Technical Note for AEMP: How Turbine Passage Mortality Trigger Levels will be Determined

1.0 Introduction

1.0.0.1 TLSB are proposing to build a Tidal Lagoon in Swansea Bay. Monitoring through an Adaptive Environmental Management Plan (AEMP) will be undertaken as part of the Project. The following technical note has been produced in support of the development of an agreed framework for determining turbine passage mortality. Once agreed, further detail will be developed where necessary and this will form part of the AEMP.

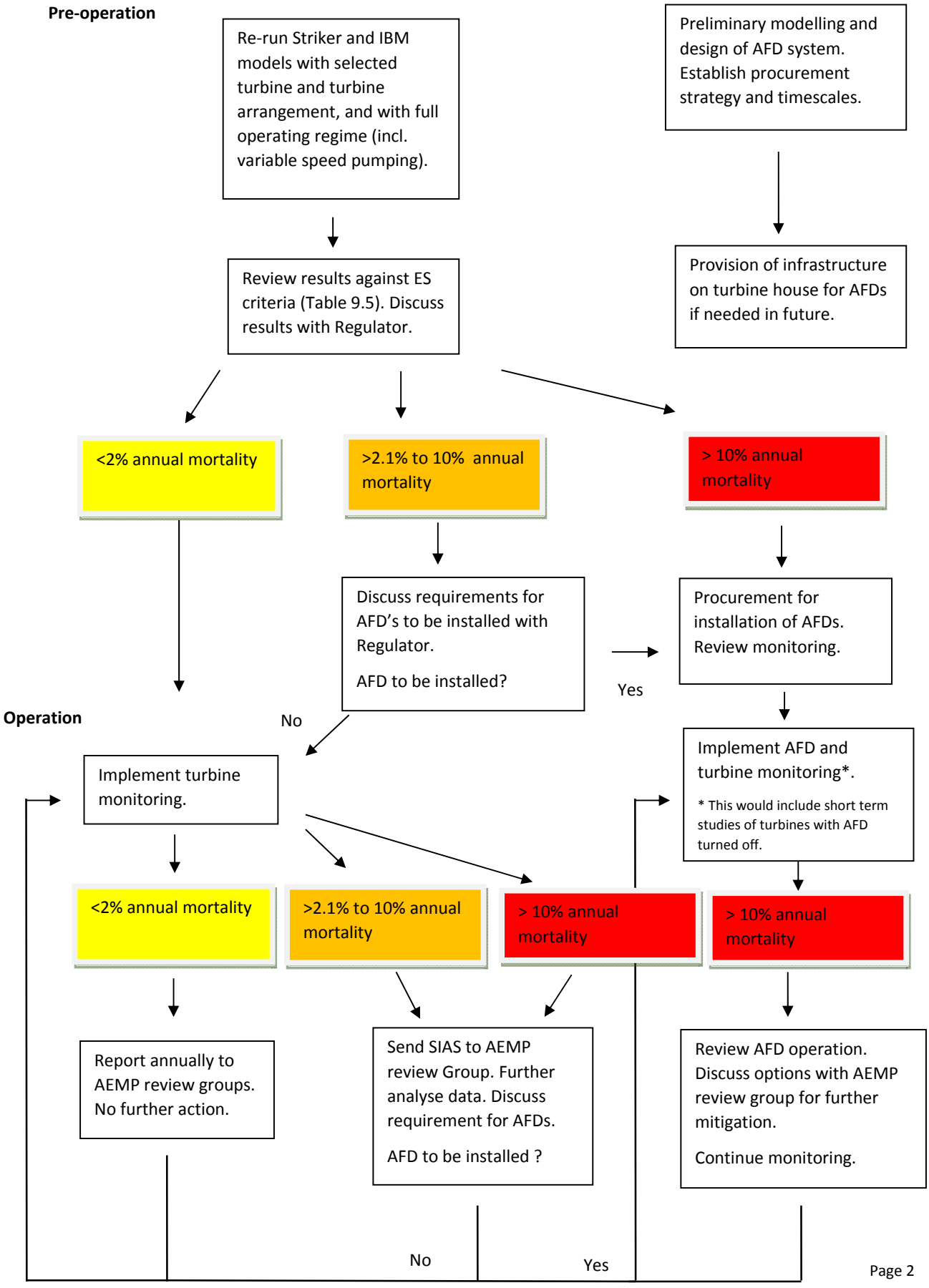
1.0.0.2 As outlined in Section 8.3.1 of AEMPr4, Objective F1 is to assess fish passage through the turbines. The following section considers how fish mortalities, estimated from turbine entrainment monitoring, as specified within the AEMP, will be assessed against the levels predicted within the ES (Table 9.22) and the subsequent revisions associated with turbine detailed design. Whereas the injury rates shown in these assessment outputs are given as percentages of the stock injured annually, the entrainment monitoring methods described in the AEMP will yield numbers affected annually. In order to represent these figures as percentages, some estimate of the stock size must be used. Presented below are the sources of information and approach TLSB will use to derive these figures. The data sources used will be reviewed at the time of the monitoring assessment to ensure that the most relevant and up-to-date figures are used.

