Centre for Environment Fisheries & Aquaculture Science

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Understanding the Value of Strategic Evidence Surveys to Support the Tidal Steam Energy Sector in Wales.

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Executive summary

The waters around Wales are home to a diverse range of habitats and species of national and international importance. They also contain a rich renewable energy resource with up to 6 GW of generating capacity potential for wave and tidal stream energy. Wales is well positioned to play a leading role in these emerging sectors; however, it is important that the sectors develop in a way that is both economically feasible and environmentally sensitive. A recently published report – '*Review of Monitoring Methodologies and Technologies Suitable for use in High Energy Environments in Welsh waters*'[1], suggested merit in gathering strategic evidence for key marine features (marine mammals, birds and fish) to support the tidal stream sector. In response, the Welsh Government has commissioned The Centre for Environment, Fisheries and Aquaculture Science (Cefas) to provide advice on the value of surveys for new strategic evidence on migratory fish, marine mammals, and diving seabirds in relation to tidal stream resource areas around Wales.

The advice, presented in this report will help to inform understanding of the need for, and practical considerations related to, potential surveys for strategic evidence which can support the sustainable growth of the tidal stream sector. The project had four objectives:

- Objective 1: What could strategic survey evidence tell us?
- Objective 2: Which methods work where?
- Objective 3: How many data are needed and what would they cost?
- Objective 4: Making strategic evidence available.

Strategic evidence in this case is defined as information on the presence, abundance, distribution, and also behaviour of the animals in and around tidal energy resource areas (RAs). For the strategic evidence to be useful it should be relevant to two areas. Firstly, it should support the overall planning and consenting processes of a developing tidal energy sector. Secondly, it should help fill some known scientific evidence gaps on the effects of tidal energy devices on marine animals.

The individual stages of the planning and consenting processes were reviewed. It was concluded that strategic evidence could be useful at all stages and could be highly relevant to wider cumulative effects studies. There are only a few small scale tidal energy developments in the UK to date. A review of the environmental impact assessments of these developments showed that marine mammals and seabirds were usually the main focus of the assessments. Migratory fish were considered in around half of previous assessments.

[1] Review of Monitoring Methodologies and Technologies Suitable for use in Welsh Waters (gov.wales)

Evidence gaps on tidal energy have been identified by Offshore Renewables Joint Industry Programme – Ocean Energy (ORJIP-OE[2]). It was determined that strategic evidence could help fill many of these gaps, either completely or partly.

The *Review of Monitoring Methodologies and Technologies Suitable for use in High Energy Environments in Welsh waters* identified methodologies for collecting suitable data on migratory fish, marine mammals, and diving seabirds. The ability of each methodology to provide useful strategic evidence versus the costs and risks were examined. The findings in this report are largely comparable with the previous study, although it was recommended that Passive Acoustic Monitoring (PAM) methods should be considered further. For migratory fish, Environmental DNA (eDNA) and arrays of acoustical tracking devices are most likely to provide useful data. For marine mammals and diving seabirds a combination of visual surveys from boats and land would be most useful and cost effective. For marine mammals PAM would also be very useful at filling gaps in visual surveys. Visual surveys and PAM for marine mammals and seabirds are tried and tested methods with low risk, albeit high cost.

Before any new surveys for strategic evidence are planned it is important to consider what the objective of the strategic evidence would be. In simple terms: what is the scientific question that strategic evidence is trying to answer? Once the objective of the strategic evidence has been defined, the next step is to determine what information is needed to meet this objective. In many cases it may be possible to use existing data as part of this information. It may also be necessary to collect new data to fill in the gaps.

Overarching strategic evidence objectives for each key feature relevant to each stage of the planning process were suggested. The existing data on each key feature was examined before recommendations on where new data would be needed were made. The review concluded that there are very few existing data on migratory fish in the marine area. For marine mammals and diving sea birds there are good data already available which could be sufficient for planning and policy. But in all cases, there are insufficient data to fill the current evidence needs in either consenting or scientific gaps.

For migratory fish, any new strategic evidence would be useful. There are, however, no guidelines or established methods on how many data should be collected and therefore this needs to be considered in planning strategic surveys. For marine mammals and diving seabirds, monthly surveys for a minimum of two years were recommended. This is in line with industry guidelines for offshore renewable energy developments.

A range of options were considered for survey work that should provide useful strategic evidence. For each option, the indicative costs, the risks of not being able to provide sufficient data, and the benefit of the data to the tidal sector were taken into account. These options are summarised in the table below.

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[2] Documents | ORJIP

Option	Indicative Costs	Risk	Benefit to tidal stream sector
Migratory Fish			
1) No survey	-	-	-
2) eDNA	Low	High	Low-medium
3) Trial tagging and acoustic tracking	High	High	Medium
4) Full scale tagging and acoustic tracking	Very High	Very High	High
Marine mammals			
1) No survey	-	-	-
2) Vantage Point surveys	Low	Low	Low
3) Trial visual/PAM vessel survey	Medium	Low	Medium
4) Aerial survey	High	Low-high	Medium
5) Static PAM	High	Medium	Medium
6) Full visual surveys (boat) with towed PAM	High	Low	High
7) Visual surveys + PAM (boat) + static PAM deployment	Very high	Low	High
Diving seabirds			
1) No survey	-	-	-
2) Vantage Point surveys	Low	Low	Low
3) Trial visual vessel surveys	Medium*	Low	Medium
4) Full visual surveys (boat)	High*	Low	High
Strategic Coordination			
Coordinated oversight of survey work and analysis	Low	Low	Very high

* Low if combined with marine mammal surveys.

Any work involving the use of boats and equipment such as acoustic recorders will have a high cost. However, savings can be made if boat surveys are combined (boat costs usually being the most significant). Due to the methodologies being relatively novel, and logistical issues in capturing and tagging rare fish, all migratory fish options are considered high risk. In contrast, the methods for surveying marine mammals and diving seabirds are tried and tested across numerous commercial projects and are therefore, much lower risk. In all cases the benefit of new strategic evidence to the tidal sector is proportional to the scale of the survey work.

A programme of strategic surveys will only be useful if the data are accessible to those who need them. A number of recommendations on data standardisation, storage and publication of metadata are made. Considering these factors from the beginning will pay dividends and help avoid unforeseen costs.

Overall, this advice concludes that monthly surveys for marine mammals and diving seabirds are likely to be useful across multiple areas of the planning and consenting processes and to address evidence gaps.

The main concern for migratory fish is that of collision risk causing population level impacts. However, this risk is a perceived risk rather than a proven risk. If this risk is not realised, then value of surveying for migratory fish is reduced. The very high cost of tagging studies versus the real risk of collecting insufficient data is of concern. For this reason it is recommended that the acoustic tagging arrays options are considered as research proposals at this stage and warrant further discussion. eDNA studies would be useful and in contrast to tagging studies are relatively low cost. While it is not recommended to carry out eDNA studies on their own, combining the work with marine mammal and or seabird surveys could be cost-effective.

The next steps from this project would be to consider which, if any, options could be taken forward. Any options progressed will need to be planned and costed in detail, bringing in the relevant scientific and fieldwork experience. The benefits of this include pooling expertise on data processing, ensuring suitable statistical power and maximising efficiencies.

Finally, the report recommends that any strategic evidence programme is centrally coordinated in Wales. Centralising the objective setting, the survey planning, and the data coordination is likely to be the most impactful action to support a developing sustainable tidal sector. The cost of strategic coordination is minimal, but the benefits would be felt by all.

1. Introduction

The Welsh Government has ambitious decarbonisation targets and recognise the role marine renewable energy will play in meeting these targets as part of an energy mix (Welsh Government, 2019).

Informed by the ORJIP-OE (2020) evidence gaps, the Welsh Government has identified a series of Strategic Projects which could be undertaken to support the consenting of wave and tidal stream energy projects in Wales. One project proposed the gathering of "*Strategic Evidence for key features of importance, assessing their status and use of key wave and tidal stream resource areas*". The key features in question are marine mammals (cetaceans, seals and otters), migratory fish including: salmon, allis shad, twaite shad, sea lamprey, river lamprey and freshwater pearl mussel, and diving birds. These features are afforded protection through the Conservation of Habitats and Species Regulations 2017[3], the Conservation of Offshore Marine Habitats and Species Regulations 2017[4] and the Environment (Wales) Act 2016[5].

On behalf of the Welsh Government, Clarke *et al.* (2021a) carried out a review of survey methodologies and technologies that could be used to monitor animal interactions with tidal energy devices in high energy environments. The conclusions of Clarke *et al.* (2021a) listed three recommendations for data collection which "*aim to provide data that developers can rely on for initial assessments, covering presence / absence, relative seasonal abundance, and in some cases abundance or the proportion of populations present"*. These recommendations were:

- *'a baseline visual observation programme for seabirds and cetaceans covering the resource areas.*
- *a strategic eDNA sampling programme for fish (and potentially all species); and*
- *the establishment of acoustic tracking arrays, together with sentinel tagging studies to provide better understanding of migration patterns for diadromous [migratory] fish around the Welsh coast'.*

Cefas has been commissioned by the Welsh Government to examine the practicalities and costs of using such methods to collect strategic evidence on the status of key features in areas that contain suitable tidal stream energy referred to as Resource Areas (RAs) (Figure 1.1). These areas are based on current technologies for extracting energy from tidal stream, however, it is conceivable these areas could change in future as technology develops.

