Channel 4 Big Art Project

HABITAT REGULATIONS ASSESSMENT OF THE 'BIG ART PROJECT' IN CARDIGAN

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1 INTRODUCTION

APEM have been commissioned by the Big Art Project – Cardigan to determine whether the proposed installation of a piece of floating art work within the tidal waters of the River Teifi will have a significant adverse impact on any nearby Natura 2000 sites.

1.1 Background

The European Habitats and Species Directive (92/43/EEC) (hereafter referred to as the 'Habitats Directive') affords habitats and species of European importance legal protection through its implementation of a network of designated areas known as Natura 2000 sites. Natura 2000 sites consist of two main protected area categories, Special Areas of Conservation (SAC) and Special Protection Areas (SPA). Each Natura 2000 site has a number of qualifying features, for which conservation objectives are to be developed. On designation, the Habitats Directive, requires measures to be taken to maintain or restore site integrity.

Articles 6(3) and 6(4) of the Habitats Directive state that 'any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives'.

The Habitats Directive is transposed into national law in England and Wales by the Conservation (Natural Habitats, & c.) Regulations 1994 (as amended). This legislation makes a requirement for a Habitat Regulations Assessment, which determines whether a proposed project or plan is likely to have a significant impact upon the integrity of a Natura 2000 site. The term Habitat Regulations Assessment is used here to cover all the stages of the European Directive process; while the phrase Appropriate Assessment (AA) is often used to refer to the whole process, it is important to note that Appropriate Assessment is actually one stage in the HRA process, which encompasses four sequential stages:

- **Stage one: screening stage:** identification of the likely impacts upon a Natura 2000 site of a project or plan, either alone or in combination with other projects or plans, and considers whether these impacts are likely to be significant.
- **Stage two: Appropriate Assessment (AA):** the impacts of a plan or project are assessed against the conservation objectives of a European Site, in order to identify whether there are any likely adverse effects on site integrity and site features.
- **Stage three: Assessment of alternative solutions:** Where significant negative effects are identified at the AA stage alternative options should be examined to avoid any potential damaging effects to the integrity of the Natura 2000 Site.
- **Stage four: Assessment where adverse impacts remain:** An assessment of compensatory measures where, in the light of an assessment of Imperative Reasons of Overriding Public Interest (IROPI), it is deemed that the project or plan should proceed.

A precautionary approach is adopted within all aspects of the Habitats Directive and as such a plan can only be permitted where no adverse impact upon site integrity can be determined.

1.2 The Big Art Project

Television broadcasters, Channel 4, have commissioned seven large scale art projects across the UK as part of their unique Big Art Project. The project is supported by the Arts Council England and The Art Fund and aims to use art to regenerate regions and to inspire local people to have pride in their community. The seven sites selected to host these works of art are Burnley, Cardigan, Mull, Newham, North Belfast, Sheffield and St Helens. Each project will be unique and has commissioned its own artist to produce the piece of art and will endeavour to use direct community involvement to increase the sense of ownership over the art work for local communities.

1.3 The Cardigan Project

The Cardigan project will be installed at a site within the tidal reaches of the River Teifi in Cardigan and Rafael Lozano-Hemmer, a Mexican artist has been chosen to produce the piece of art. The project, named ‘Turbulence’ by its creator, will consist of a cluster of 127 interactive buoys floating in the River Teifi. The buoys contain a LED light source and a detector sensing motion in the water, with loudspeakers mounted on poles at two locations among the buoys. Voices of passers-by will illuminate the buoys and their voices will be played back via the loudspeakers (Evans, 2008). Quotes from the artist Rafael regarding his vision of the project include:

‘A number of microphones placed at various locations around the quayside will record people’s voices and automatically convert them into blinking lights within the buoys. The stored voices stay quietly in the buoys until the river’s periodic turbulence – caused by the constant ebb and flow of the River Teifi – activates the buoys to ‘release’ the stored sounds, which can be heard from the shore.’

‘The piece is intended as a reflection on Welsh oral traditions, poetry and song, creating a playful participative platform that is activated by the natural cycles of tides.’

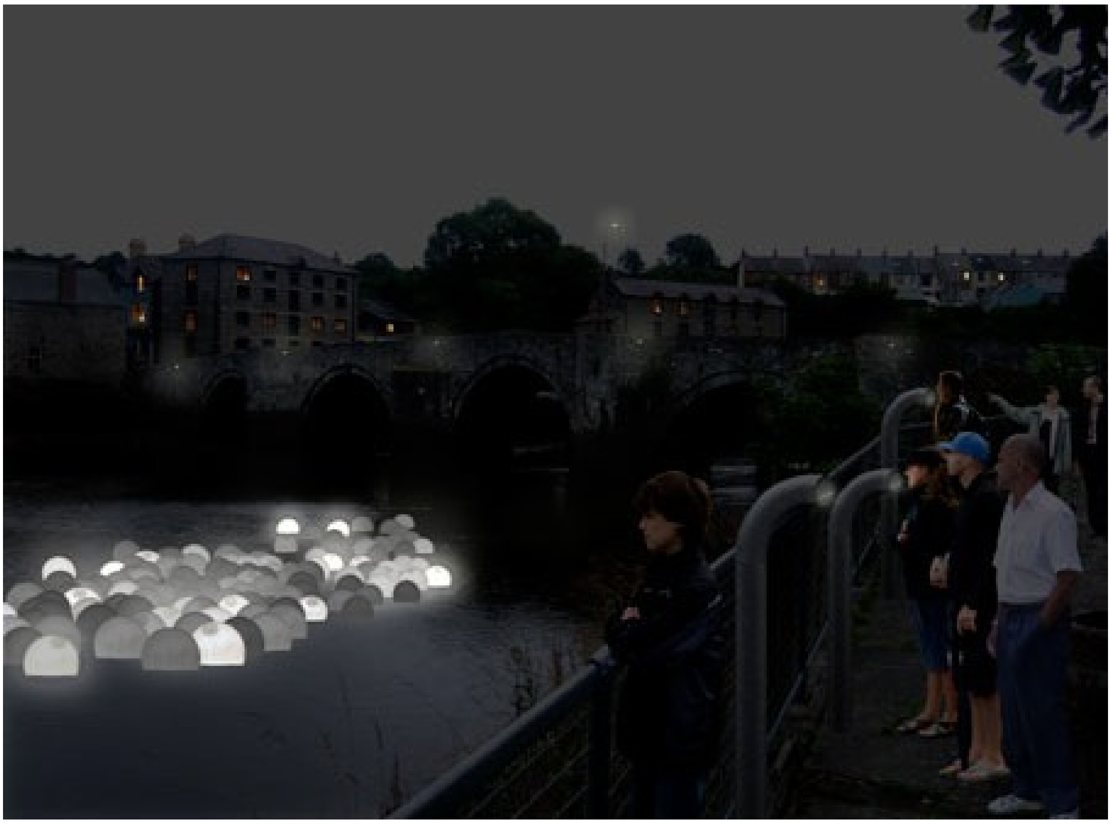

Figure 1.1 An artist's impression of 'Turbulence' at the quayside in Cardigan within the tidal waters of the River Teifi

1.4 Project specifics

This assessment is made on the basis of 'turbulence' remaining in position in the River Teifi for the entire 12 month period. There is potential that the piece of art will not remain in the River Teifi and may be taken on a tour of Wales. This document provides an assessment for its time in the River Teifi only.

The supporting structure for 'turbulence' will take the form of a sunken boat hull measuring approximately 14 m in length and 6 m in width. The structure will be held in place via two concrete mooring structures equivalent to the moorings for a 18 m boat in a river. The fore and aft of the structure will be attached to the moorings with chains and bridles to allow it to move up and down with the tide.

The 127 buoys will contain 32 LED light sources mounted to a metal chassis inside the buoys at their midpoint. The metal plate and upwards directive placement of the LEDs has been designed to be directed upwards and therefore minimise light penetration into the water column. The buoys have been further designed to be made of milky polyethylene material to disperse light. The LEDs will never be used at full power with their default state being set to off. Upon activation by a voice, the pattern of the voice will be visualised by the pulsation of a single buoy. The visualisation will not be a strobing effect and is designed to be a gentle, gradual light intensity modulation. It is envisaged that each single buoy will be activated approximately 50% of the time on a busy day. The maximum brightness setting is envisaged to be approximately 30% of the LED's capacity, and is likely to result in at least one buoy being at this capacity on a busy day.