1.0.0.3 Assessment criteria for turbine passage are given in Environmental Statement (TLSB, 2014) Table 9.5 (below). Based on this, an annual mortality rate of 2.1% or above is deemed to have a Medium Impact Magnitude and levels above this will trigger further requirements, such as fitting of fish deterrent systems at the turbine house. The flow chart below sets out the decision making process.

Table 9.5 Assessment criteria for turbine passage

Impact Magnitude	Annual Mortality Rate Due to Project
High	> 10 %
Medium	2.1 - 10 %
Low	1 - 2.0 %
Negligible	< 1 %

1.0.0.4 Since data sources and stock assessment approaches are different for migratory fish stocks versus commercial marine stocks, the two groups are treated separately below. Tables 1 to 3 summarise how stock data figures will be derived for assessment of turbine passage mortality estimates. The process of estimating turbine passage mortality will be described in a separate note.


Pre-operation
Re-run Striker and IBM models with selected turbine and turbine arrangement, and with full operating regime (incl. variable speed pumping).
Review results against ES criteria (Table 9.5). Discuss results with Regulator.
Preliminary modelling and design of AFD system. Establish procurement strategy and timescales.
Provision of infrastructure on turbine house for AFDs if needed in future.
<2% annual mortality
>2.1% to 10% annual mortality
> 10% annual mortality
Discuss requirements for AFD's to be installed with Regulator.
AFD to be installed?
Yes
No
Procurement for installation of AFDs. Review monitoring.
Operation
Implement turbine monitoring.
Implement AFD and turbine monitoring*.
* This would include short term studies of turbines with AFD turned off.
<2% annual mortality
>2.1% to 10% annual mortality
> 10% annual mortality
> 10% annual mortality
Report annually to AEMP review groups. No further action.
Send SIAS to AEMP review Group. Further analyse data. Discuss requirement for AFDs.
AFD to be installed ?
Review AFD operation. Discuss options with AEMP review group for further mitigation.
Continue monitoring.
No
Yes

2.0 Migratory Fish

2.0.0.1 Tables 1 and 2 list the migratory species that pass through Swansea Bay and which have been subject to turbine entrainment modelling (IBM + STRIKERv4 models) with the ES.

2.1 Salmon and sea trout adults

2.1.0.1 There are currently no formal stock size data for salmon and sea trout adult annual returns on the rivers Tawe, Neath and Afan, and no currently available fish trap or counter data for these rivers. Available data include:

- Rod catch records over 30+ years for all three rivers
- Panteg Trap data 1991-2001
- Afan Green Park fish pass video data.

2.1.0.2 Panteg trap data are not considered sufficiently recent to use for this application and at present there are no formal counts available from the Green Park video records. This leaves rod catch data as the main data source.

2.1.0.3 Rod catch data can be used to approximate adult returns provided that two quantities are known:

1. The exploitation rate of the stock (*U*)
2. Rod catch reporting rate (*R*).

2.1.0.4 From this adult sock size *N* is estimated as:

$$N = Rod\ Catch/(U * R)$$

2.1.0.5 There are no published values of these parameters (*U* and *R*) for the rivers Tawe, Neath and Afan, nor for other rivers in the region and so figures from elsewhere must be used.