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3 The Conservation of Habitats and Species Regulations 2017 (legislation.gov.uk)
4 The Conservation of Offshore Marine Habitats and Species Regulations 2017 (legislation.gov.uk)
5 Environment (Wales) Act 2016 (legislation.gov.uk)

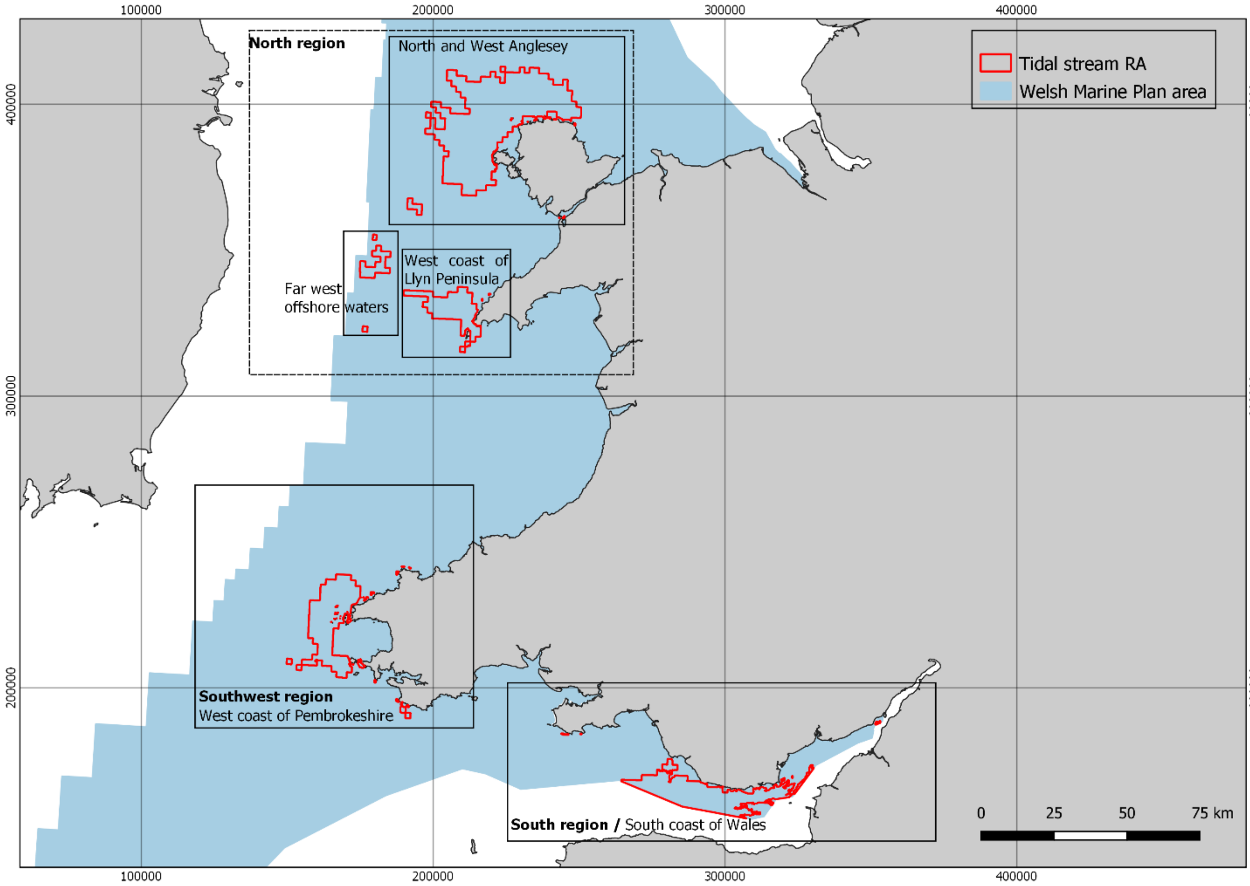

Figure 1.1: Locations of suitable tidal stream energy resource areas. The resource areas are grouped into regions and areas following the approaches in Clarke et al. (2021a) and ABPmer and Welsh Government (2021) respectively.

1.1. Objectives

The scope of this project was limited to tidal stream devices only. Wave energy, and tidal lagoon devices were not considered within this project. Otters and freshwater pearl mussels were also excluded from this work as they are unlikely to encounter offshore tidal stream devices.

The overarching objective of this project is to understand the value of strategic evidence which could support the sustainable growth of the tidal stream sector.

The project has four objectives:

Objective 1: What could strategic evidence tell us? (Section 2).

- Examine how collecting and analysing strategic evidence for key features (migratory fish, marine mammals and diving birds), identifying their status and understanding their use of tidal stream RAs relate to the current overall critical evidence gaps for this sector.

Objective 2: Which methods work where? (Section 3).

- Building on the work by Clarke *et al.* (2021a), confirm the suitability of recommended survey methodologies identified for the strategic RAs.
- Determine whether there are specific benefits or limitations to each of the methods within the individual strategic RAs that may make one more appropriate.

Objective 3: How many data are needed and what would they cost? (Sections 4 and 5).

- Define the objective of gathering strategic evidence.
- Determine what data are already available.
- Define how many data would be required to make a meaningful package of strategic evidence for each tidal RA.
- Describe low, medium, and high costs options for collection of strategic evidence.

Objective 4: Making strategic evidence available (section 5.4 and section 6).

- Discuss the most effective way(s) of making data collected from strategic evidence available to those that need it, considering factors such as data collection protocols, size, retention, processing, hosting and access.

This project will support sustainable growth of the tidal stream sector in line with Welsh Government policy. The ambition is that this report will be used by marine research institutes, the Welsh Government and its partner organisations, and the tidal stream sector; to inform future priority research plans to facilitate consenting of tidal stream energy projects in the Welsh marine area.

It should be emphasised that the outputs from this project are intended to inform decisions on strategic evidence needs and support growing the evidence base for development of the tidal stream sector. Recommendations in this report do not prescribe where future developments may or may not progress. Furthermore, specific project level considerations will always be necessary as part of the relevant consenting process.

2. What could strategic evidence tell us?

Firstly, we must define what is meant by “*Strategic Evidence for key features of importance, assessing their status and use of key wave and tidal stream resource areas*”. In the context of this project, we are referring to survey data which describe the key features of importance, assessing their status and use of tidal stream RAs. Essentially this is data on the presence, abundance, distribution, and behaviour of the animals in and around the RAs which can be used to inform the planning and the consenting of tidal stream projects. Some of these data may already exist and could be brought together into larger datasets. Additional data are likely to be required, which may need new surveys to collect them.

Strategic evidence has the potential to help in two areas. Firstly, it has the potential to support the tidal stream sector directly by providing evidence for the consenting process. Secondly, there is the possibility to fill some of the key evidence gaps that may slow the development of a tidal steam sector.

2.1. How could strategic evidence support the tidal stream sector?

It is important to consider how any new strategic evidence would contribute to the planning or consenting processes for any proposed tidal stream development, and specifically what is meant by ‘initial assessments’ as referred to in the Clarke *et al.* (2021a) recommendation. To be useful to a developer or regulator, strategic evidence collected for entire RAs must fit into the progressive stages of the policy, planning, consenting, and monitoring process. RA scale survey data must not however, compromise the confidence in conclusions, for example by being of lower spatial or temporal resolution, if it were used in place of site-specific (i.e. project level) data. The main stages in the planning and consenting process which require environmental data are:

1. **Policy and Planning**: Plans such as the Welsh National Marine Plan (WNMP) must consider the potential consequences of policies on the natural environment. Habitats Regulations Assessments (HRA) are required for Plans and Projects which have the potential to have significant impacts on Marine Protected Areas (MPAs). The HRA for the WNMP described that for the tidal stream sector: ‘*(a) data is lacking, particularly for large-scale schemes and (b) effects will be highly dependent on the technologies employed’* (Wood, 2019). This suggests that while the policies in the WNMP such as ELC_03 and ELC_04[6] promote tidal energy development, a knowledge gap for prospective developments exists which introduces uncertainties in the consenting process in terms of potential impacts. Additional strategic

[6] ELC_03: Low carbon energy (supporting) tidal stream and ELC_04 Low carbon energy (supporting) tidal range. (Welsh Government, 2019)

evidence, of any type or spatial/temporal resolution would increase the confidence at planning stages that environmental impacts can be managed effectively.

Therefore, while new, even relatively low-resolution, data may not be sufficient for project level assessments, such data at a strategic level may allow prospective developers to progress projects with greater confidence and speed.

2. **Site selection and screening and scoping**: At the project level, this stage identifies species and habitats potentially at risk from the proposed development. This is typically a desk-based exercise used to define the limits of subsequent stages, and/or identify major knowledge gaps or consenting risks. In certain cases data collection may be required at this stage. The level of available data at this stage can influence various factors such as if proposals proceed, the size and scale of developments, the location of developments and the pace of the project.

   A strong strategic evidence base available to prospective developers at this stage could reduce consenting risks and cost by decreasing or eliminating the need for some site-specific surveys.

3. **Characterisation**: This stage details the species and habitats which may be affected by the proposed development in sufficient detail to inform impact assessments (typically Environmental Impact Assessment (EIA), HRA, and Water Framework Directive (WFD) compliance). The level of detail varies depending on the feature, such as species or habitat, which could be impacted and risks (i.e. the pressures which could act on the species or habitat resulting in impacts). However, typically it is important that the characterisation identifies the presence/absence and distribution of species and habitats in the zone of influence of the project. Characterisations typically help identify whether a species or habitat may be subject to significant impacts or adverse effects, however, they are often broad scale and typically do not provide sufficient detail to measure change against. Characterisations can sometimes be completed using existing data, although site-specific surveys, especially for species considered to be sensitive or at high risk are often required.

   New strategic evidence is likely to be useful at this level and may either reduce or eliminate the need for developers to complete some site-specific surveys. This should not however, be taken as a given.

4. **Pre-construction baseline**: Following characterisation and assessment, species or habitats identified as potentially at risk of significant adverse effects may require monitoring (i.e. measurements of changes attributed to the development). Although dependent on the specific aims of the monitoring, monitoring typically requires a detailed pre-construction baseline which provides detailed measurement of a specific habitat or species against which change can be measured.

Such baselines are highly location and species/habitat specific. Any survey for strategic evidence in a RA would have to be of very high resolution, or designed with future monitoring in mind, to be useful at this stage.

5. **Monitoring**: The final stage is to monitor a specific species or habitat for effects after the inception of the proposed project. This normally involves collecting data for a particular feature, for a set period and comparing those data to the pre-construction baseline. Trigger points for action may be included in consents which require mitigation actions if pre-defined effects thresholds are exceeded.

   Monitoring occurs after baseline conditions are established and therefore this stage is outside of the scope of surveys for strategic evidence.

In some circumstances characterisation data may be sufficient to serve as pre-construction baselines or detailed pre-construction baseline data may not be required to meet the objectives of the monitoring. For example, monitoring for marine mammal collisions with tidal energy devices may be a requirement of consent. Pre-construction baseline data may not be required as the characterisation data would detail marine mammals were potentially at risk, and given the high conservation value of these species, any collisions could be significant. In this case the aim of the monitoring is not to measure change in a population or habitat, but instead to identify all collision events during operation. Additionally, appropriate monitoring may instead be for the pressure (e.g. underwater noise) with thresholds for mitigation applied to the pressure rather than species or habitat potentially being impacted.