The proposed colour temperature to be used within the LEDs is 7000K, daylight temperature for half of them and 3500K, warm white colour temperature for the other half. During daylight hours the 3500K LED's will be used which have a slight yellowish colour enabling them to be visible to the naked eye during daylight. These LED's will be used during daylight only with the 7000K LED's being operational at night. The LEDs can be set to a specific very narrow light frequency and it is the intention of the artist that during the hours of darkness that the levels of light cascading on to the water surface and potentially penetrating through the water column be not greater than those of existing sources of light pollution such as, for example, the builders merchants yard on the opposite river bank or the lights on the footbridge over the river.

The LEDs to be used will be one of the following two types; Philips LUXEON® K2 with TFFC or OSRAM Diamond DRAGON®. The specifications of each of these LED types are as follows:

Philips LUXEON® K2 with TFFC

- Compliant to the European Union directives on the Restriction of Hazardous Substances in electronic equipment
- The luminous flux (the measure of the total power of light emitted) at 1000 mA (minimum performance at test current) is between 160 and 200 lm (220 to 275 at 1,500 mA).

OSRAM Diamond DRAGON®

- Compliant to the European Union directives on the Restriction of Hazardous Substances in electronic equipment
- A typical luminous flux of 255 lm at 1,400 mA

A total of 6 loudspeakers are proposed for the entire structure, 3 at the bow (front) and 3 at the stern (back) of the sunken hull. The speakers will be mounted to a pole fixed to the sunken hull structure set at 120º projecting out of the water. The speakers will be of a fully waterproof, anti-magnetic design and will be mounted to ensure that they are always above the water surface. The peak power for each single speaker is 200 watts with a continuous power of 50W RMS. For electronics such as telephones the usable voice frequency band ranges from 300 Hz to 3,400 Hz. It is assumed that the sound projected from the speakers in the form of human voice will be within this frequency range.

The buoys and speakers will be powered by either a 24v battery on shore with cables running to the floating supporting structure or 240v cables on the river bed and a transformer on the supporting structure.

1.5 Potential sources of impact

The main potential sources of impact from this project include the emission of sound and light, underwater cabling and the deployment of the floating structure. Each of these potential impacts will be discussed further in relation to the Natura 2000 sites within the vicinity of the proposed installation on the River Teifi.

1.6 Assessment methodology

The method used for this assessment has been informed by the European Commission document 'Assessment of Plans and Projects Significantly Affecting Natura 2000 Sites – Methodological Guidance on the Provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC'.

This method adopts a 3 stage assessment process that reflects the first 3 stages of the HRA process as described above, including:

1. ***Screening*** – 'the process which identifies the likely impacts upon a Natura 2000 site of a project or plan'.
2. ***Appropriate Assessment*** – 'consideration of the impact on the integrity of the Natura 2000 site of the project or plan,….with respect to the site's structure and function and its conservation objectives'.
3. ***Mitigation and alternative solutions*** – where an assessment of a significant impact to site integrity is concluded, consideration should be made to potential mitigation measures and alternative solutions.

Professional judgement has been used during this assessment process in both gathering and interpretation of data, except where standard methodologies were available and in relation to the determination of the significance of potential impacts. In line with Habitats Directive guidance a precautionary approach to the identification and assessment of risks has been taken.

The following report details the screening stage forming a Habitat Regulations Assessment for the proposed art installation within the tidal reaches of the River Teifi. It is intended that this document will act as supporting information for the competent authorities (CCW and EAW) to make a determination upon consenting of the proposed works.

1.7 European sites

There are two Natura 2000 sites within the vicinity of the proposed installation:

- Afon Teifi/River Teifi SAC and
- Cardigan Bay/Bae Ceredigion SAC.

In addition to these Natura 2000 sites, there are a total of five Sites of Special Scientific Interest (SSSI):

- Aberarth – Carreg Wylan;
- Afon Teifi;
- Banc Y Mwldan;
- Banc-Y-Warren; and
- Coedydd a Corsydd Aberteifi (Teifi Estuary woodlands and marshes).

Of these protected sites it is considered that the River Teifi SAC will be the only site at risk of impact due to the localised nature of the proposed installation within a short section of the tidal river section.

Table 1.1 Natura 2000 sites within the vicinity of the proposed installation

Name of site	Reasons for designation
Afon Teifi/River Teifi SAC	***Primary reasons for site selection:*** o Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation o Brook lamprey (*Lampetra planeri*) o River lamprey (*Lampetra fluviatilis*) o Atlantic salmon (*Salmo salar*) o Bullhead (*Cottus gobio*) o Otter (*Lutra lutra*) o Floating water-plantain (*Luronium natans*) ***Qualifying features:*** o Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* o Sea lamprey (*Petromyzon marinus*)
Cardigan Bay/Bae Ceredigion	***Primary reasons for site selection:*** o Bottlenose dolphin (*Tursiops truncatus*) ***Qualifying features:*** o Sandbanks which are slightly covered by sea water all the time o Reefs o Submerged or partially submerged sea caves o Sea lamprey o River lamprey o Grey seal (*Halichoerus grypus*)

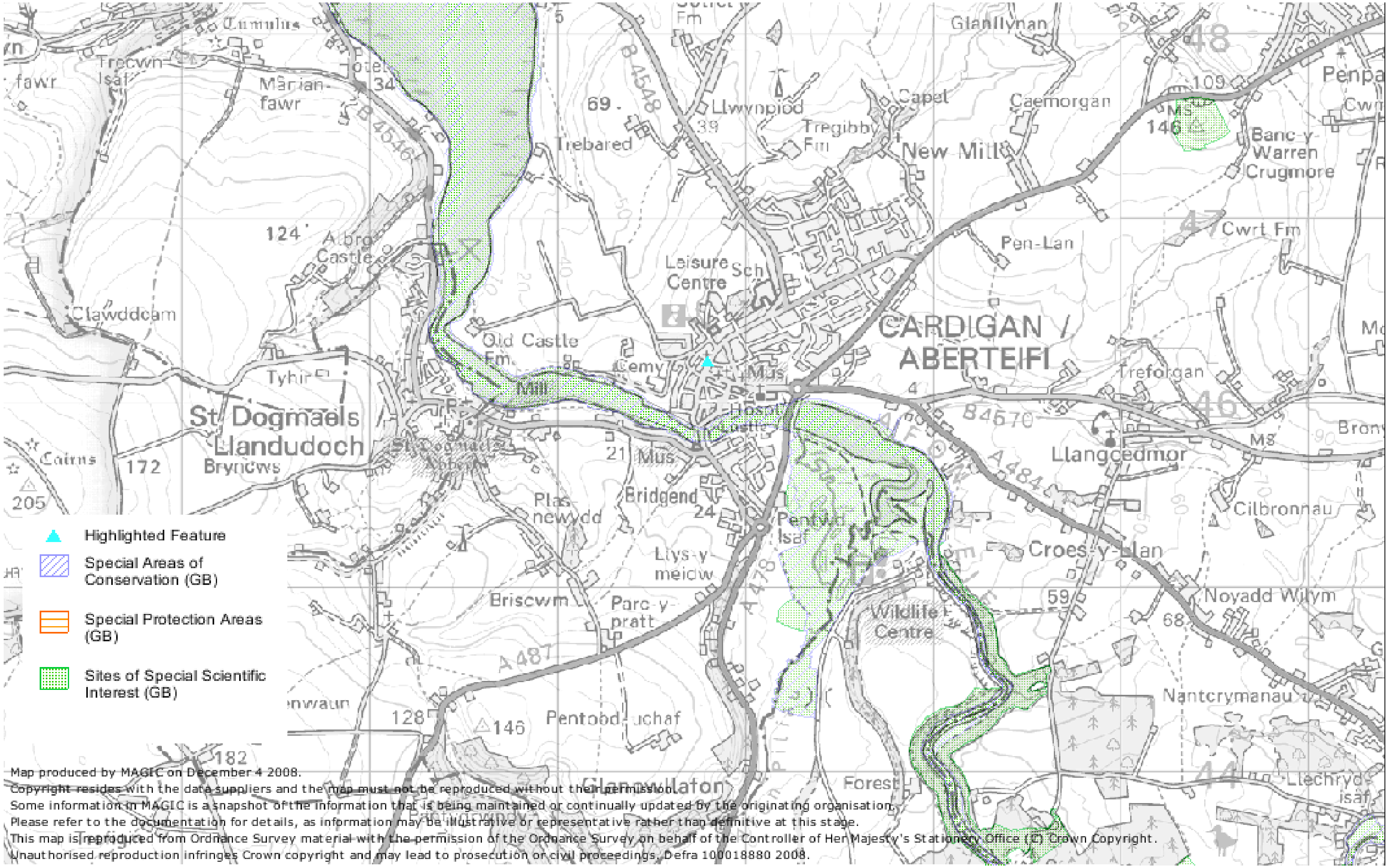

Figure 1.2 Location of Natura 2000 and SSSI sites within the vicinity of the proposed works