2.1.0.6 Milner *et al*. (2000) cite values of *U* in the range 0.09 to 0.42 for British rivers and a value of *R* of 0.91. More recent values of *U* are available from annual salmon stock assessments for England and Wales, the most recent one being available for 2013 (Cefas, 2014). This gives a 5-year mean of *U* ranging from 0.03 to 0.36. A mid-range value of *U*= 0.20 has been adopted for present purposes. In this case, *N* can be calculated by multiplying rod catch returns by a factor of 5.5. Data are summarised in Table 1.

2.1.0.7 For sea trout, Solomon (1995) gives an exploitation rate on the river Tawe of 0.30 for the year 1992. No figures for the rivers Neath and Afan are available, and so the value of 0.30 has been assumed in all three cases. No figures are available for *R* on any of the three rivers but it is reasonable to assume reporting rate would be similar to that for salmon rod catches and a value of *R*=0.91 has been assumed (Table 1).

2.1.0.8 For assessment purposes, the annual mortality of adult salmon and sea trout numbers associated with turbine passage will be estimated from hydroacoustic/netting surveys and represented as a percentage of adult returns as described above. These will be compared with trigger levels shown in ES Table 9.5.

2.2 Salmon and sea trout smolts

2.2.0.1 No counting of smolts occurs on any of the Swansea Bay rivers and therefore again only approximations can be made, in this case using marine survival rates for smolts measured elsewhere. These are only available from a small number of UK rivers, on which counting facilities are operated for both outmigrating smolts and in-migrating adults. In Wales, this occurs only on the River Dee, and data from this source will be used to estimate smolt escapement.

2.2.1 Salmon smolts

2.2.1.1 Data on marine survivals of salmon smolts are presented for the Dee in Cefas (2011 *et seq*.) annual reports. These are presented separately for 1 sea-winter (1SW) and multi-sea-winter (MSW) fish and the most recent data available indicate a 2:1 split between 1SW and MSW fish:

Year	**% 1SW**	**%MSW**
2011	66	34
2012	66	34
2014	62	38

2.2.1.2 Average smolt to adult return survival rates for the period 2007- 2011 are shown as 3% for 1SW fish and 0.8% for MSW fish. A 2:1 weighted mean of these two figures gives an average of 2.27% marine survival across all adults. Using this figure, salmon smolt numbers can be estimated from returning adult numbers (as presented above) as:

No. of salmon smolts = No. of returning adults x 100/2.27,

or by multiplying the estimated adult returns by 44.05

2.2.2 Sea trout smolts

2.2.2.1 Sea trout smolt-to-adult survival is generally higher, owing to the shorter time spent at sea. Data from the River Dee (Davidson and Cove, 2011) indicates a 6-year average marine survival of 16.3%.

No. of sea trout smolts = No. of returning adults x 100/16.3,

or by multiplying the estimated adult returns by 6.12.

2.2.2.2 The above information is summarised in Table 1.

Table 1 Summary of data used for Salmonids trigger levels

Fish Species	Source of Data	Data	Figure for Comparison with Target Levels
Atlantic salmon adult returns	Rod catch data, average of most recent 5 yrs (source: NRW)	Rod catch reporting rate *R*=0.91 Stock exploitation rate, *U*= 0.03-0.36 (assume *U*=0.20) (source: Milner *et al*., 2000) **Multiply mean rod catch by 5.5 to estimate adult returns**	Estimated annual mortality of adult salmon and sea trout numbers associated with turbine passage as a percentage of adult returns
Sea trout adult returns	Rod catch data, average of most recent 5 yrs (source: NRW)	Assume rod catch reporting rate *R*=0.91 as for salmon Stock exploitation rate, *U*= 0.30 (source: Solomon, 1995, 2000) **Multiply mean rod catch by 5.5**	
Atlantic salmon smolt escapement	R. Dee smolt marine survival data (Cefas 2012*et seq.*). Adult returns estimated from rod catch data., average of most recent 5 yrs (source: NRW)	No. of salmon smolts = No. of returning adults x 100/2.27, i.e. **by multiplying the estimated adult returns by 44.05**	Estimated annual mortality of salmon and sea trout smolt numbers associated with turbine passage as a percentage of estimated smolt escapement
Sea trout smolt escapement	R. Dee smolt marine survival data (Davidson, 2010). Adult returns estimated from rod catch data., average of most recent 5 yrs (source: NRW)	No. of sea trout smolts = No. of returning adults x 100/16.3, i.e. **by multiplying the estimated adult returns by 6.12**	