An additional benefit of strategic evidence is in support of Cumulative Effects Assessments (CEAs). One of the challenges of carrying out CEAs or similar regional scale assessments is collating multiple data sets. Site specific data from individual developments may be suitable for that project, but less so for wider assessments. Differences in survey methodology, statistical power and the period covered by the data can result in difficulties when combined with data from other sites. A strategic evidence programme can help overcome these challenges if wider assessments are considered in the survey planning.

Overall, there are considerable benefits to be gained from collecting strategic evidence. Information on the status of key features is likely to help tackle key evidence gaps surrounding the development of tidal energy in Wales. Strategic evidence has the potential to benefit multiple projects in the same region. It has the potential to benefit the industry and regulators in the consenting of tidal stream projects. Strategic evidence, if coordinated well, could help in understanding cumulative effects. It could also benefit other sectors including nature conservation.

2.1.1. Previous tidal stream projects

A full review of the evidence used in tidal stream consent applications made in the UK to date is outside of the scope of this project. However, a summary of relevant projects is provided to give context to the evidence standards that may be expected by Regulators.

While it is important to take this into account when considering new strategic evidence collection to ensure that data is both required and useful, it must be noted that the current EIAs and consents are a) small scale developments and b) tidal stream is an emerging sector and therefore evidence requirements may develop in line with the sector.

There are very few examples of fully consented tidal stream projects in the UK. Most that have been through the consenting process are small scale or demonstration sites. Most have required a full EIA following screening under the Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended), however, the breadth and detail of the EIAs are limited (for example some species or habitats are scoped out or not considered in detail) due to the size and scale of the developments. For the projects listed below, the relevant sections of the EIAs have been reviewed to establish the scale and location of the development, the relevant environmental issues and in particular the assessment effort dedicated to key features of migratory fish, marine mammals, and diving seabirds (Table 2.1).

To date, likely due to the scale of developments, site characterisation surveys for migratory fish have not been carried out. However, for marine mammals and seabirds they are more common, especially for projects with more than one to three devices. Projects to date have generally collected two years of monthly survey data, which is typically regarded as the standard for marine offshore renewable projects (Sparling *et al.*, 2015).

Table 2.1: Summary of marine ecological characterisation evidence and surveys for previous tidal stream projects.

Name	Details	Migratory Fish	Marine Mammals	Seabirds
Welsh waters				
Holyhead Deep – Minesto (Minesto, 2016)	'Deep Green' underwater kite. Single 0.5 MW device. In operation.	Not considered	Desk-based (pre-existing) data only[7]. However, area specific pre-existing data were available.	Desk based (pre-existing) data only
Ramsey Sound - Tidal Energy Ltd (Tidal Energy Limited, 2009)	Bottom horizontal turbines (three). 400 kW.	Desk study – high level only.	Shore based surveys (vantage point). Monthly for three years.	Desk based (pre-existing) data only supplemented with partial year (9 months) of shore-based surveys (vantage point).
Morlais Demonstration Zone - Menter Môn (Menter Môn, 2019a, 2019b, 2019c)	Multiple arrays of tidal energy devices up to 240 MW. Consent awarded (pre-development stage).	Desk study[8]	Monthly visual surveys (vessel based) for 2 years. Plus, additional 2 years of near monthly surveys.	Monthly visual surveys (vessel based) for 2 years.

[7] "*In recognition of the amount of existing baseline data covering the project location and the small scale of the project itself, Minesto consulted with NRW on the need for dedicated site-specific surveys. It was concluded that any such surveys were unnecessary to inform the impact assessment based on the proposed impact assessment and collision risk assessment methodology proposed*" (Minesto, 2016)

[8] "*No site-specific surveys for fish and shellfish were conducted for the project. Based on the nature of the area and likely (low level of) impacts on fish species it was determined that site-specific surveys were not required. This approach follows the clear precedent set by offshore energy developments in recent years*" (Menter Môn, 2019a)

Name	Details	Migratory Fish	Marine Mammals	Seabirds
Other UK				
Pentland Firth – MeyGen (Scotland) (MeyGen, 2012)	Bottom horizontal turbines (four installed, however, 86 assessed in EIA) 6 MW (phase 1). In operation	Desk study[9]	2 years of boat and shore visual. Three acoustic (PAM) surveys.	2 years of boat and shore visual.
Shetland Tidal Array - Nova Innovation (Scotland) (NOVA Innovation, 2021)	Bottom horizontal turbines. Three devices. 300 kW. Three further licenced to be installed.	Not considered	Shore based surveys (vantage point). 4 years preconstruction and post construction monitoring.	Shore based surveys (vantage point). 4 years preconstruction and post construction monitoring.
SeaGen Strangford Lough - Marine Current Turbines (NI) (Marine Current Turbines, 2005)	Single twin turbine device on monopole. 1.2 MW Decommissioned.	Not considered	Three-month seal survey. (Post consent monitoring required)	Desk based only.

[9] *"Through consultation with Marine Scotland, a site specific fish ecology survey was not considered a requirement for the proposed Project"*

2.2. Evidence gaps

In addition to providing evidence to support the consenting of tidal stream energy projects, strategic evidence could also help to fill evidence gaps. It is therefore useful to understand the relevance of strategic evidence to the tidal stream energy sector in Wales. Copping *et al.* (2020) carried out an extensive review of the state of the science on environmental evidence gaps of tidal energy devices. Alongside this review, ORJIP-OE (2020) compiled a list of critical evidence gaps for tidal stream devices, both of which helped inform this work.

A review of the critical evidence gaps described by ORJIP-OE (2020) in comparison to the potential strategic evidence that could be gathered is presented in Annex 1. The evidence gaps are divided into eight strategic topics, each with a set of priority actions. Many of these strategic actions and priority actions are relevant to this study (Table 2.2)

ORJIP-OE Strategic topic 3 *'Occupancy patterns, fine-scale distribution and behaviour of mobile species in [wave and] tidal stream habitats'* could largely be addressed by gathering strategic evidence, at least for the key features under discussion in this report. The topic has two priority actions:

- *'Further characterisation of marine mammal, seabird occupancy patterns and behaviour in marine energy sites including habitat use in relation to hydrodynamic features and conditions, to understand the likely degree of spatial and temporal overlap with deployed devices and arrays.'*
- *'Baseline fish distribution to determine which species are in vicinity of potential tidal energy sites.'*

Strategic surveys have the potential to inform both marine mammals and diving seabird distribution and abundance, provided both are targeted appropriately. Additional information on the hydrodynamic features and conditions would be needed to complement this evidence gap. However, this information will likely be collected as part of detailed studies carried out by the tidal stream industry to characterise the tidal energy resource.

While "*baseline fish distribution*" implies all fish, strategic evidence surveys have the potential to inform on the distribution of migratory fish species in the RAs, if these species are targeted. Migratory fish are thought to be those most of risk of perceived impacts.

A further 14 of the ORJIP-OE evidence gaps priority actions could be partially or indirectly filled by carrying out the strategic evidence (Table 2.2).

Table 2.2: Strategic evidence needs highlighted by ORJIP-OE (2020) that strategic evidence could addressed and to what level. *Strategic Topic number refers to the ordering in ORJIP-OE (2020) report.

Strategic Topics*	Priority Actions	Relevance to Strategic Evidence
1. Methods and instruments to measure mobile species occupancy and behaviour in high energy environments and around marine energy devices.	Improvement of the reliability and survivability of instruments in high energy waters, to address challenges including: • Hydrodynamic forcing. • Corrosion and biofouling. • Pressure and sealing.	**Indirectly:** large scale strategic evidence could indirectly provide the opportunity (assuming that funding for the test instrumentation is available) for improvements in instrumentation reliability and servicing.
	Cooperation between regulatory bodies, industry and researchers to agree on a preferred suite of instruments and platforms to accelerate data collection and facilitate national and international cooperation on the development of an improved evidence base.	**Partly:** strategic evidence would require coordination and cooperation between industry, researchers, and regulators to ensure data were fit for purpose. Platforms for data hosting and sharing can be addressed by strategic evidence collection.
	Development of solutions to improve efficiencies in storing, processing and analysing large amounts of data generated by monitoring, including improved integration of algorithms and machine learning to recognise images of marine animals around turbines to reduce processing of large quantities of data generated by monitoring programmes.	**Partly:** as above.
	Development of solutions to reduce electronic interference between instruments on platforms.	**Indirectly:** large scale strategic evidence could indirectly provide funding for improvements in electronic interference.

Strategic Topics*	Priority Actions	Relevance to Strategic Evidence
	Development of reliable approaches to powering monitoring equipment to achieve a balance between conserving power and carrying out observations over long periods of time (due to the rare probability of interactions).	**Indirectly:** large scale strategic evidence could indirectly provide funding for improvements in instrument power supply.
2. Near-field interactions between mobile species and tidal stream turbines.	Quantification of near-field responses (evasion) of marine mammals, fish and diving birds to devices.	**Partly:** The strategic evidence should provide data on the distribution and abundance of marine mammals, fish and diving birds in tidal stream RAs. Being able to quantify numbers in the wider area will help validate near-field responses and is critical for inclusion in collision risk modelling to inform impact assessments.
	Cooperation between government, regulatory bodies, industry, and researchers to agree on a collaborative approach to gathering and sharing information on measurements of animal interactions with devices.	**Indirectly:** Lessons learned on cooperation between parties at the strategic evidence survey stage will be beneficial when sharing information on measurements of animal interactions with devices.
3. Occupancy patterns, fine-scale distribution and behaviour of mobile species in wave and tidal stream habitats.	Further characterisation of marine mammal, seabird occupancy patterns and behaviour in marine energy sites including habitat use in relation to hydrodynamic features and conditions, to understand the likely degree of spatial and temporal overlap with deployed devices and arrays.	**Yes:** Strategic evidence surveys would allow for the characterisation of marine mammal and seabird occupancy patterns in the tidal RAs. Depending on the level of survey effort, this should directly provide spatial and temporal coverage of these species in and around the tidal RAs.