2 SPECIES BACKGROUND

2.1 Salmon

Atlantic salmon are a primary feature of the River Teifi SAC and are protected under the Habitats Directive. Salmon remain within the freshwater environment for a period of up to 4 years. At the end of the parr life stage they begin the smoltification process. Smolts migrate downstream to the estuary predominantly between April and June although a smaller autumn migration is also seen in a number of UK rivers. Migration is predominantly nocturnal in particular within the earlier period of the run becoming more evenly distributed between the diurnal and nocturnal periods for the latter portions of the migration period (Welton, 2002). Smolts move within the surface water layers, following the fastest flows with downstream migration often being triggered by increases in flow (Hendry & Cragg-Hine, 2003 & O'Keeffe & Turnpenny, 2005). In estuaries migration is still primarily nocturnal, with a strong tidal component to the direction of migration, and with movement seawards occurring on ebb tides (Moore *et al*., 1995). Following a period of several years at sea, adult salmon migrate back into estuaries and up the rivers to spawn. These migrations occur all year round but peak numbers of spawning adult salmon usually enter rivers in the UK between July and October. On the Teifi fish counter at Abercych (approx 1mile above head of tide), provisional results showed evidence of dawn-dusk preference for activity (salmon and sea trout combined), especially at lower flows, but again not exclusively so and daytime movements also occurred (Richard Davies, pers. comm.).

The Joint Nature Conservation Committee summary description of the site states the following regarding the salmon population within the River Teifi SAC:

> 'The Teifi is a medium-sized mesotrophic river system in west Wales. In 1999 the salmon rod catch in the Teifi was the third-largest in Wales, and the system has not experienced the steep decline in stock numbers seen in many other rivers in the area. This is likely to reflect the high quality of the catchment, with a semi-natural channel largely unaffected by poor water quality or artificial barriers to migration. However, in common with many other Welsh rivers, acidification in the upper reaches is a cause for concern. In common with many other rivers in west Wales, grilse are the main stock component. There is a small traditional coracle fishery that exploits the salmon and sea trout (*Salmo trutta*).'

2.2 Lamprey

There are three species of lamprey within the UK; river, brook and sea, all of which reside within the waters of the River Teifi, with river and brook lamprey being primary features of the sites SAC designation and sea lamprey a qualifying feature.

River and sea lamprey are anadromous species with complex life-histories that encompass a wide range of habitat requirements and involve migrations through rivers, estuaries and the marine environment. River and sea lamprey spawn within freshwater where their larval life stage, called ammocoetes, remain burrowed within nursery sediment for up to 6 years before transforming into an intermediate life-stage called macrophthalmia or transformers, and migrating seaward to the estuary where they metamorphose into the adult form and reside at sea before returning to rivers to spawn.

Brook lamprey, by contrast, complete their lifecycle within freshwater and do not migrate from rivers to the sea. All three UK lamprey species spawn once and then die and as such do not make a downstream migration as spent adults.

River lamprey adults begin their upstream spawning migration from the estuary between winter and spring commencing from around December until May. The main upstream migration period for sea lamprey adults is May to June. Upon transformation from the larval stage, the macrophthalmia drift downstream between autumn and spring peaking between September and October and again between April and May although the timing varies between individual river systems. Evidence suggests that this migration takes place predominantly during the hours of darkness 19:00 to 07:00 with transformers moving within the mid and bottom portions of the water column (Long, 1968).

The Joint Nature Conservation Committee states the following regarding the lamprey populations within the River Teifi SAC;

> 'The Teifi is a large catchment of high conservation value in west Wales. It contains a healthy population of river lamprey. The semi-natural channel containing a mixture of substrates and in-stream features provides excellent habitat for juvenile lampreys.'

> 'The Teifi is a predominantly mesotrophic river in west Wales supporting a large population of brook lamprey. A mixture of habitat and substrate types provides the combination of spawning gravels adjacent to silt beds that are favoured by this and other lamprey species. A large number of tributaries have been included in the SAC; these are thought to be important for lampreys in the Teifi because the main channel is prone to severe floods that may result in washout of smaller ammocoetes.'

2.3 Sea trout

Although not a feature of a Natura 2000 site and therefore not requiring an assessment of impact under the Habitats Regulation process, sea trout (*Salmo trutta*) are a feature of the Afon Teifi SSSI and are considered of concern by local interested parties and as such have been included briefly for completeness. Sea trout biology is broadly similar to salmon including their juvenile seaward and adult upstream migratory behaviour (Crisp, 1999, Harris & Milner, 2006). Sea trout however often spend extended periods in estuaries, in some cases never going to sea and as such may be more susceptible to anthropogenic impacts within estuarine and tidal environments.

As detailed above, the fish counter at Abercych on the River Teifi suggests that both salmon and sea trout show a preference for nocturnal movement through the river. Although there has been very limited scientific studies investigating the subject, sea trout are however, considered to be more active at night than salmon. As a result of this behaviour most angling for sea trout takes place in darkness (Falkus, 1977).

Due to the similarity of salmon and sea trout migratory behaviour, the impacts upon salmon smolts and adults identified within this assessment will be considered broadly applicable to the migratory sea trout life stages.

2.4 Conservation Objectives

A Conservation Strategy was written for the River Teifi SAC as part of the Life in UK Rivers project (Davis, 2003). This document details the conservation objectives for each of the interest features as detailed below for each individual species of concern.

2.4.1 Salmon

The Atlantic salmon population of the River Teifi catchment was classified as in unfavourable condition during the 2007 Habitats Directive reporting cycle.

Favourable conservation status:

- The Atlantic salmon population of the SAC will be viable throughout its 2001 distribution (maintaining itself on a long-term basis).
- There will be no contraction of the 2001 Atlantic salmon distribution in the SAC.
- Within the 2001 Atlantic salmon distribution there will be sufficient habitat to support a viable Atlantic salmon population.
- Migration of adults and smolt Atlantic salmon must be unhindered by unnatural barriers.

Key factors: As well as factors relating to the functioning of the Teifi as a wetland ecosystem and general management of fish features, the following are important:

- Declining catches of Atlantic salmon in the Teifi, in particular Multi-Sea-Winter (MSW) fish
- Competition with sea trout
- Exploitation of salmon at sea
- Poaching
- Legal exploitation by rods and nets
- Predation

The following factors are thought to be of minor importance:

- Fisheries targeted on other species in salmon feeding grounds
- Natural mortality caused by oceanic climate change/low marine survival
- Disease and parasites
- Pike predation

Performance indicators:

- Juvenile (fry and parr) Atlantic salmon distribution.
- Juvenile Atlantic salmon density.
- Juvenile Atlantic salmon age class structure.
- Adult Atlantic salmon run size. This will measure the abundance of adult Atlantic salmon returning to the Teifi to spawn.
- Abundance of MSW Atlantic salmon.

Conservation objectives:

To maintain the Atlantic salmon at favourable conservation status where:

Juvenile Atlantic salmon distribution

Upper limit: None set.
Lower limit: Juvenile Atlantic salmon must be present every year at all juvenile salmon index monitoring sites.

Juvenile Atlantic salmon must be present one year in three at all juvenile Atlantic salmon monitoring sites (standard and index).

Index monitoring sites have good juvenile Atlantic salmon abundance and the population has a good demographic structure (sites that underpin the long-term viability of the species in the Teifi catchment).

Juvenile Atlantic salmon density
Upper limit: None set.
Lower limit: A juvenile Atlantic salmon density of >X/m-2 must be present every year at all juvenile Atlantic salmon index monitoring sites.