2.3 European eel

2.3.0.1 The Rivers Tawe, Neath and Afan fall within the Defra (2010) Eel Management Plan for the Western Wales River Basin District, which reviewed the status of its eel stocks. Eel populations have not been well studied in the area and eels within the rivers are known to be under-represented in EA/NRW's routine electrofishing surveys. There is no reliable estimate of stock in these rivers and no estimate of glass eel recruitment. The Management plan therefore adopted data from the better-studied River Wnion which falls within the District as a surrogate for the whole District, which has a catchment area of 16,653 km^2 (Defra, 2010). From this a silver eel escapement for the whole District of 93.2 tonnes per year was estimated, with no subdivision by individual river catchment.

2.3.0.2 It is proposed therefore to report yellow/silver eel mortalities associated with turbine passage to this figure but after scaling down to the relevant catchment areas for the Tawe, Neath and Afan. These are given by Cefas (2011) as Tawe, 278 km^2; Neath, 317 km^2; Afan, 127 km^2, giving a combined total area of 722 km^2, equivalent to 3.34% of the Western

Wales RBD. On this basis, annual the silver eel output for the Tawe, Neath and Afan combined is estimated to be 4.04 tonnes per year.

2.3.0.3 Estimated annual eel mortality from hydroacoustic/netting surveys of turbine fish passage will be converted to biomass using length-weight relationship from local survey data and reported as a percentage of this biomass value and compared with the trigger levels as discussed previously.

2.4 Twaite shad, river lamprey, sea lamprey

2.4.0.1 Twaite shad are noted within the ES (Baseline Table 9.7) as 'regularly present within Swansea Bay' but are not known to have breeding populations within its rivers. Such fish are thought to emanate from breeding populations in the rivers Severn, Wye, Usk and Tywi. Currently the best estimate of population size for shad in these rivers combined is that derived for the Severn Tidal Power Strategic Environment Assessment (O'Keeffe *et al.*, 2010) and it is proposed to use this to compare with trigger level.

2.4.0.2 In the absence of population estimates for river and sea lamprey in the Swansea Bay rivers, it is proposed to use figures from the same source for these species. As lampreys of neither species are recorded as abundant in electrofishing surveys (ES Baseline), the lower figures from the River Usk (catchment area 1340 km^2) have been adopted in this case. Again, these have been scaled relative to the combined catchment areas of the Tawe, Neath and Afan (278 km^2: 20.7%). The data for other migratory fish is summarised in Table 2 below.

Table 2 Summary of data used for other migratory species trigger levels

Fish Species	Source of Data	Data	Exceedance of Target Levels
Twaite shad	Severn Tidal Power - Sea Topic Paper Migratory and Estuarine Fish (O'Keeffe *et al.*, 2010)	'The predicted twaite shad population is in the region of 184,000 adult individuals split between the Rivers Severn, Wye, Usk and Tywi, although the population size in a given year may range between 112000 and 596,000 adult individuals'.	Estimated annual mortality of adult twaite shad numbers associated with turbine passage as a percentage of a stock size of 184,000 individuals
European eel	Eel Management Plan for Western Wales River Basin District (Defra, 2010).	The silver eel escapement for the Western Wales River Basin District has been estimated at approximately 93,000 kg. Scaled to the Tawe, Neath and Afan only this equates to 4040 kg /y.	Estimated annual yellow/silver eel mortality biomass as a percentage of 4040 kg or agreed updates of this figure.
River lamprey	Severn Tidal Power - Sea Topic Paper Migratory and Estuarine Fish (O'Keeffe *et al.*, 2010)	Population estimates for the River Usk approximately, 3.5 million transformers and 28,000 adults; for the Wye approximately 11 million transformers and 88,000 adults. Using Usk figures scaled for	Estimated annual mortality of adult river lamprey numbers associated with turbine passage as a percentage of a stock size of 724,000

		Tawe/Neath/Afan catchment area equates to 724,000 transformers and 5,796 adults	transformers and 5,796 adults
Sea lamprey	Severn Tidal Power - Sea Topic Paper Migratory and Estuarine Fish (O'Keeffe *et al.*, 2010)	Population estimates approximately 2 million transformers and 3,000 adults on the Usk and 9 million transformers and 12,000 adults on the Wye. Using Usk figures scaled for Tawe/Neath/Afan catchment area equates to 414,000 transformers and 2,484 adults.	Estimated annual mortality of adult sea lamprey numbers associated with turbine passage as a percentage of a stock size of 414,000 transformers and 2,484 adults.