Strategic Topics*	Priority Actions	Relevance to Strategic Evidence
	Baseline fish distribution to determine which species are in vicinity of potential tidal energy sites.	**Yes:** Strategic evidence surveys have the potential to inform on the distribution of migratory fish species in the RAs, if these species are targeted.
4. Far-field responses of mobile species to wave and tidal stream devices and arrays.	Development of methods to relate specific marine animal behavioural responses to the range of frequencies and sound levels from single wave and tidal stream devices, or the physical presence of devices.	**Partly:** Quantifying abundance and distribution of key features in RAs will help understand potential responses such as avoidance and barrier effects.
	Development of a framework for studying the behavioural consequences of radiated noise from wave and tidal stream devices, to move beyond using audibility as a proxy for behavioural response.	**Partly:** Understanding behavioural responses will likely require a greater understanding of the abundance and distribution of key features within and around the tidal RAs.
5. Subsea acoustic profiles of [wave and] tidal stream sites and technologies.	Further measurements of radiated noise generated by a range of operational wave and tidal stream devices, distinguished from ambient noise, in particular across sound frequencies within the hearing range of sensitive marine animals.	**Indirectly:** By identifying which species may be present in the area.
6. Tools for assessing and managing risk to mobile species populations for large-scale [wave and] tidal stream development.	Validation/revision of collision risk predictive models using empirical data and field measurements.	**Partly:** Understanding the distribution and abundance of species in an area would provide data to feed into collision risk models to understand how many animals could be at potential risk. And also the extent of disturbance, far field avoidance effects.

Strategic Topics*	Priority Actions	Relevance to Strategic Evidence
	Development of models or frameworks for translating individual collision risk to population level risk, and to scale collision risk from single tidal stream turbine to arrays.	**Partly:** Understanding the distribution and abundance of species would provide data to feed into collision risk models to understand how many animals could be at potential risk.
8. Tools for assessing social and economic impacts of wave and tidal stream developments.	Development of tools and databases to classify key social and economic indicators.	**Partly:** Quantifying the distribution and abundance of key features that are relevant to social and economic ecosystem services will provide data to support assessment of any impacts.
	Development of incentives to collect and share MRE data across the MRE industry.	**Partly:** Understanding the distribution and abundance of key features that are relevant to social and economic ecosystem services may help emphasise the need to share data.

3. Which survey methods work where for collecting strategic evidence?

A range of methods are available for surveying marine mammals, diving seabirds and migratory fish, however, not all methods are suitable in all locations. The review by Clarke *et al.* (2021a) provides an extensive account of methods for surveying key features. Building on that review, this section assesses the suitability of the survey methodologies identified for the strategic RAs, for each key feature, noting specific benefits or limitations to each of the methods with appropriate recommendations.

3.1. Migratory fish

There is a lack of knowledge on potential impacts of marine renewable energy (MRE) projects on migratory fish species (ABPmer, 2019; ORJIP-OE, 2020). Evidence gaps identified by the ORJIP-OE include strategic evidence on abundance, distribution, seasonality and key migration routes of migratory species to understand their utilisation of potential development areas (ORJIP-OE, 2020), particularly those that are features protected by MPAs.

The reports reviewing methodologies and technologies, suitable for deployment in high energy environments in Wales (Clarke *et al.*, 2021a, 2021b, 2021c) provide a detailed account of key migratory fish species of concern, their ecology and survey options. The key migratory fish species identified to inhabit fresh, transitional and coastal waters in Wales are sea lamprey *Petromyzon marinus*, twaite shad *Alosa fallax,* allis shad *Alosa alosa*, Atlantic salmon *Salmo salar*, smelt *Osmerus eperlanus*, sea trout *Salmo trutta*, river lamprey *Lampetra fluviatilis* and European eel *Anguilla anguilla.*

Clarke *et al.* (2021a, 2021c) reviewed methodologies for monitoring interactions between key fish species and tidal stream devices, which included visual surveys, environmental DNA (eDNA, underwater optical cameras, passive acoustic monitoring (PAM), active acoustics, unmanned aerial vehicles (UAV), remotely operated vehicles (ROV), integrated devices, tagging, and blade sensors. The majority of the methods were not deemed appropriate for monitoring migratory fish species in RAs unless multiple methods were combined (for example capture studies and multibeam or acoustic cameras), but this can be labour intensive and can acquire high costs (Clarke *et al.*, 2021a). However, eDNA surveys and acoustic tracking studies were suggested as suitable methods for migratory fish species. Thus, Clarke *et al.* (2021a) concluding recommendations for strategic evidence were:

1. "*A strategic eDNA sampling programme for fish (and potentially all species), to create a common baseline data set benefiting all developers, again ideally run over a two- year period*".
2. "*The establishment of acoustic tracking arrays, together with sentinel tagging studies to provide better understanding of migration patterns for diadromous [migratory] fish around the Welsh coast.*" Where life stages were not suitable for tagging capture studies specific to species of interest were recommended.

The viability of surveys to collect strategic evidence on migratory fish is discussed in further detail in the sections below.

3.1.1. Capture surveys

There are two main types of capture surveys (fishing) used to collect data on fish in transitional and coastal waters; fishery-independent and fishery-dependent surveys. Fisheries-independent surveys include scientific research programmes at sea. These surveys provide a high quality but usually short time-series of data. Fishery-dependent surveys include data from commercial fishing activity, such as catch and landing data. These types of surveys provide data with a long time-series which takes into consideration long term changes. The disadvantages of fishery-dependent surveys include biased catches due to selectivity of gear and location due to the commercial aspect of operation. This can misrepresent the characterisation of a species.

Various methods are used to survey fish in transitional and coastal waters. Survey design needs to be location and species specific as entire fish communities cannot be surveyed using a single gear type given high diversity of life stages and strategies as well as the variety of habitats they inhabit (Franco *et al.*, 2020a). Thus, a multi method approach is generally recommend for surveying fish communities in transitional and coastal waters (Franco *et al.*, 2020b, 2020c). In addition, repeated sampling is required to ensure confidence in the data, (minimum of three duplicated samples during a survey). The survey schedule also needs to take into account for seasonality of fish movement, daily activity patterns and any potential tidal influences (Judd, 2012).

Sampling can be done using passive (e.g. fyke nets) and active gears (e.g. trawls). The most common techniques applied in inshore waters include a variety of trawl nets (e.g. beam and otter trawls) towed across the seabed or in the water column (Judd, 2012; Franco *et al.*, 2020b, 2020c).

Some migratory fish can be caught by beam and otter trawls, but apart from smelt, they are very rarely represented in the survey catches (Franco *et al.*, 2020a). Various fixed nets and traps (e.g. fences, stake nets) as well as drift or trammel nets of appropriate sizes can be used inshore to survey salmon, sea trout and shad juveniles and adults. High speed plankton nets can be used to target glass eels in coastal waters, especially if applied during their migration peak (Clarke *et al.*, 2021b). Specific alterations can be made to available gear to target migratory fishes, as was done with a pelagic trawl net to catch juvenile twaite shad in the lower Seine estuary or with a modified fyke net (1 ha corral trap) to sample eels in coastal waters of Germany (Franco *et al.*, 2020a). Some information may come from power stations screens, but this can only provide information on fish community of a small area, given the fixed position of the cooling water inlets (Franco *et al.*, 2020a). A description of traditional fish surveying techniques is given in greater detail in Judd (2012) and Franco *et al.* (2020a).

There are difficulties in surveying migratory fish at sea to provide data for the tidal stream sector. First, surveying RAs at the wrong time can result in no catches as the fish could have already passed through those areas on their upward or seaward migration. Second, it is hard to determine the origin of those fish caught at sea, which is particularly important for discrete populations, unless coupled with genetic, stable isotope or microchemistry studies. Thirdly, there are many difficulties in capturing migratory fishes at sea given the available gear, their rarity and specific habitat restrictions, especially in deep waters. Even with a multi methods approach, surveys might still miss some of the rarest species. Finally, capture surveys targeted at migratory species can be very labour intensive and costly and may still not provide adequate information. Therefore, capture surveys alone, especially at a strategic level are not considered feasible to establish a robust data for migratory fishes in Welsh marine waters. A summary of the advantages and disadvantages of capture surveys is given in Table 3.1.

Table 3.1: Summary of the advantages and disadvantages of capture surveys of migratory fishes at RAs.

Advantage	Disadvantage
• Can provide data on presence, relative abundance, and biometry of fishes • Can provide temporal and spatial data on fish occupation patterns • Allows for site-specificity	• Multi method approach required (species/life stage/habitat specific) • Likely to be very expensive • Labour intensive • Difficult to capture some of the rare migratory species at sea • Cannot provide information on fish origin

3.1.2. Environmental DNA (eDNA)

The use of eDNA surveys to detect DNA of species found in the water has proved effective for detecting a range of species in all aquatic environments, with increased applications in inshore and offshore waters. The technique has potential for detecting fish and cetaceans within the tidal stream RAs. Caution should be taken when using this method in open sea environments as there is a potential that DNA could be transported into a RA through ocean processes, producing inaccurate representation. Water samples can be analysed either for the DNA of specific species of interest or for all species within a taxonomic group such as fish. Targeted assays are used to identify specific species (Bylemans *et al.*, 2019), while using metabarcoding methods and generalised primer assays are used for groups (Deiner *et al.*, 2017; Ruppert *et al.*, 2019). Metabarcoding is the amplification and sequencing of DNA (or RNA) in a manner that enables the simultaneous identification of many species (or taxa) within the same sample.

Metabarcoding of water samples for eDNA has proven a good method for monitoring marine fish communities (Miya, 2022), and compares well with traditional survey methods. Analysis for eDNA has often been shown to detect rare or elusive fish species which are often overlooked by other survey methods. For example, eDNA metabarcoding detected 76% of species observed in visual diving surveys in an MPA in California, as well as a further 23 species not seen visually (Gold *et al.*, 2021). Fish community studies based on eDNA detection have typically shown that some species can be missed by eDNA metabarcoding, and suggest that the best method to survey all species within a given area is a combination of eDNA metabarcoding with traditional survey methods (e.g. Stat *et al.*, 2019; Gold *et al.*, 2021). Different generalised primers have been developed for fish which typically amplify DNA of a different set of species from the same water sample (e.g. Cole *et al.*, 2022), so several different primer sets should be used for community fish surveys if resources allow for this.