A juvenile Atlantic salmon density of >X/m-2 must be present one year in three year at all juvenile Atlantic salmon monitoring sites (standard and index).

N.B. The above objectives are based on unknown data regarding density.

Juvenile age class structure
Upper limit: None set.
Lower limit: Two juvenile Atlantic salmon age classes must be present two years in three in the populations sampled at juvenile Atlantic salmon index monitoring sites.

Adult Atlantic salmon run size
Upper limit: Not set.
Lower limit: To be developed.
Recovery target value: To be developed

Abundance of MSW Atlantic salmon
Upper limit: Not set
Lower limit: X% of the adult Atlantic salmon annual run size must consist of MSW Atlantic salmon every year.

Recovery target value: To be developed

Development of monitoring of Atlantic salmon will require liaison with Environment Agency to build on their existing monitoring program for the species. The Life in UK Rivers salmon monitoring report will inform this work (Cowx & Fraser 2003).

2.4.2 Lamprey

The brook, river and sea lamprey populations of the River Teifi catchment were all classified as in unfavourable condition during the 2007 Habitats Directive reporting cycle.

Favourable conservation status:

- The lamprey populations of the SAC will be viable throughout their current distribution (maintaining themselves on a long-term basis)
- There will be no contraction of the current lamprey distribution in the SAC
- Within the current lamprey distribution there will be sufficient habitat to support a viable lamprey population
- Migration of river and sea lamprey adults and ammocoetes must be unhindered by unnatural barriers (Maitland, 2003)

Key factors: the key factors for lampreys are the functioning of the Teifi as a wetland ecosystem and the management of fish features generally. Management of the Cardigan bay SAC is relevant but not within the scope of this plan.

Conservation objectives:

To maintain the lamprey at favourable conservation status where:

Ammocoete distribution:

Upper limit: not set

Lower limit: ammocoetes must be present every year at ammocoete monitoring sites (sites to be determined - all optimal and sub-optimal habitat sites)

Ammocoete density:

Upper limit: not set.

Lower limit: for brook and river lamprey, ammocoete density must be >10 m^{-2} every year at all monitoring sites classified as optimal habitat and >2 m^{-2} every year at all monitoring sites classified as sub-optimal habitat. For sea lamprey, ammocoete density must be at least 0.2 m^{-2} every year at all monitoring sites classed as optimal habitat and at least 0.1 m^{-2} at all monitoring sites classified as sub-optimal habitat.

Ammocoete age-class structure:

Upper limit: not set.

Lower limit: for each species two age-classes must be present two years in three in the populations sampled at ammocoete monitoring sites classified as optimal habitat.

Adult river and sea lamprey run size:

Upper limit: not set.

Lower limit: to be determined.

3 SALMON AND LAMPREY SENSE ORGANS – LITERATURE REVIEW

Due to the placement of 'Turbulence' within the tidal reaches of the River Teifi it is considered that the only fish species potentially to be impacted by the installation are river and sea lamprey and Atlantic salmon. The life stages potentially to be impacted are those with a migratory element to their life-history: river and sea lamprey adults and transformers; Atlantic salmon smolts, adults and kelts.

The most likely causes of impact will be the projection of light and sound into the water column. To enable the assessment of any such impacts and ensure that any predicted impacts are minimised it is first necessary to identify the sensitivity of salmon and the two lamprey species to the projection of light and sound and identify any potential effects that they may have on their behaviour. The literature review contained within this chapter summarises information regarding the sensory perception of salmon and lamprey and examples of anthropogenic impacts upon the three species resulting from light and sound projection.

3.1 Fish vision and light detection

Light is normally described by wavelength and intensity. Light has a high transmission rate in water although various factors affect the penetration of light through the water column. Subsequently the intensity and wavelengths of light that may reach a fish at any given depth is variable. Such factors include angle of incidence, water clarity, proportion of suspended solids, originating intensity and wavelength of the light source among others. In addition, fish species, and developmental stages, have differing sensitivities to light (e.g. Simenstad *et al*., 1999; Job and Bellwood 2000; Job and Shand, 2001).

The majority of fish species have excellent visual capabilities which assist them in activities such as prey detection, mate selection, maintaining their position in flowing waters and staying in contact with other shoal members. Many species are able to see in colour and also in very dim light (Nakano *et al*., 2006). The eyes of fish are somewhat different to human eyes in several ways. The lenses in a fish eye are typically spherical to aid in underwater vision due to the higher refractive index of water (Bone *et al*., 1999). In most terrestrial vertebrates, the lens is stretched to focus whereas fish move the lens inwards and outwards (Bone *et al*., 1999).

In addition to the eyes, some fish possess other specialised organs which whilst not involved in vision, are capable of detecting changes in light levels. Lamprey, for example, have two such organs, the pineal gland and special photoreceptors (light receptors) found in the skin (particularly in the tail region) (Kleerekoper, 1972; Young, 1935).

3.2 Fish hearing

Water is 14000 times less compressible than air at 1 atmosphere and sound travels approximately five times faster in water than in air (Bone, *et al*., 1999). Two types of stimulus result from a sound source in water: particle displacement and sound pressure. Particle displacement (the to-and-fro movement of water molecules) is of more importance close to the sound source and sound pressure (change in pressure above and below hydrostatic pressure) becomes more important at distance from the source.

Most fishes, have similar acoustic capabilities to those exhibited by many mammals. They are able to detect a sound in the presence of other signals, determine the direction of a sound source and differentiate between sounds of different frequencies and magnitudes (Hastings and Popper, 2005). The hearing capability of fish is dependent upon the physiology of individual species in terms of both the presence/absence of a swimbladder and the connection between the swimbladder and inner ear. Species fall into three broad categories: *Non-specialists* which have no swimbladder, *Generalists* which have a swimbladder but no special connection between it and the inner ear and *Specialists* which not only have a swimbladder but also a connection between it and the inner ear which can extend their upper hearing ability by several kilohertz.

Sound frequencies audible by fish are split into three main categories: infrasound (<20 Hz), low frequency sound (10 Hz to 3 KHz) and ultra sound (>100 KHz). For the majority of fish species, their maximum sensitivity lies within the low frequency range (20 to 3 KHz) (Hawkins, 1981). The alosids including shad are unique in that they can detect sound of far higher frequencies than other fish and are the only group known to be able to detect frequencies within the ultrasound range (Popper, 2004). It is has also been demonstrated that a number of fish species including cyprinids, salmon and eel can detect frequencies within the infrasound range (Karlsen, 1992, Sand *et al*., 1986 & Sonny *et al*., 2006).

3.3 Salmon sense organs

3.3.1 Vision and light detection

As with most fish species, Atlantic salmon have paired, image-forming eyes. Salmon eyes are adapted for vision in both bright and dim light (Brett and Ali, 1958). Young salmonid eyes have cones able to detect UV light. Many prey items of juvenile salmonids (e.g. zooplankton species) reflect UV light and as such the ability to detect light in this range provides an advantage (Novales-Flamarique and Hawryshyn, 1996; Bowmaker and Kunz, 1987). As the salmon develop and their diet shifts to larger items that do not reflect UV light, these cones gradually disappear. Some studies however, have shown that new, temporary, UV receptors can develop at other times, and appears to coincide with spawning migrations. It is possible therefore that salmon are using polarised light as a navigational aid (e.g. Parkyn *et al*., 2003; *and references therein*). Therefore, mature, upstream migrating salmonids may be able to detect at least some UV light providing it falls within the range of 350-700nm (Simenstad *et al*., 1999; Browman *et al*., 1993; Novales-Flamarique and Hawryshyn, 1996).

3.3.2 Hearing

With regards to the fish species of concern in this report, salmon are classed as hearing *generalists*. As such, salmon are believed to be unable to detect the high sound frequencies that fall in the ultrasound band (>100KHz) and the hearing is concentrated within the low frequency range. Experiments investigating the use of sound as a deterrent to fish have provided evidence that salmon can detect low and infrasound frequencies (Hawkins and Johnstone, 1978; Knudsen *et* al., 1992; Turnpenny *et* al., 1993; Knudsen *et al*., 2005). Hawkins and Johnstone (1978) concluded that Atlantic salmon (*Salmo salar*) are functionally deaf at bandwidths above 380 Hz and optimum sensitivity is at around 200 Hz.