3.0 Commercial Fish

3.0.0.1 The more important commercially exploited fish stocks in seas around the British Isles are monitored and assessed by fishery scientists from various nations under the auspices of the International Council for the Exploration of the Seas (ICES). For reporting purposes, ICES divides the sea areas into regions depicted by Roman numerals, with subdivisions of these, as shown in Figure 1. Swansea Bay falls within ICES area VIIf under this reporting scheme. Within the areas depicted, smaller rectangles are also defined and when landings are reported skippers are required to report from which of these smaller rectangles fish were taken.

3.0.0.2 Since the life-cycles of many of the commercially exploited marine fish species involve large-scale movements between spawning, nursery and feeding grounds, the stocks are generally spread over large sea areas. ICES reports on fish stock management at the regional level and stock management units may spread across more than one ICES regions or subdivisions. For fish stock management purposes, it is therefore not appropriate to consider small, discrete areas such as Swansea Bay on their own, since this area will be a small, fringe, subcomponent of the stock, except in certain special cases where a unique sub-stock can be identified e.g. through genetic or tagging studies. The Swansea Tidal Lagoon Fisheries Baseline Report (ES, Appendix 9.1) demonstrates that Swansea Bay is not a uniquely or regionally important spawning, nursery or feeding habitat for any of the species present.

3.0.0.3 The stock size parameter normally used in fish commercial fish stock assessments is the **spawning stock biomass (SSB)**, for which ICES publishes estimated figures annually (or less frequently) for the major stocks. Figures are presented in ICES Working Group Reports, available online. Where it is preferred to work with stock numbers, the SSB value can be divided by mean fish weight at the median threshold age of sexually maturity to estimate the equivalent number of just-mature adults in the stock.

3.0.0.4 The procedure for comparing impacts of power generation on fish stocks (more usually associated with fish entrapment in cooling water systems) is well established (Turnpenny,

1988; Turnpenny & Taylor, 2000) and provides a model for assessing impacts of fish mortality associated with tidal turbine passage. This follows a standardisation procedure in which any fish killed is allocated an age at death (based on its length, using age-length keys) and is then converted to an **Equivalent Adult Value (EAV)** as described by Turnpenny (1988): the EAV represents the likelihood of the fish surviving to become just-mature. The total annual mortality of the species converted to EAV terms can then be directly compared to the stock size figure calculated from the SSB-to-stock numbers conversion described above and represented as an annual percentage mortality relative to the specified stock. This procedure will be used to represent and assess fish mortalities associated with turbine passage where relevant ICES stock size figures are available. It is proposed that the stock size figures used for this comparison will be those available in ICES reports for the smallest ICES area within which Swansea Bay falls (i.e. it could be Area VIIf or for a group of areas including VIIf).

3.0.0.4 Where SSB figures for the stock are not available from ICES, it is common practice (see e.g. Taylor & Turnpenny, 2000) to compare project-related mortalities with reported fish landings from the area. The main purpose is to provide a fisheries context for comparison, but the landings can be taken as a surrogate for absolute minimum stock size; more realistically, where a typical exploitation rate is known (based on **Fishing Mortality, F**), the stock size can be approximated by dividing reported landings by the exploitation rate. For Swansea it is proposed to use Marine Management Organization (MMO) landings figures for ICES Area VIIf for this purpose. Landings biomass will be converted to numbers as described above for SSB.

3.0.0.5 A further helpful context into which estimated EAV losses associated with the development can be placed is the **Total Allowable Catch (TAC)** figure published annually by ICES for certain stocks. TAC figures are published as management advice to the fishing industry as a guideline to sustainable fishing. It is therefore relevant to show how estimated mortality figures compare with TAC advice. It is proposed that this is shown only as an informal comparison that will not be used to trigger mitigation. Table 3 shows the formal basis that will be used for assessing estuarine/marine species against trigger levels.