The alternative method, targeting selected species using primers developed for those species, can be more sensitive than metabarcoding for detection of rarer organisms or those which are likely to have contributed less DNA into the water (Schenekar *et al.*, 2020). This could conceivably include migratory fish species in coastal waters. Species-specific assays have been developed and published for most of the migratory fish occurring in Welsh waters: Atlantic salmon (Atkinson *et al.*, 2018); brown trout (Gustavson *et al.*, 2015), shad (Antognazza *et al.*, 2021), European eel (Cardás *et al.*, 2020), and sea lamprey (Bracken *et al.*, 2019). These assays have all been validated under field conditions, although in rivers rather than open sea where the DNA signals for these species may be expected to be more dilute.

One major limitation of eDNA surveys is that eDNA may have been transported by water movement from outside the RA, especially so in open coastal environments. The likely detectable lifetime of DNA in sea water is estimated to be around 48 hours but degrading faster in inshore environments than offshore (see review on marine eDNA degradation times by Collins *et al.*, 2018). If surveying the proposed tidal stream RAs, surveys would ideally be informed by hydrological information to determine likely areas from which water-transported DNA could originate from in that time. However, there is increased evidence that there is high spatial resolution to eDNA in marine environments, despite mixing through water movement (Jeunen *et al.*, 2019; Cole *et al.*, 2022).

A recent advancement in this area which could facilitate improved monitoring of fish in coastal waters is the development of passive samplers for eDNA (Bessey *et al.*, 2021). This approach is currently being trialled at several coastal sites in Europe, and has proven successful in detecting marine fish communities (Mirimin *et al.*, 2021).

A summary of the advantages and disadvantages of eDNA techniques for migratory fish is given in Table 3.2.

Table 3.2: Summary of the advantages and disadvantages of eDNA monitoring of migratory fishes at RAs.

Advantage	Disadvantage
• Relatively simple sample collection and data processing. • Non-invasive nature of sampling, under any weather or sea state conditions. • Relatively quick tool to identify presence of a range of species. • Very useful for detecting rare or elusive species which are difficult or time-intensive to detect using other methods. • Relatively inexpensive compared to other methods. • The same sample can be re-analysed for multiple taxonomic groups.	• Only suitable for inferring presence of fish in a wider area (limited site-specificity). • Absence cannot be inferred unless threshold detection level is agreed. • Great caution should be applied when inferring absence of migratory fish which could transit rapidly through the study area. • It can provide only indicative information on fish abundance, and no information on fine scale distribution, life stage or origin.

3.1.3. Acoustic telemetry

Acoustic telemetry has been increasingly used in recent years as a powerful tool for assessing migratory fish habitat use, movement and behaviour, but also impacts of environmental and anthropogenic factors on both individuals and populations across different habitats (Russell *et al.*, 1998; Walker *et al.*, 2014; Moore *et al.*, 2018a). It involves attaching or inserting an electronic tag to an animal which emits a specific signal that can be used to determine the individual's habitat use, movement and behaviour, and also provide information on their position in the water and activity if coupled with integrated sensors (Lucas and Baras, 2000). However, for transmitted signals to be detected an array of receivers is required with detection range dependent on the study design, tag frequency and local conditions (Lucas and Baras, 2000). The benefit of using this methodology is that there are limited environmental restrictions as long as the receivers are unobstructed and submerged, for example there are no limitations of water visibility or substrate type (unless fish is burrowed in the substrate which can block the signal) (Clarke *et al.*, 2021b).

While it can be applied in low and high-energy habitats, detection range will generally be reduced in very noisy locations (e.g. from shipping traffic, wave action, current action, turbine noise; (Clarke *et al.*, 2021a, 2021b). Acoustic telemetry is generally used in the marine environment to determine fish survival rates during migration and residence time across different habitats (Thorstad *et al.*, 2012; Lauridsen *et al.*, 2017) and to detect major migration pathways (Holm *et al.*, 2007; Righton *et al.*, 2016), which can provide information on some of the identified evidence gaps on migratory species. Although not the focus of this study, if receivers are well arranged, fine scale positioning can also be inferred, which can be particularly useful for collision/avoidance studies (Clarke *et al.*, 2021a, 2021c). Most marine tracking studies use 69 kHz for coarse scale detections and 180, 307 or 416 kHz for fine scale positioning, which are less affected by noise but also have more limited detection range, especially in marine habitats (Clarke *et al.*, 2021a, 2021c).

For the purposes of establishing information on the presence and ecology of migratory fish in the Welsh marine area, Clarke *et al.* (2021b) suggested using a coarse grid approach covering tidal stream and tidal range areas, and a combined fence and grid approach in hotspot development areas to detect if fish utilise those areas and at what proportion. If population level risk is a factor, focus should shift to fine scale positioning to determine potential collision risks for the species of interest. More specific details are provided in Clarke *et al.* (2021b, 2021c).

There are, however, several considerations which must be reviewed regarding tracking studies to provide data on migratory fishes for the tidal stream sector. These considerations are covered in detail in Clarke *et al.* (2021c) and summarised here.

1. Tagged fish may not approach the RAs. While an array of receivers should detect some fish, a considerable number of fish would need to be tagged and then detected, to determine impacts at the population level.
2. Of critical importance, not all migratory fish species can be captured easily or in high numbers. Tracking adult salmon around RAs is impractical given their high post spawning mortality and low adult return rates from previously tagged smolts (~2% for Welsh rivers). Alternatively, adults could be netted at sea and tagged, but it would be unclear if they have already passed the study area and the origin of fish would be unknown, furthermore successfully capturing sufficient numbers at sea is likely to be unviable. Similarly, adult sea and river lamprey could not be caught and tagged in rivers as they die after spawning, while capturing them at sea is very difficult given their rare occurrence.
3. Not all life stages can be tagged due to size restrictions (see Clarke *et al.*, 2021b) for further details). Specifically, acoustic tags are not suitable for juvenile stages of lampreys, shads, smelt or eel.
4. Tagging itself can influence fish behaviour (i.e. due to the presence and weight of the tag on the individual).
5. Local environmental conditions can influence the detection range of receivers (e.g. tidal noise) (Mathies *et al.*, 2014; Reubens *et al.*, 2019). Detection range testing and control tags are needed to ensure no detection gaps.
6. There are difficulties associated with deployment of monitoring devices (receivers) in areas with high tidal velocity and waves and challenges associated with their operation and maintenance under those conditions, including corrosion (careful consideration of enclosure material) and biofouling (regular cleaning required) (Heupel *et al.*, 2008).

There are also survey logistic considerations such as power for receivers, data transfer, storage and analysis and potential conflicts with other marine users, particularly fishers if large areas are covered with arrays of receivers potentially restricting fishing activities.

Acoustic telemetry has strong potential for Atlantic salmon smolts, sea trout smolts and kelts, European eel adults (yellow and silver eel stage) and twaite shad adults in all RAs. However, there are still risks that limited viable data would be collected given the above-mentioned limitations of capturing, tagging and tracking migratory fish at sea. Table 3.3 summaries the advantages and disadvantages of acoustic telemetry techniques.

Table 3.3: Summary of the advantages and disadvantages of acoustic telemetry of migratory fishes at RAs.

Advantage	Disadvantage
• Suitable for a variety of habitats and environmental conditions. • Allows for site-specificity. • Can provide information on habitat use, residency, fine scale distribution, population level impacts, collision risks and fish behaviour.	• Very expensive. • Very labour intensive. • Not suitable for some species (difficult capture and/or rare occurrence) and life stages (size limitation). • High numbers of fish need to be captured and tagged to infer about population level impacts. • Tagged fish might not enter the area of interest. • Tagging process can influence fish behaviour and survival. • Detection range is generally reduced in noisy locations. • Potential conflict with other marine users (fisheries) if large arrays deployed.

3.1.4. Summary for migratory fish

In summary, there are few viable options for surveying migratory fishes in tidal stream RAs and at sea in general. Standard methodology for surveying fish at sea includes capture surveys, but these are high risk and high cost options for surveying migratory fishes given their transient nature, rare occurrence, and diversity of life strategies, with specific gear modifications required for some species/stages. The most suitable options are as already identified by Clarke *et al.* (2021b); strategic eDNA surveys and acoustic telemetry studies targeted solely at easy captured species and life stages at locations with viable capture options.

eDNA methods can be a relatively quick, easy and cheap tool for identifying rare migratory species present in the RAs. However, it would not offer evidence of absence of migratory species in the particular RA or their abundance, fine scale distribution, life stage or origin.

Acoustic telemetry could provide relevant information for Atlantic salmon smolts, sea trout smolts and kelts, European eel adults (yellow and silver eel stage) and twaite shad adults in RAs, but given high costs and risks associated with capturing and tagging enough fish to obtain adequate tracking data and operational and maintenance challenges, there are still uncertainties about the suitability of this method. In addition, evidence gaps would remain for a range of migratory species and/or life stages.

3.2. Marine mammals

The key marine mammal species in the Welsh marine area are; bottlenose dolphins (*Tursiops truncates*), harbour porpoise (*Phocoena phocoena*), short-beaked common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), minke whale (*Balaenoptera acutorostrata*) and grey seals (*Halichoerus grypus*) (Baines *et al., 2012*). See Section 4.3.1 for further details of existing data for marine mammals in the tidal stream RAs.

Clarke *et al.* (2021a) discussed the variety of different methods for surveys of marine mammals. Their concluding recommendation for strategic evidence was:

> "*A baseline visual observation programme for seabirds and cetaceans covering the resource areas; and run for two years pre-construction could be considered. This would include visual surveys for both mammals and seabirds.*

While the recommendation above states cetaceans, non-cetacean marine mammals (in this case seals) are also relevant and have been included herein.

Another method which can contribute to survey evidence of marine mammals and is commonly used in combination with visual surveys is PAM. PAM surveys use submerged hydrophones to listen for vocalising marine mammals. Furthermore, tagging and tracking can provide fine scale data on individual occupancy and behaviours.

3.2.1. Visual surveys

There are three main types of visual survey techniques for observing marine mammals: land-based, boat-based and aerial surveys.