Different parts of the salmon's sound detection system respond to sound, gravity and pressure. In addition to an inner ear (or membranous labyrinth) the sound detection system includes the lateral line which consists of lines of small sense organs distributed over the head and body (Hawkins and Johnstone, 1978). Sensory hair cells are located in the ears and lateral line system in salmon. It is these cells that provide the basic mechanism by which sound is transformed into electrical signals that can be interpreted by the nervous system (Bone *et al*., 1999).

Salmon, like most fishes, have two inner ears located inside the cranial cavity (Hawkins and Johnstone, 1978). Unlike other vertebrates, fish typically lack a middle and outer ear. The inner ear has three semi-circular canals and three otolith organs (utricule, saccule and lagena). Each otolith organ contains a calcified otolith overlying a sensory tissue layer covered in sensory hair cells. These otolith organs are involved in sound detection as well as acting as balance organs (Bone *et al*., 1999).

Because the lateral line can perceive stimuli from sound sources it can also be said to be involved in hearing. However, the main hearing organ in salmon is the inner ear. In addition, the gas-filled swim bladder enhances the particle displacement aspect of the sound stimulus (Bone et al., 1999).

3.4 Lamprey sense organs

3.4.1 Vision and light detection

A comprehensive, detailed discussion of the sense organs of lampreys has previously been undertaken by Kleerekoper (1972) and as such will not be provided here. In summary, the major light sensing organs for adult lamprey include well developed paired eyes, the pineal complex and dermal light sensing organs which appear to be concentrated in the tail region (Young, 1935; Ullen *et al*., 1993). Each of these organs contributes differently to light related behaviour (Ullén, 1993).

The eyes in adult lampreys are relatively small in comparison to teleosts but are still considered to be optically functional. Indeed, vision is believed to be the primary sense used by parasitic adult lampreys to locate their prey hosts (Kearn, 2004). However, at the end of the migratory season, the cornea of adult lampreys clouds over effectively blinding the animal (Binder and McDonald, 2007; Manion and Hanson, 1980). According to Franz (1932; referenced in Kleerekoper, 1972) the sight distance of adult river lamprey is probably only around 12cm.

The role of vision in the life of adult lampreys is uncertain in spite of them having well-developed eyes (Binder and McDonald, 2007). The pineal complexes of adult and ammocoete *Lampetra* and *Petromyzon* species exhibit very little difference other than size and position (Studnička, 1893, 1899 & 1905; references in Eddy, 1972). According to Morita *et al*., (1992), the pineal organ is a photoreceptive organ that functions as an oscillator for the daily movement rhythm of lampreys. This organ increases locomotor activity during the night and suppresses it during the day (Ullén, 1993). Binder and McDonald (2007) recently demonstrated that light directed at the head of blinded adult sea lamprey induced a locomotory response. This recent evidence further indicated that light detection in lamprey is at least in part accomplished by the pineal gland.

Dermal light sensing organs, known as photoreceptors, have been identified using microscopic examination of lamprey skin (Ullen *et al*., 1993; Steven, 1951; Steven, 1963). Prior to these studies however, Young (1935) had already identified that the skin of young (ammocoete) lamprey was sensitive to light.

Few if any studies have been carried out to determine the light sensitivity of lamprey transformers. It seems likely that they will have an equivalent pineal organ reaction, and photoreceptors in the skin as found in ammocoetes. In addition, one notable outcome of the transformation process is the development of the eyes, and it seems reasonable to suggest that sight in lamprey transformers is equivalent to that of adults.

3.4.2 Hearing

Lamprey lack a swim bladder and as such they fall within the *non-specialist* hearing group. Fish in this group typically have no adaptations assist with sound detection or transmission and are generally considered insensitive to most sound frequencies. There is some evidence that lampreys are likely to be able to detect infrasound, but studies in this field are in their infancy.

4 ANTHROPOGENIC IMPACTS OF LIGHT AND SOUND ON SALMON AND LAMPREY - LITERATURE REVIEW

4.1 Effects of light on salmon

Light is of great importance in the life of salmon as it is necessary for spatial orientation, prey capture, schooling, predator avoidance and migration/navigation (Simenstad *et al*., 1999). The reaction of salmonid species to light stimuli depends upon the light level the fish is adapted to prior to any changes it encounters (Simenstad *et al*., 1999). The main factors affecting the prevalence and extent of any reactions to light are related to the perceived change in light level as experienced by the fish, and the nature of the change relative to the fish's experience (e.g. sudden versus gradual, flashing versus continuous) In some cases the fish may be repelled by light stimuli (see examples described below) and in others they may even be attracted to it perhaps due to the fact it may attract/increase the visibility of prey items in the case of juvenile salmonids (e.g. Weitkamp, 1982; Puckett and Anderson 1987, 1988). Where reactions to artificial light do occur this can result in temporary/localised delays to migration for example when fish are attracted to a light source, such as dock lighting, at night Weitkamp, 1982; Simenstad *et al*., 1999).

Studies in salmon cage farms have shown that submerged lighting reduces local fish density within different sections of cages and increases the depth at which Atlantic salmon swim (Juel *et al*., 2003). The use of such lighting has been used to create artificial photoperiods which postpone sexual maturation in salmon and increase growth (Juel *et al*., 2003).

Juvenile salmon have been described as showing an aversion to entering a light environment to which they are not adapted/have no experience of (Simenstad *et al*., 1999). In addition, based on reviews of other reports (e.g. Prinslow *et al*., 1980; Weitkamp, 1982a, b; Ratte and Salo, 1985; Dames and Moore, 1994; Taylor and Willey, 1997) there is evidence that delays in juvenile migration can occur when there are different light conditions (Simenstad *et al.,* 1999). There is also anecdotal evidence of juvenile salmonids avoiding shaded and darkened areas (such as culverts) during their downstream migration, which can again result in delays to migration (S. Clough *pers. obs*.)

Craddock (1956) reported avoidance behaviour by salmon, finding that 81% of downstream migrating juvenile coho salmon were diverted by ten 400 W floodlights at night. Three species of salmon exhibited a predominantly (>50%) photonegative response when exposed to light intensities of 1000 footcandles (Hoar *et al*., 1957). Sensitivity to light has also been shown to increase during the smoltification process in some salmon species (Hoar *et al*., 1957). Fields (1966) demonstrated that migratory salmonids were attracted to certain lights, in particular 200 W, but avoided more powerful lights (1000 W).

In general, submerged strobe lighting repels fish (Nemeth and Anderson, 1992). Strobe lights, with a flash rate of 86 flashes/minute (Richards *et al*., 2007), elicits avoidance responses and stress responses (elevated plasma cortisol concentrations) in several fish species including Chinook salmon (*Oncorhynchus tshawytscha*). Maiolie *et al*. (2001) observed that strobe lights with flash rates of 300, 360 and 450 flashes per minute all repelled fish even at light intensities only marginally greater than ambient light levels. For Atlantic salmon smolts, the use of strobe lighting to reduce entrainment in a water intake at Walton-on-Thames resulted in a 62.5% reduction in the numbers of smolts being entrained, suggesting avoidance behavior (Solomon, 1992 cited by Turnpenny & O'Keeffe, 2005). Similar avoidance has also been recorded from the use of strobe lights to reduce entrainment of Chinook, coho, sockeye and steelhead salmon into locks in Seattle (Johnson *et al*., 2005).

Anecdotal evidence suggests that salmonids move at night through illuminated harbours, for example nocturnal movement is known to take place through Aberdeen harbour under conditions of strong dockside and ship-borne illumination (Milner, 2008).

In summary, salmon have been shown to change their behaviour in response to artificial fluctuations in light intensity, with bright and/or flashing submerged lights known to elicit an avoidance response.

4.2 Effects of sound on salmon

Salmonids have been shown to exhibit fright, or startle, responses to sound i.e. short and sudden bursts of rapid swimming (Moore and Newman, 1956; Burner and Moore, 1962). However, salmon have typically been observed to habituate to sound stimuli quite rapidly and therefore sound generally doesn't attract or repel salmon over great distances or for long periods of time. In addition, pure tones are generally considered to not deter fish.