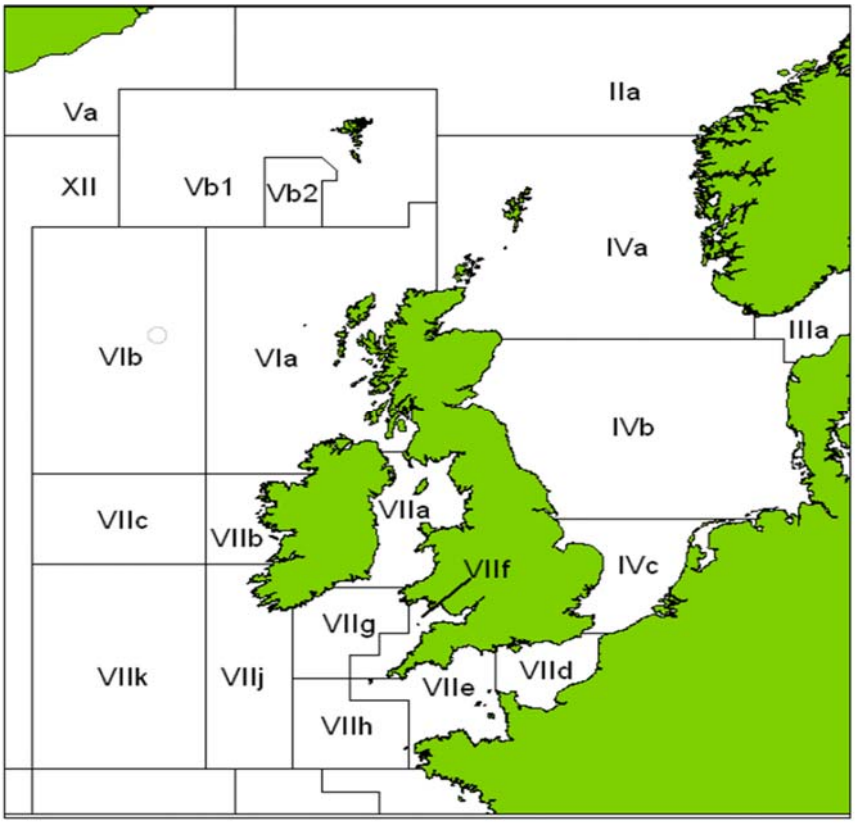


Figure 1 ICES regions and subdivisions. Swansea Bay falls within VIIf

Table 3 Proposed data sources and periods for determining stock sizes of estuarine/ marine species of commercial or ecological value

Fish Species	Source of Published Information	ICES Region/ Sub-division	Period to be Used	Parameter to be Used	Exceedance of Target Levels
Herring, sprat, bass, cod, whiting, hake, plaice, Sole, dab, Rays, sandeel	ICES Herring Assessment Working Group Reports	Smallest available sub-divisions of VII	Average of most recently available 3 years.	1. SSB – if available 2. Commercial landings	Estimated annual turbine-related mortality of species converted to EAV as a percentage of: 1. SSB converted to stock numbers 2. Commercial landings biomass divided by exploitation rate 3. TAC (for info only, not trigger)

4.0 References

Cefas (2011). Classification of Bivalve Mollusc Production Areas in England and Wales, Sanitary Survey Report, Swansea Bay (Wales)

Cefas (2012). Annual Assessment of Salmon Stocks and Fisheries in England and Wales 2011.

Cefas (2013). Annual Assessment of Salmon Stocks and Fisheries in England and Wales 2012.

Cefas (2014). Annual Assessment of Salmon Stocks and Fisheries in England and Wales 2013.

Davidson, I.C. and Cove, R.J. (2010). Dee Stock Assessment Programme Annual Report 2010, Environment Agency, Bristol.

O'Keeffe, N. et al. (2010) Severn Tidal Power – Strategic Environmental Assessment, Topic Paper: Migratory and Estuarine Fish. Parsons Brinckerhoff Ltd, Queen Victoria House, Redland Hill, Bristol, BS6 6US

Solomon, D.J. (1995). Sea trout stocks in England and Wales. NRA R&D report 25.

Turnpenny, A.W.H. (1988). Fish Impingement at Estuarine Power Stations and its Significance to Commercial Fishing. *Journal of Fish Biology*, **33** (supplement A).

Turnpenny, A. and Taylor, C.J.L. (2000). An assessment of the effect of Sizewell power station on fish populations. *Hydroécologie Appliquée* (Paris) **1-2**: 87-134.