Land-based (or 'vantage point') surveys can observe marine mammal at individual sites and allow for high temporal and spatial resolution of small survey areas. However, land-based surveys are only suitable for tidal stream areas that are close to the coastline and will often not be able to cover the whole tidal stream area from onshore. Harbour porpoises can only be detected within a maximum of ~2 km from shore. The survey field is further influenced by the sea state and visibility, which are influenced by the currents, weather and daylight (Gordon *et al.*, 2011).

Boat-based surveys allow observations of marine mammals at individual sites and also allow high temporal and spatial resolution of small survey areas. In contrast to land-based surveys, boat-based surveys would allow observations of marine mammal species over the whole of the tidal stream RAs, by following a predefined survey track. Large research vessels are the most suitable for marine mammal surveys at sea, in particular in the high tidal velocity conditions which would be expected in the RAs. Large research vessels can remain at sea for extended amounts of time covering large areas and also provide a better proficiency in searching and species identification as observers can scan from a height (the bridge, flying bridge or crow’s nest). However, the use of large vessels is expensive. Although small- and medium-sized vessels can also be used for marine mammal surveys at sea and are less expensive, they have a smaller range and visibility is reduced due to being low on the water (Moore *et al.*, 2018b). Furthermore, smaller boats may not be suitable for the high tidal velocity currents expected in the RAs. Both land-based and boat-based surveys are labour intensive, however, data volume is generally minimal and processing is relatively easy for both (Clarke *et al.*, 2021a).

It is important that boat-based surveys can adequately incorporate the inshore sections of the tidal stream RAs. If this is not possible, for example due to sandbanks or obstructions which limit ability to operate the vessel near to the coastline, then vantage point-based surveys from suitable locations on land should complement boat-based surveys. This is likely to be applicable only in specific situations.

Aerial surveys can either be done by aircraft or UAVs. Aircrafts are, however, expensive and provide limited information about the surface behaviour of marine mammals in comparison with land and boat-based surveys as from aircrafts it is harder to distinguish what type of activity a marine mammal is involved in due to the distance and equipment used. UAVs could allow for a more fine-scale distribution of a whole tidal stream RA. Although consideration should be taken that UAVs can be obtrusive to marine mammals if flown below 120 to 150 metres above sea or land (Clarke *et al.*, 2021a; Palomino-González *et al.*, 2021). Marine mammal responses might also differ per season. Harbour seals showed more agitation towards UAVs during pre-breeding and moulting season (Palomino-González *et al.*, 2021). UAV surveys require an operator with a commercial license and post-survey-processing. Furthermore, flying an UAV within the RAs may require consent if within a MPA (e.g. consent may be required to fly within a Site of Special Scientific Interest). UAVs are also restricted by battery duration and as with other observation methods UAVs are limited by weather conditions especially wind speed and the number of hours of daylight. In general UAV surveys are not labour intensive (depending on deployment location and coverage), however, they produce high volumes of data which require post-processing (Clarke *et al.*, 2021a). Sparling *et al.* (2015) noted that, while aerial survey methods offer excellent wide scale coverage, they do not provide the fine temporal or spatial scale needed to inform a project level characterisation.

Visual surveys of all types can provide evidence on the absence/presence of seals at haul-out sites and seals and cetaceans at sea, and if repeated over time can be used to determine abundance and distribution of species. However, there is a chance of misidentification of species, with the risk increasing with poor weather conditions and visibility (e.g. Sparling *et al.*, 2015). Visual surveys are also only limited to surface behaviour, the time spent on the surface, and daylight hours (Clarke *et al.*, 2021a). Further, there are likely to be temporal variability (e.g. seasonal and tidal state) in marine mammals presence in the tidal stream RAs (Gordon *et al.*, 2011), and therefore surveys need to be repeated throughout the year and ideally for several years to account for interannual variability.

Overall, all three visual survey techniques could be used in and around the RAs, however, shore-based observations would be very limited in coverage. A summary of the advantages and disadvantages of visual surveys for marine mammals is given in Table 3.4.

Table 3.4: Summary of the advantages and disadvantages of visual survey monitoring of marine mammals at tidal stream areas.

Advantage	Disadvantage
Land-based	
• Relatively cheap. • Coastline provides strategic observation points. • Allows high spatial and temporal resolution. • Data processing is relatively easy and data volume is minimal.	• Only suitable for areas close to shore <~2 km • Limited spatial scale. • Survey field influenced by sea state and visibility (current and weather dependant). • Limited to daylight hours. • Labour intensive.
Boat-based	
• Allows high spatial and temporal resolution. = • Spatial coverage. • Data processing is relatively easy and data volume is minimal.	• Vessel cost can be expensive. • Survey field influenced by vessel type. Smaller boats have a smaller spatial range and visibility is reduced by being low on the water. • Survey field influenced by sea state and visibility (current and weather dependant). • Limited to daylight hours. • Labour intensive.
Aerial surveys	
• Aircraft's large spatial coverage.	• Poor fine scale coverage. • Aircrafts are expensive.

Advantage	Disadvantage
• UAVs allow for fine-scale spatial coverage. • UAVs are not labour intensive.	• Aircrafts give limited information about the surface behaviour of marine mammals. • UAV's can be obtrusive to marine mammals when flown below 120 to 150 meters. • UAV surveys may require consent if within an MPA. • UAVs are restricted by battery duration. • Survey field influenced by sea state and visibility (current and weather dependant). • Limited to daylight hours. • Data processing is labour intensive.

3.2.2. PAM – Passive acoustic monitoring

PAM is the use of hydrophones to listen for vocalising marine mammals. The major limitation therefore is that some species (e.g. seals) cannot be detected and others may be missed if they are not vocalising in a particular area at the time of the survey. PAM comes in two forms:

- Towed PAM – where the hydrophone(s) is towed by a vessel.
- Static PAM – where the hydrophone(s) is moored to the seabed usually with the device suspended in the water column.

Static PAM devices can provide temporal marine mammal patterns. Through the analysis of recordings some species can be identified (Clarke *et al.*, 2021a). Arrays of static hydrophones can also be used to determine the location of specific individuals of a given species.

Towed PAM can be combined with boat-based visual survey. This allows for a larger coverage of the area and allows for monitoring during bad weather conditions and at night, although again only for vocalising cetaceans. PAM used in conjunction with visual surveys also has the distinct benefit that animals which do not surface in the observation zone can still be detected. However, when using a towed PAM the amount of data collected at any specific location is small and therefore the ability to detect small-scale temporal and spatial differences is reduced compared to static PAM. Static PAM collect data intensively on a fine temporal and spatial scale. The spatial coverage is limited, depending on the detection range and number of PAM devices used. Towed PAM, compared to static PAM, will also be more impacted by noise from the vessel, potentially masking some vocalisations in the lower frequency range (Gordon *et al.*, 2011). The data can be recovered in real time, whereas the data from static PAM need to be recovered periodically (unless very expensive cabled arrays).

The types of static PAM suggested by Clarke *et al.* (2021a) were cetacean porpoise detectors (C-PODs) or full waveform capture porpoise detectors (F-PODs). These are self-contained omni-directional static acoustic click detectors comprising of a hydrophone, filter and digital memory (Clarke *et al.*, 2021a). F-PODs are the newer versions of the C-PODS with improved species classification and train detection. A conventional hydrophone that can also be used is a SoundTrap[10]. A SoundTrap also allows for the monitoring of background noise (tidal speed, sediment, etc) and cetacean vocalisations due to a high sampling rate. However, SoundTraps collect large amounts of data causing problems for data storage and so influencing the deployment length. With external batteries, SoundTraps can record continuously for up to 70 days.

Static PAM devices used for location studies need to be deployed in a close cluster, the maximum acoustic range, while dependent on the device and conditions, is typically around 200 m (Sparling *et al.*, 2015). Using regular baseline signals from a known point should be used to enable precise clock synchronization. Consideration should be given that cetacean vocalisations are not omni-directional and are produced in a narrow beam forward (Fregosi *et al.*, 2020). Furthermore, the frequency in which some marine mammal species vocalise can also differ, for example, harbour porpoise seem to be more vocal than minke whales (Clarke *et al.*, 2021a).

The software PAMguard (Gillespie *et al.*, 2008) is currently the most advanced software used to process and analyse vocalisations recorded on a hydrophone. However, species can be misclassified by this software, this can potentially impact the estimates of cetacean abundance (Gillespie *et al.*, 2013). Furthermore, the amount of data collected by PAM is high and can cause problems for data storage and processing afterwards in PAMguard (Clarke *et al.*, 2021a). It is worth noting that PAMguard is open source software. This can be very relevant as it allows future development of the analysis and peer-review of the outputs. C-PODS and F-PODS use the software CPOD.exe. & FPOD.exe to process and analyse the collected click trains. The data storage and classification process are quite easy and usually takes 1 minute for a day of recordings. However, C-POD.exe and F-POD.exe are only capable of distinguishing harbour porpoises (high frequency) and narrow-band high-frequency species. This means they can only identify harbour porpoises to species level (Chelonia Limited, n.d.). C-Pods and F-PODs also only record click trains in the frequency of 20 – 160 kHz and therefore they are not able to detect one of the main species in the Welsh waters, the Minke whale. In 1970 it was hypothesised that minke whales also produce high-frequency clicks, up to 14 kHz (Winn and Perkins, 1976) and in in more recent studies on minke whales only pulse trains were observed up to 1.4 kHz (Mellinger *et al.*, 2000; Risch *et al.*, 2013).

One of the principle limitations of PAM is that background noise and tidal velocities can mask the vocalisations, potentially leading to underestimates of the presence of cetaceans (Gordon *et al.*, 2011; Clarke *et al.*, 2021a). Methods for reduction of flow noise such as a flow shield, can be used, however, there are mixed reviews on their effectiveness (Copping *et al.*, 2020). Additionally, C-Pods and F-Pods need to be vertical in the water column to record, which could be impractical, or difficult to achieve in high tidal velocity

[10] http://www.oceaninstruments.co.nz/product/soundtrap-st600-std-long-term-recorder/

areas (Clarke *et al.*, 2021a). As such PAM may not be viable in some or the RAs due to the high tidal velocities expected. A trial deployment and development of methods is suggested to ensure data are collected and usable.

A summary of the advantages and disadvantages of PAM surveys for marine mammals is given in Table 3.5.

Table 3.5:Summary of the advantages and disadvantages of PAM of marine mammals at tidal stream RA.