Knudsen (1992) observed that intense sound (150 Hz) had no observable effect on Atlantic salmon smolts even at 114 dB above the hearing threshold at that frequency. However, in 1994, studies of fish passage into the Sandvikselven (Oslo) by Knudsen suggested that sound at frequencies of <35 Hz could be used as a deterrent for Atlantic salmon smolts based on spontaneous avoidance responses from fish within 2 m of the sound source (Knudsen, 1994). These studies showed a 98% reduction in fish passage as a result of infrasound deterrent systems (Knudsen, 1994).

Welton *et al*., (2002) trialled Bio-Acoustic Fish Fence (BAFF) systems in the River Frome (UK) to test their efficiency at deflecting Atlantic salmon smolts. The system used sound pressure levels of 170 dB re 1µPa and was successful in significantly deflecting smolts (Welton *et al*., 2002). Further success in the use of infrasound to deter Atlantic salmon was achieved at Blantyre hydro-electric plant, where 74% of salmon were deflected by acoustic deterrents (Anon, 1996 cited by Turnpenny & O'Keeffe, 2005).

Acoustic fish deterrent systems use a sound frequency range of 20-500Hz (see EA Best Practice Guide for fish screening; Turnpenny& O'Keeffe, 2005). Knudsen *et al*., (2006) found that the lowest sound frequencies (5-10 Hz) were most effective at eliciting a reaction from juvenile Atlantic salmon. 150 Hz sound failed to evoke an avoidance response even at 30 dB above the threshold for spontaneous awareness reactions. Varying levels of avoidance efficiency have been determined however for both low frequency and infrasound acoustic deterrent systems.

Most of these studies have focussed on water borne noise, deliberately presented to elicit a behavioural response. In contrast, very few studies have considered the transmission of air borne noise into water. Based on studies in the River Dee near Aberdeen, Hawkins and Johnstone (1978) concluded that air borne sounds are probably not detectable by Atlantic salmon. They did however conclude that salmon were sensitive to substrate borne sounds. Responses to sound in both the laboratory and the sea were only observed for substrate borne tones with a frequency of <380Hz.

In summary, salmon are sensitive to certain frequencies of underwater noise, particularly low frequencies (<30 Hz), however it is considered that air borne sounds are unlikely to be detected by salmon.

4.3 Effects of light on lamprey

Lampreys are known to be sensitive to light, although there are conflicting reports of avoidance and attraction in the literature. Adult and juvenile lamprey species have been shown to exhibit higher levels of activity at night than during the day suggesting that they are predominantly nocturnal (Tuunainen *et al*., 1980; Moser *et al*., 2002b).

Both ammocoete larvae and adult lamprey have been shown to exhibit a clear preference for less illuminated areas (Ullén *et al*, 1993; and references therein). Ullén *et al*., (1993) demonstrated two mechanisms resulting in negative phototaxis (movement away from light) in adult river lamprey. First, illumination of the dermal photoreceptors in the tail results in increased movement and secondly, asymmetric illumination of the lateral eyes results in a directional motor response away from the light source (a 90W bulb). Thus, these behavioural responses may result in adults being 'directed' away from light.

Negative phototaxis (movement away from light) has been observed in several lamprey species (Ullen *et al*., 1997). Stone (2004) therefore concluded that any changes in lighting, including an increase in light intensity, could affect lamprey movements. Certainly, laboratory observations have shown significant, negative phototaxis by ammocoetes (species not given) exposed to white light and in response to abrupt changes in lighting (R. Moursund, personal communication; referenced in Stone, 2003). This is of course to be expected for a cryptic burrowing species.

Several factors are known to potentially inhibit the upstream (and sometimes downstream) migration of lampreys. These include chemical and physical obstructions to passage such as pollution, eutrophication, flow, weirs, dams and sluices (e.g. Tuunainen, *et* al., 1980; Kostow, 2002; Stone, 2004). However, little is known about the effects of other anthropogenically created pollution sources such as light, potentially suggesting that this has not been demonstrated to be an issue for lamprey species.

Migratory activity of adult lampreys in Finland is known to be significantly reduced during bright moonlit evenings, so much so that lamprey fishermen would not set traps on such evenings due to poor returns (Tuunainen *et al*., and reference therein).

Illumination from man-made structures close to water courses is believed to have a similar effect to bright moonlight i.e. it reduces lamprey activity. This effect was observed in the Kymijoki River in the Gulf of Finland where fishermen have reported that bright lights on a newly built bridge prevented lampreys migrating upstream past the bridge (Tuunaninen, *et al*., 1980).

Adult river lampreys are known to be inactive during the day, starting to move at the onset of darkness (Kearn, 2004). In the studies of Morita *et al*., (1992), *Lampetra japonica* were active mainly in the first part of the dark period and were inactive in the light period when maintained in a 12:12 light-dark cycle. Despite the fact that upstream spawning migration of lampreys is guided by olfactory cues (Binder and McDonald, 2007; *and references therein*) light appears to have a significant effect on their behaviour (Harden Jones, 1955; Purvis *et al*., 1985; Morita, *et al*., 1992; Fredricks *et al*., 1996). Certainly, migrating lampreys appear to move mainly during the night (Tuunainen *et al*., 1980; Purvis et al. 1985; Steir and Kynard, 1986; Fredericks *et al*., 1996).

Experiments by Binder and McDonald (2007) demonstrated a clear behavioural response to light in sea lamprey. The response was apparent even in fish that had been experimentally blinded, suggesting that the negative phototaxis response is at least partly elicited by the action of the pineal gland and dermal receptors. In one set of experiments Binder and McDonald (2007) illuminated the whole body of adult sea lamprey using a surface light intensity similar to that on a cloudy day. The response consisted of tail deflections followed by detachment and swimming (Binder and McDonald (2007)).

There is also some evidence of lamprey being attracted to light (Sterba 1962; Purvis *et al*., 1985 *referenced in* Frederiks *et al*., 1996). In the study by Purvis *et al*., (1985) significantly more lampreys were caught in lit traps than unlit traps. Increased attraction appeared to be linked to sexual development with greater attraction being exhibited by more sexually mature lamprey (Purvis *et al*., 1985). There have also been reports that Russian fishermen have used light to guide lampreys into traps (Abakumov, 1956; *referenced in* Tuunainen, *et al*., 1980).

In summary, lampreys have been shown to be sensitive to light, and demonstrate both attraction and avoidance in certain circumstances.

4.4 Effects of sound on lamprey

The relatively poor hearing of lampreys, with the non-specialist capabilities characteristic of jawless fish that lack a swim bladder and evolutionary developed auditory organs, suggest that lamprey are not considered to be sensitive to the effects of sound.

An acoustic sense in sea lamprey (*Petromyzon marinus*) has been demonstrated by Lenhardt and Sismour (1995) who demonstrated an acoustic startle in response to clicks at wavelength frequencies between 20 and 100 Hz providing some evidence that at least certain sound frequencies are detectable by sea lampreys. Additionally, Maes *et al*. (2004) showed evidence of some repelling effect of low frequency sounds (20-600 Hz) on river lamprey. In this study, entrainment into a power station cooling water intake was reduced by 5.9% by low frequency sound deterrents (Maes *et al*., 2004), although this low % deflection reduction could equally be taken to demonstrate a lack of response by the vast majority of individuals.

5 ASSESSMENT OF POTENTIAL IMPACTS ON SALMON AND LAMPREY FROM THE BIG ART PROJECT – CARDIGAN

The design of the Big Art project in cardigan has been described in Section 1 of this report, with details of the project specifications as known at the time of writing of this report.

The details of these specifications are described here in order to characterise the potential impacts on salmon and lamprey. It should be emphasised that this assessment is restricted to discussion of potential impacts on Atlantic salmon, sea lamprey and river lamprey. Other designating features of the River Teifi SAC, including brook lamprey, are not considered to be important features at the location where the installation is to be located, or are assessed in another report (e.g. otter populations).

It is important to recognise that a precautionary approach has been adopted throughout the design stage of the installation and that the design team sought early consultation with fisheries specialists, and a number of important considerations were factored in at the design stage, including the number, placement orientation and intensity of light and sound generation.

5.1 Light

The light emitted from the 127 buoys that constitute the 'Turbulence' installation could potentially result in disturbance to salmon and lamprey that reside or are migrating through the location of the art piece. The potential impacts of this light emission, in the absence of any mitigation measures, are described below.

