality calculated using the STRIKER model were accurate. It would not however, give an indication of the number of individuals passing through the turbines and as such would have to be used in combination with another technique such as tracking.
	Adult mortality	Annual encounters and losses through turbine strike	Netting surveys to assess numbers of fish passing through the turbines and their survival, Video of turbines	1	As above.

Some of the detail in Table 8.1 would vary between salmon and trout because their life cycles are different in important aspects. Sea trout have partially migrating populations (Chapman *et al*., 2012) and in the freshwater juvenile stage are indistinguishable from resident brown trout; they are in fact the same species and interbreed. The boundaries between anadromous migrants and non-migrants are imprecise and so parr surveys are less valuable for estimating future smolt production than in the case of salmon. Costs can be attached to these options, but the minimum would comprise:

1. ***The rod catch and effort*** (numbers and size distributions). They service both fisheries and stocks evaluation; but note the essential inclusion of the factor analysis for the stock application.
2. ***Panteg trap*** (assuming appropriate review, *cf* its functionality and application to catchment scale assessment has been questioned, Environment Agency(2002))
3. ***The time fry surveys***, appropriately stratified
4. ***The salmon egg deposition indices***, these are produced anyway by Cefas/ NRW

Fisheries monitoring has suffered significant decline from reduced resourcing in NRW and its predecessors, yet is necessary for proper delivery of most environmental and fisheries management. Given the growing body of opinion that new developments should try to deliver net ecological gain (IEEM, 2010) the wider benefits of a robust monitoring programme extend beyond the immediate scheme. Also, there is a body of motived stakeholders who could be brought collaboratively into some aspects of monitoring (trapping, logbooks, electro-fishing) and this is highly recommended.

8.2 Monitoring the effectiveness of mitigation measures

Many of the monitoring options discussed above would also aid in assessing the effectiveness of mitigation measures whilst otherwise would require dedicated specific monitoring techniques. Monitoring techniques would need to be defined once specific mitigation measures are identified and developed.

9 STATEMENT OF TRUTH

We confirm that insofar as the facts stated in our report are within our own knowledge, we have made clear which they are and we believe them to be true, and that the opinions we have expressed represent our true and complete professional opinion.

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