Advantage	Disadvantage
Towed hydrophones	
• Can be used in conjunction with boat-based surveys. • Provides small-scale spatial coverage. • Allows for monitoring during bad weather conditions and at night.	• Limited temporal coverage. • Marine mammals might not vocalise when present in the area. • Amount of data collected at any specific location is small. • Impacted by the anthropogenic noise of the vessel. • Masking of marine mammal vocalizations due to anthropogenic noise and tidal velocities.
Static acoustic monitoring devices: C-PODS, F-PODS & SoundTraps	
• Can be deployed during boat-based surveys. • Continuous data collection. • Provides temporal coverage. • Amount of data collected is high. • C-PODS and F-PODS data processing are relatively easy.	• Limited spatial coverage (~200 m range maximum). • Marine mammals might not vocalise when present in the area. • SoundTraps produce high volumes of data influencing data storage and deployment length. • Data processing of SoundTraps in the software PAMguard can be labour intensive and species can be misclassified by the software. • Masking of marine mammal vocalizations due to anthropogenic noise and tidal velocities. • C-PODS and F-PODS can only identify harbour porpoises on a species level. • C-PODS and F-PODS only record clicks between 20 – and 160 kHz. Not covering vocalisation of marine mammals producing low-frequency vocalisations. • C-PODS and F-PODS need to stay vertical in the water column to be able to record, which can be difficult to achieve in high velocity environments.

3.2.3. Tagging and tracking

Tags can quantify fine-scale space use and behaviour of seals, especially as they are hard to spot by eye in the water and spend about >85% submerged. Seals Global Positioning System- Global System for Mobile Communications (GPS-gsm) telemetry tags can help determine the distribution of seals at sea, providing fine-scale habitat use of the tidal stream RAs. The GPS-gsm telemetry tags collect and store data of the locations and behavioural data (diving), and once a seal is in a suitable network coverage the data will be sent onshore (Sparling *et al.*, 2015).

The main limitation of tagging for marine mammals is that it can only be used for seals which can be tagged on shore. Tagging cetaceans at sea would be challenging. A further significant limitation of tagging is that enough animals need to be tagged to represent the population. Furthermore, the tagging process can influence and disturb the animal. Finally, grey seals can swim long distances between distant haul-out and foraging areas *(Sparling et al.*, 2015), therefore, tagged animals might not enter the areas of interest (Clarke *et al.*, 2021a), but this would not necessarily determine the absence of the species from the area.

There are no specific reasons why tagging (of seals) could not be utilised in and around the RAs. A summary of the advantages and disadvantages of tagging and tracking of marine mammals is given in Table 3.6.

Table 3.6: Summary of the advantages and disadvantages of tagging and tracking of marine mammals at tidal stream RAs.

Advantage	Disadvantage
• Quantify fine scale-space use and behaviour.	• Tags can only be deployed on seals onshore. • Tagging cetaceans at sea is very challenging. • Large number of animals need to be tagged. • Tagging process can influence and disturb the animal. • Tagged individuals might not enter the RA which may incorrectly imply absence on the wider population.

3.2.4. Summary for marine mammals

Overall, for visual surveys, boat-based surveys would be the most suitable survey method for key marine mammal species in all tidal stream RAs. Land-based surveys would have insufficient coverage of offshore areas and while aerial surveys would be able to cover all the areas, they would provide less detailed information, due to altitude, than boat-based surveys. Furthermore, the data processing for traditional visual surveys is less labour intensive compared to aerial surveys.

Boat-based surveys can also be combined with PAM, by either deploying moored hydrophones/PODs or by towing a hydrophone array. Towed hydrophones would provide the distinct benefit that animals which do not surface in the observer's field of view during boat-surveys can still be detected if they vocalise. While the deployment of static PAM/hydrophones would allow for continuous monitoring when no boat-based surveys are carried out. However, both towed and static PAM have limitations in the high tidal stream environments expected in the RAs which may mean deployment is not possible (e.g. tidal currents are too strong) or vocalisations are masked by background noise.

For seals, tagging and tracking is a viable survey option. However, grey seals can swim long distances between distant haul-out and foraging areas (Sparling *et al.*, 2015). Therefore, tagged animals might not enter the areas of interest (Clarke *et al.*, 2021a), but this would not necessarily infer the absence of the species from the area. Additionally tagging would only provide data on one out of the six species of interest. Therefore, tagging and tracking would provide limited strategic evidence.

3.3. Diving seabirds

Clarke *et al.* (2021a) discussed the range of methods for strategic studies of seabirds. Their concluding recommendations for strategic evidence was:

"*A baseline visual observation programme for seabirds and cetaceans covering the resource areas; and run for two years pre-construction could be considered. This would include visual surveys for both mammals and seabirds."*

Tagging and tracking can also provide fine scale data on individual occupancy and behaviours and is also discussed in Clarke *et al.* (2021a), and can provide information on occupancy of sea areas outside of the daylight hours.

This report focuses on those seabird species which dive underwater for feeding, as these are most likely to come into contact with underwater devices. Key diving seabird species, many with nesting colonies, in the Welsh marine area include:

- northern gannet *Sula bassana*
- Manx shearwater *Puffinus puffinus*
- auks (puffin *Fratercula arctica*, razorbill *Alca torda*, and common guillemot *Uria aalge*, plus black guillemot *Cepphus grylle* which has a very small population on Anglesey)
- terns (common tern *Sterna hirundo*, arctic tern *S. paradisaea*, roseate tern *S. dougalli*, sandwich tern *S. sandviciensis* and little tern *Sternula albifrons*)
- cormorant *Phalacrocorax carbo* and shag *P. aristotelis*
- divers (red throated diver *Gavia stellata*, black throated diver *G. arctica*)
- grebes (Great crested grebe *Podiceps cristatus*, Slavonian grebe *P. auritus*, Red-necked grebe, *P. grisegena*, and Black-necked grebe *P. nigricollis*)

These species include those which forage by plunge diving (gannets, terns), by dives from the surface (Manx shearwater), and by pursuit diving (auks, cormorant and shag), with these different foraging strategies likely to result in different encounter rates of devices under the water. In addition to these species which nest in Welsh waters, other species occurring on migration and in winter should be considered, including scoters and other sea ducks, divers, and grebes. The main wintering aggregations of these species in Welsh waters occur outside the currently proposed RAs, in Liverpool Bay, Cardigan Bay, Carmarthen Bay and Conwy Bay.

3.3.1. Visual surveys

The recommended methodology for surveying seabirds in the potential tidal stream RAs is visual surveys from boat transects. The methodology for these is well established and also standardised to enable comparison with other datasets, using the methods outlined by Tasker *et al.* (1984) and reviewed by Camphuysen *et al.* (2004) as applied in the European Seabirds at Sea database.

Detailed guidance for ship-based bird surveying is provided by Camphuysen *et al.* (2004), but key recommendations include:

- Use of a vessel which enables forward viewing height from a height of 10 m above sea level (acceptable range 5 – 25 m).
- Ship speed should be 10 knots (acceptable range 5 – 15 knots).
- Surveys should be conducted at or below sea state 5.
- Two competent observers are required, recorded birds in distance bands from the ship (to account for missed individuals at greater distances from the ship).
- A high-resolution grid should be covered which ideally includes an area 6 x the size of the proposed RA, with line transect methodology recommended within that grid (with a strip width of maximum 300 m).

An advantage of boat transect surveys is that they can be combined with cetacean surveying (if sea state is below sea state 3; Camphuysen *et al.*, 2004).

It is important that boat-based surveys can adequately incorporate the inshore sections of the tidal stream RAs, for which data may not exist from previous surveys which have concentrated on open sea transects. If this is not possible, for example due to sandbanks or obstructions which limit ability to operate the vessel near to the coastline, then vantage point-based surveys from suitable locations on land would be worthy of consideration (to complement the boat-based surveys). This is likely to be applicable only in specific situations.

Aerial surveys are another potential survey method (Camphuysen *et al.*, 2004; Buckland *et al.*, 2012), increasingly used in combination with digital image analysis to improve sighting and identification rates (Žydelis *et al.*, 2019). The requirements for surveys using manned aircraft (as opposed to UAVs) are reviewed by Camphuysen *et al.* (2004). These methods have proved most useful for surveying large flocks of birds (e.g. scoters, divers) on the sea surface (e.g. Buckland *et al.*, 2012; Allen *et al.*, 2020), and have the advantage of being able to rapidly survey a very large area. However, boat-based surveys enable higher identification rates for many of the species of importance in the proposed tidal stream RAs, such as auks which are particularly difficult to identify to species level from aerial surveys (Russell *et al.*, 1998). Surveys in the North Sea found that 23% of seabird sightings could be identified to species level using aerial digital imagery, compared to 95% using boat surveys (Johnston *et al.*, 2015). This factor, combined with the enhanced ability to record behavioural data or fine-scale distribution and the higher costs involved with aerial surveys, leads to the recommendation that surveys in the proposed areas focus on use of boars rather than aircraft.

3.3.2. Tagging and tracking

Tracking studies have the potential to overcome the main disadvantage of any visual surveys, which is that they provide only a 'snapshot' of bird distribution at one point in time, during daylight hours. Rapid advances in technology over the last few decades, particularly in relation to the miniaturisation of electrical components, have resulted in many published studies globally (reviewed by Bernard *et al.*, 2021). The technological approach needs to be assessed for each case depending on the research question, with particular considerations being the duration of data collection required (i.e. battery life), the probability of being able to retrieve the logger from the bird, and the size of the bird.

Global Positioning System (GPS) tags were initially mostly applied to larger seabird species such as gannets, but recent advances have enabled this technology to be applied to smaller seabird species, and low-cost GPS tags have been deployed on guillemots and razorbills (Carroll *et al.*, 2019). Information on foraging behaviour can be obtained through the use of accelerometers or depth loggers, which can be deployed on seabirds in tandem with GPS tags (Dean *et al.*, 2015; Patterson *et al.*, 2019) and may be useful in the context of assessing whether proposed RAs are used for underwater foraging.