In each of the 127 buoys, 16 LED light sources, as specified in section 1.4, will be mounted. Light emitted from these buoys, has the potential to penetrate into the water column. The effects of this lighting is not considered to be significant during daylight hours, as the proposed colour temperature is designed to be just visible to the naked eye. However, operation during hours of darkness could potentially affect fish in the vicinity.

To address the concerns that local light penetration from the installation could potentially illuminate the river habitats in the vicinity of the project, APEM have undertaken some field measurements to determine the potential zone of impact of light form the buoys. A series of measurements were taken from buoys that were illuminated and calculations made regarding the light penetrating the water. Light penetrating through the water was recorded at regular distances away from the buoys and at varying depths in the water column.

The background light levels in a dark area of the river channel with no obvious ambient light cascading onto the waters surface was measured to be approximately 0.025 µmol. Within the vicinity of the bridge over the river with pedestrian lighting and the builders merchants service yard, with flood lights the background light levels were determined to be approximately 0.06 µmol. Adjacent to the buoys when set at maximum brightness, the light levels within the river were recorded as 1.66 µmol at the surface, 0.33 µmol at a depth of 0.5 m and 0.08 µmol at a depth of 1 m. At a distance of 1 m from the buoys light levels within the water column were measured as 0.09 µmol at the surface, 0.06 µmol at a depth of 0.5 m and 0.06 µmol at a depth of 1 m. Measurements taken 2 m from the buoys were 0.05 µmol at the surface, 0.04 µmol at a depth of 0.5 m and 0.02 µmol at a depth of 1 m. Within 1 m from the buoys at a depth of 0.5 m the light readings were therefore equivalent to those recorded within the vicinity of the pedestrian bridge over the river. Within 2 m from the buoys at a depth of 1 m, the light readings were equivalent to the background readings taken within a dark area of the river channel away from ambient light.

Therefore, the worst case zone of impact of lighting from the buoys at night is restricted to a distance of 2 m from the cluster of buoys that comprise the installation on the basis of all buoys being illuminated at once and set at maximum brightness. On this basis the total impacted area would be 180 m^2 in total, with a width of 18 m. The width of the Teifi at the planned point of mooring is approximately 70 m, and as such the potential impacted area would represent approximately 26% of the river channel leaving 52 m un-impacted. It must be stressed that this is on the basis of all buoys being illuminated simultaneously and at maximum brightness. This is unlikely to be the case as it is the intention for individual buoys to be illuminated and not all the buoys at once and not maximum power. The area of river channel being illuminated by the structure will in fact therefore be far smaller than this worst case.

5.1.1 Salmon

The effect of lighting from the buoys could potentially result in disturbance of salmon resident or migrating past the vicinity of the installation. This could lead to salmon avoiding the area and the surrounding illuminated areas, and potentially deterring them from passing through the area when migrating. Depending on the depth and distance that the light penetrates through the water, the potential barrier effect to salmon migration could result in a significant effect on the migratory patterns of salmon in the Teifi SAC.

Effects on salmon smolts

Salmon smolts typically migrate downstream from the river headwaters to the sea, usually between April and June. Downstream migration within the river is predominantly nocturnal and is often triggered by increases in flow (Hendry & Cragg-Hine, 2003), with a preference for the upper section of the water column, near to the surface (S. Clough, pers. Comm.). In estuaries migration is still primarily nocturnal, with a strong tidal component to the direction of migration, and with movement seawards occurring on ebb tides during the hours of darkness (Moore et al. 1995 cited in Hendry & Cragg-Hine, 2003).

The light penetration studies, described above, suggest that the potential zone of light impact arising from the installation, is likely to be limited to the structure and an area 2 m surrounding it. It is likely that migrating smolts would avoid this immediate area at night when the buoys are illuminated, favouring the darker reaches of this stretch of the river. However, given that the location of the structure is sited on the inside of a river bend, it is unlikely that this will constitute a barrier to downstream migrating individuals as these individuals tend to follow the fastest downstream flows and as such are likely to take a route following the outside bend.

Effects on adult salmon

Adult salmon migrate upstream from the sea to spawn, with the migration primarily occurring at higher river flows, and typically triggered by increases in flow. For the reasons stated above, it is considered unlikely that light emitted from the installation would constitute a significant barrier to upstream migration of adults, as its zone of impact would be restricted to the immediate vicinity of the structure itself and the unaffected outer bend of the river provides an optimal migration route.

5.1.2 Lamprey

The effects of lighting on lamprey are also likely to result from the potential penetration of light into the water column. While this is not likely to be adverse during daylight hours, during the hours of darkness, the light may result in disturbance of lamprey species, leading to their avoidance of the area occupied by the installation, inhibition of migration through the illuminated area, and localised displacement of fish to areas beyond the effect of the lighting.

Effects on lamprey transformers

The light emitted from the illuminated buoys may affect transformer lampreys while they are migrating through the tidal Teifi on passage to the Cardigan Bay. While in operation, it is considered that the structure may result in some localised displacement of individuals and the avoidance of the area by migrating transformers. However, as the impact zone from the lighting is likely to be restricted to the area immediately surrounding the structure representing at worst case 26% of the river channel, it is not considered that this would represent a significant barrier to migration and thus would not adversely affect the lamprey populations.

Effects on adult lamprey

Adult lamprey, particularly river lamprey may reside in the Teifi estuary, and thus be affected by the light emitted from the structure as resident adults as well as during their spawning migration. However, as the zone of impact is limited to the area immediately surrounding the structure, and the penetration of light is likely to be restricted to the upper water column, the installation is only likely to displace any resident individuals from this localised area of 180 m^2 representing 26% of the river channel at the worst case. For the reasons provided for migrating transformer lamprey, it is unlikely that the illuminated structure would represent a barrier to migrating adult lamprey, as it is considered unlikely to be visible above background light levels a distance greater than 2 m from the structure at worst case.

5.2 Sound

A total of 6 loudspeakers are proposed, 3 at each end of the structure, mounted to a pole that is fixed to the sunken hull structure, but projecting out of the water surface. The power output is predicted to be at a continuous level of 50W at a frequency comparable to usable sound frequencies, in the range of 300 Hz to 3,400 Hz.

5.2.1 Salmon

As stated in Section 3.3.2 , the generalist hearing capabilities of Atlantic salmon are concentrated within the low frequency range, with salmon being functionally deaf at bandwidths beyond 380 Hz (Hawkins and Johnstone, 1978). As a result, the potential effects of the installation are likely to be restricted to those frequencies at the lower end of the operational range, between 300 and 380 Hz.

Given that the speakers will emit sound above the surface of the water, and that airborne sounds are probably not detectable by Atlantic Salmon (Hawkins and Johnstone, 1978) it is considered unlikely that the speaker system as specified for the installation of the project would constitute a barrier to the migration of salmon or have significant impacts on local salmon or migratory fish.

It is possible that a small proportion of the sound may be transmitted to the water column via the mounting pole, however this is not considered likely to result in a significant impact on local or migratory salmon. Measures to prevent this sound transmittance via the mounting poles will be proposed in the following section.

5.2.2 Lamprey

As non-specialist hearing fish, and in view of the poor transmission of air borne noise to water, it is considered that the penetration of sound from the installation into the water column is unlikely to be detectable by lamprey, and is therefore unlikely to result in significant disturbance effects on resident or migrating lamprey.

5.3 Buoy mooring structure

The mooring structure for the buoys comprises a sunken boat hull, approximately 14 m in length and 6 m in width. The presence of this structure, held in place by two concrete mooring structures, would result in modification to the river bottom environment in the area immediately below the structure. In this area, the presence of the sunken hull, which would move up and down with the tide, would result in reduced light conditions immediately below it. This could potentially result in a shadow effect, particularly at low tide, when the hull would be lower in the water, although this would be comparable to that generated by any other moored vessel.

The area of river bottom affected by the sunken hull is relatively small, in relation to both the habitat present in the local area and in the wider estuarine area of the River Teifi SAC. Therefore, this habitat modification is not considered to represent a significant adverse impact in relation to the Habitats Regulation Assessment.

The reduced light conditions present under the mooring structure, may potentially provide a beneficial effect to fish species, by providing shelter and cover during daylight hours. Lamprey species for example favour shaded areas and may be able to shelter under the structure, or attached to it, and thereby benefit from its presence.

5.4 Electrical cabling

The buoys and speakers will be powered by either a 24v battery on the shore with cables running to the floating supporting structure or 240v cables on the river bed and a transformer on the floating structure.

In both potential options, the location of the cabling is not considered to result in potential significant impacts on either salmon or lamprey species. While the installation of the cabling may potentially result in very localised disturbance to individual fish that are present in the location at that time, the displacement of fish is likely to be short-term and over a relatively short distance from the shore to the floating structure. During the operation of the installation, the presence of cables is not considered to affect salmon or lamprey species.

Therefore, it is unlikely that any significant effect on salmon or lamprey will result, particularly in relation to the conservation objectives of these species or the favourable conservation status of these species.

5.5 Summary of potential significant impacts

The proposed installation could potentially result in a number of impacts on lamprey and salmon that are either resident or migrating through the stretch of the River Teifi where the project is to be located. Although light emitted from the installation could potentially lead to salmon and lamprey avoiding the area affected by the light, this impact is considered to result in a localised zone of impact, restricted to within just a few metres of the structure itself. In addition, the location of the structure, on the inside bend of the Teifi, means that any displaced fish would be able to migrate through the river in the middle and outer bend sections, which are likely to be preferred due to the faster water currents.

Similarly, the sound emitted from the speakers may potentially result in disturbance in the immediate vicinity of the structure, with potential impacts on salmon. Lamprey, which have very poor hearing functions, are not considered to be likely to be affected by the sound emitted. The potential impact on salmon is not considered to adversely affect resident or migrating salmon, as they are functionally deaf to the majority of sounds likely to be emitted, and only a small proportion of the sound from the speakers would be transmitted in to the water column.

No adverse impacts on salmon and lamprey are considered likely to arise from either the installation of the sunken hull as a mooring structure or the cabling required to link the structure to the shore. In both cases, these impacts are considered to be similar to the presence of floating moored boats and existing cables/mooring ropes respectively.

Consequently, based on the specifications for the project described in this report, it is considered that the ‘Turbulence’ installation would result in no significant adverse impact on the fish populations that could potentially be affected.

6 IDENTIFICATION OF POTENTIAL MITIGATION MEASURES

In consideration of the protection afforded the River Teifi and in acknowledgement of Habitats Directive guidance a precautionary approach to the identification and assessment of risks has been taken from the very early stages of the project conception. As a result, a precautionary approach has been adopted throughout the design stage of the installation. The design team sought early consultation with fisheries specialists, to ensure that the design incorporated the implications of the biodiversity constraints present and ensured that potential impacts were avoided totally or reduced such that they did not adversely affect the fish populations.

This integration of biodiversity concerns into the design of the project has led to a number of design modifications, summarised below:

6.1 Location of installation

The moored structure will be located on the inside bend of the river Teifi in Cardigan. This location, while being favourable from aesthetic and navigation perspectives, is also optimal in preventing adverse impacts on the fish designated features. This location, means that potential impacts are restricted to one side of the river (as opposed to a mid-stream location) and that the favourable migration stretch of river (in the more rapid flow streams on the outside bend of the river) is avoided.

6.2 Mooring structure

The mooring structure has been designed to reduce impacts on the underwater river environment. By rising and falling with the tide, in the manner of a floating hull, and designed to have a latticed hull construction, the structure will present limited resistance to tidal currents. Thus disturbance to flow patterns will be minimised and will not or result in significant river substrate habitat modifications beyond its immediate vicinity. Indeed, the presence of the hull may even provide additional shelter for migrating salmon and lamprey, particularly during daylight hours when there would be no significant light disturbance in the immediate area.

6.3 Lighting

The lighting to be used in the installation has been selected to ensure that it meets the aesthetic aspirations of the artist, while reducing the penetration to the river environment. In particular, the design of the lights in each buoy have been planned to ensure upward light transmission, with upward facing LED lights, construction of buoys using ‘milky’, or opaque, polyethylene material, and the placement of the LED’s on an aluminium base plate preventing downwards light penetration through the buoy. These design specifications all ensure that the light penetration downwards is minimised. The preliminary results of measurements have shown that these mitigation measures have restricted the zone of impact of light penetrating the water column to an area of within 2 m around the structure.

In addition, the LED lights selected for use, have been selected to ensure that the colour temperature is similar to that of sunlight, and will be just visible to the naked eye during daylight hours. The light emitted has been designed to be no greater than other potential sources of light pollution that are present in Cardigan, such as street lighting and a nearby builder merchants yard beyond a couple of meters from the structure at worst case.

6.4 Sound

Based on the evidence from scientific studies into fish hearing, as described in the literature review sections of this report, it is considered unlikely that the sound transmitted from the speakers will adversely affect salmon or lamprey species. This is primarily a result of the speakers being mounted above the water surface, and the greatly reduced transmission properties of airborne sound into water. In addition, lamprey have a very reduced hearing function, and salmon are functionally deaf for much of the operation frequency range at which the speakers will operate.

However, as a further mitigation measure, it is recommended that the mounting poles on which the speakers are to be attached, should be insulated for all submerged sections using waterproofed lagging to further reduce the transmission of sound from the speakers down the pole and into the water column.

7 SCREENING MATRIX

Name of Project or Plan	Big Art Project – Cardigan 'Turbulence'
Name and Location of Natura 2000 Site	**Afon Teifi/River Teifi SAC** See www.jncc.gov.uk
Description of the Project or Plan	The installation of a large scale art sculpture consisting of a floating moored structure supporting 127 interactive buoys each of which contains 16 LED light sources and 6 speakers in total at either end of the floating structure. **Landtake/Physical change** The entire structure will be approximately 14 m in length and 6 m wide with a total area of approximately 84 m^2 (assuming a rectangular structure). The buoys will be attached to a floating structure similar to a boat hull. The structure will be fixed to the river bed with two concrete moorings one at for and the other at aft. The mooring arrangement will be similar to that for an 18 m boat in a river. The floating structure will be attached to the mooring with a chain and bridle allowing the structure to move up and down with the tide. Physical habitat change will be restricted to the sites of the two moorings and potentially the area under the floating structure. **Emissions and waste** The only emissions and waste anticipated to result from this installation will be engine fumes from the vessel deployed to fix the structure to the moorings and that of maintenance boats. **Construction activities/Transportation requirements** Activities will be restricted to the placement of the moorings, the fixing of the structure to the moorings and maintenance visits. **Project programme** The art installation will be present within the river from one month to the structures lifetime. It is proposed that the structure will be fixed into place in the river during spring/summer 2009. **Distance from Natura 2000 site** Works are to be undertaken directly within the Afon Teifi/River Teifi SAC.
Is the project or plan directly connected with or necessary to the management of the site?	No.
Are there other projects or plans that together with the project or plan being assessed could affect the site?	Plans are in place to regenerate the quayside adjacent to the planned installation position for public pedestrian use.
Describe how the project or plan is likely to affect the Natura 2000 site – boulder placement	**Atlantic salmon** 1. *Disturbance - sound* – localised effects from transmission of sound to water column and potential displacement and /or deterrence of

	fish 2. *Disturbance - light* – penetration of light from illuminated structure into water column leading to avoidance and/or displacement of fish from zone of impact 3. *Barrier to migration* – potential effects of light and/or sound disturbance could potentially lead to structure acting as a barrier to migration of salmon smolts downstream and adult salmon upstream **Lamprey** 1. *Disturbance - sound* – localised effects from transmission of sound to water column and potential displacement and /or deterrence of fish 2. *Disturbance - light* – penetration of light from illuminated structure into water column leading to avoidance and/or displacement of fish from zone of impact 3. *Barrier to migration* – potential effects of light and/or sound disturbance could potentially lead to structure acting as a barrier to migration of both lamprey transformers downstream and adult lamprey upstream
Provide indicators of significance as a result of the identification of effects set out above	1. *Disturbance - sound* – No significant impacts 2. *Disturbance - light* – No significant impacts 3. *Barrier to migration* – No significant impacts
Describe any likely impacts on the Natura 2000 site as a whole	No likely impacts on the Natura 2000 site as a whole are considered to result from the proposed project, as the structure is not considered to be likely to have a significant impact as a barrier to migration.
Describe from the above, those elements, where the above impacts are likely to be significant or where the scale of magnitude of impacts is not known	No significant impacts on integrity of the Natura 2000 or its conservation objectives – see Sections 5 and 6 of report for further detail

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