Use of tracking studies to complement visual surveys could be particularly useful for those species which are active at night when different sea areas could be used compared to daylight hours. In the context of the proposed RAs in Welsh waters, the Manx shearwater is a key species for which important locations at sea vary during the daily cycle, which would mean that daytime visual surveys could miss important locations. GPS tracking of shearwaters from the colony at Skomer revealed a shift from deeper water to shallower water at night (Guilford *et al.*, 2008). Manx shearwaters returning from foraging flights form dense rafts on the sea near breeding colonies from late afternoon prior to returning to the nest burrows at nightfall. The use of very high frequency (VHF) radio telemetry has proved instrumental in determining important rafting locations at both the Skomer and Bardsey colonies (Wilson *et al.*, 2009; Richards *et al.*, 2019).

Limitations of tracking studies include the relatively small numbers of birds that can be tagged, for reasons of cost and practicality and that some colonies can be difficult or impossible to access and therefore tag. One analysis of seabird tracking datasets demonstrated that 39 shags (confidence interval 29 – 73) would need to be tagged to predict 95% of the active range of those species in a colony, using a methodology that tracked the birds for four foraging trips (Soanes *et al.*, 2013). Although increased miniaturisation is enabling smaller birds to be tagged, serious consideration needs to be given to whether bird's behaviour is affected by carrying the tags (e.g. Chivers *et al.*, 2016).

In view of the high costs, logistical difficulty and expertise required for tracking programmes, any such study undertaken would need to be planned carefully to add to the knowledge gained from previous tracking studies undertaken in RAs (e.g. Manx shearwaters in the Pembrokeshire and Llyn Peninsula RAs: Wilson *et al.*, 2009; Richards *et al.*, 2019).

3.3.3. Summary for seabirds

In summary, boat based visual observations are the most appropriate method for collecting strategic evidence for diving seabirds. An important consideration is that these surveys are able to include areas near to the coastline, and point-based surveys from suitable coastal vantage points should be considered to complement the boat-based surveys, if required.

Aerial surveys could be suitable in situations where rapid coverage of a larger sea area is desirable but high-resolution data are not a necessity, or where the target is accurate enumeration of large flocks consisting largely of a single species.

These visual surveys could be complemented by tracking studies on key species, which can provide data on the foraging ranges of birds from colonies in the proposed RAs at all times of day or night (unlike visual surveys which can monitor only diurnal behaviour). Due to the costs and logistics involved, any such studies would need to be planned to answer key questions not already answered by the tracking studies conducted on seabirds in Welsh waters and be undertaken in liaison with universities with expertise in this field.

4. How many data are needed?

Section 4 is broken into four sub-sections: firstly, a discussion of the objectives of possible new strategic evidence (Section 4.1). The next three sections discuss, for each key feature, a high-level review of existing data and how many data would be needed to make a meaningful impact. These sections are drawn together into a series of options for strategic evidence with associated estimated costs/effort and risks in Section 5.

When defining the purpose of any strategic evidence it is important to consider the following:

1) What is the objective of the survey – what is the question to be answered?

2) What data are needed to answer the question?

3) Does data already exist that could help answer the question?

4) How many additional data are required to answer the question?

5) How will these additional data be collected?

The recent Welsh Government 'Sustainable management of marine natural resources' (SMMNR) project (Welsh Government, 2021) provides an up to date review of, and signposts to relevant environmental data for marine tidal stream projects. In particular, the catalogue of datasets with data scored as to their usefulness provides a key resource for data planning (ABPmer, 2020). The information and data are summarised on a web based evidence package for tidal stream (ABPmer and Welsh Government, 2021)**.**

Another useful reference for general ecological data specific to the Welsh marine area is the Natural Resources Wales (NRW) website 'Marine ecology datasets for marine developments' (NRW, 2021), however, many of the datasets are common between this source and the SMMNR project.

Section 4 does not attempt to duplicate the outputs of the SMMNR project, but instead summarises the amount of existing data and discusses the potential usefulness of these data at different stages in the planning and consenting processes. For each key feature the survey evidence available and evidence gaps are summarised with a discussion of what data are needed to facilitate development of the tidal stream sector in the Welsh marine area.

Discussions on the amount of data required for each key feature are based on the existing data, guidelines for evidence requirements and applicable examples from previous tidal stream projects. For marine mammals, NRW have published guidance on the evidence requirements to inform site characterisations at tidal stream energy sites in Wales (Sparling *et al.*, 2015), this guidance is discussed further in Section 4.3.2. There are no similar specific tidal stream sector evidence guides for fish or diving seabirds. There are, however, general guides for survey data which can be used to inform the evidence standards that may be expected (e.g. Judd, 2012; CIEEM, 2019; Marine Energy Wales, 2020).

4.1. Defining the objectives of strategic evidence

When collecting any form of data it is essential to consider the scientific questions that need to be answered to ensure data are suitable and of sufficient quality. This is particularly pertinent at the strategic level where even modest studies at sea can be expensive.

Proposals for new strategic evidence need to have clear objectives linked to the requirements of the planning and consenting process (see Section 2). The objectives will, however, vary depending on the scale of the surveys and intended use of resulting data. For example, survey data to support policy and planning would be high level and have very different objectives to data intended to support EIA assessment characterisations. The level of data aimed for, and the objectives of the surveys, will also be dependent on the resources available (principally funding and commitment to longer term projects).

It is important to consider how the objectives will contribute towards the critical evidence gaps discussed in Section 2. In all cases survey effort would contribute towards the ORJIP-OE strategic topic 1 - methods and instruments to measure mobile species occupancy and behaviour in high energy environments and around marine energy devices. However, ORJIP-OE strategic topic 3 - occupancy patterns, fine-scale distribution, and behaviour of mobile species in [wave and] tidal stream habitats would require fine-scale distribution data.

Examples for survey objectives for each stage in the planning and consenting process are given in Table 4.1. Specific objectives, however, should be developed for any survey options taken forward to ensure their success can be objectively measured.

It should be noted that the strategic evidence objectives described in Table 4.1 relate only to the proposed broadscale surveys and not site-specific developments. The availability of strategic evidence would not replace the need for developers to complete EIA studies but could in some cases reduce the need for project specific surveys. Strategic survey data could also reduce the risk of unacceptable environmental impacts by identifying areas of particular importance for key features which can be avoided in the early planning of tidal stream projects. As noted by Sparling *et al.* (2015) in regards to marine mammals "*a one size fits all approach to marine mammal site characterisation surveys to inform the Environmental Impact Assessment (EIA) and Habitats Regulations Appraisal (HRA) processes [for wave and] tidal stream projects is not fit for purpose and may not always provide useful information for these environmental assessments*". Therefore, it should be recognised that while new strategic evidence will fill part of the evidence gaps, project specific considerations will always be required and where sufficient existing evidence (for example from strategic evidence) is not readily available site-specific surveys would be required.

Table 4.1: Examples of overarching strategic evidence objectives for each key feature relevant to each stage of the planning process.

Stage	Migratory fish	Marine mammals	Diving seabirds
Planning and Policy level	Confirm the presence or absence of key migratory fish species in the RAs.	Confirm the presence or absence of marine mammals in the RAs.	Confirm the presence or absence of key seabirds in the RAs.
Site Selection, scoping and screening level	Confirm the presence or absence, seasonal occurrence and abundance / distribution of key migratory fish species in the RAs.	Confirm the presence or absence, seasonal occurrence and abundance / distribution of marine mammals in the RAs.	Confirm the presence or absence, seasonal occurrence and abundance / distribution of key seabirds in the RAs.
Site characterisation level	Confirm the presence or absence, seasonal occurrence and distribution of key migratory fish species in the RAs. Confirm habitat utilisation (e.g. depth in the water column), and duration in the project area with sufficient detail to inform a collision risk model.	Confirm the presence or absence, seasonal occurrence and abundance / distribution of marine mammals in the RAs. Confirm specific functional use of the area (e.g. feeding, breeding, diving depth, prey species, residence time, individual 'turnover' etc.) with sufficient detail to inform a collision risk model.	Confirm the presence or absence, seasonal occurrence and abundance / distribution of marine mammals in the RAs. Confirm specific functional use of the area (e.g. feeding, breeding, diving depth, prey species etc) with sufficient detail to inform a collision risk model.
Pre-construction baseline level survey objectives:	Detail the abundance/ distribution and behaviour of key migratory species in the project area over multiple years with statistical confidence (power analysis) to detect change.	Detail the abundance / distribution and behaviour (e.g. feeding, residence time etc.) of marine mammals in the project area with statistical confidence (power analysis) to detect change.	Detail the abundance / distribution and behaviour (e.g. diving rate, depth etc.) of diving seabirds in the project area over multiple years with statistical confidence (power analysis) to detect change.

4.2. Migratory fish

4.2.1. Existing data

Existing data on migratory fish that are relevant to the tidal stream sector have recently been reviewed and catalogued in the SMMNR project (ABPmer, 2019, 2020). That project identified 14 migratory fish datasets, however, only eight of these were regarded by the SMMNR as 'high scoring'[11]. The identified data were all river based and focused on MPA monitoring of lamprey populations (River Dee, River Usk, River Teifi and River Wye) and shad egg surveys (Afon Tywi, River Usk, River Wye). Notably all have low 'appropriateness' meaning data were local or not broadscale and indicated presence/absence only. The existing datasets are unable to fill the current evidence gaps for migratory fish (Table 4.2).

There are, however, data on other migratory species from WFD surveys in fresh and transitional waters, as well as historic catch data for eels, salmon and sea trout and trap and counter data on some of the rivers (see Table 4.3 for more detail). However, using these data alone it is difficult to determine marine distribution given high temporal and spatial variation in distribution of highly mobile species. In general, there is an absence of useful survey data on migratory species in the Welsh marine area.

[11] Scoring by ABPmer (2019, 2020) in the SMMNR project was based on the appropriateness, methodology, timing (age) and accuracy of the data. Criteria for high, medium and low are defined in ABPmer (2019).

Table 4.2: Migratory fish - strategic evidence objectives and data gaps.

Stage	Migratory fish	Suitable existing data?	Additional data required?
Planning and Policy level	Confirm the presence / absence of key migratory fish species in the RAs.	Partial – inferred from MPA monitoring	Yes
Site Selection, scoping and screening level	Confirm the presence / absence, seasonal occurrence and abundance/distribution of key migratory fish species in the RAs.	Partial – approximately inferred from river-based surveys.	Yes
Site characterisation level	Confirm the presence / absence, seasonal occurrence and abundance/distribution of key migratory fish species in the RAs. Also, confirm habitat utilisation (e.g. depth in the water column), and duration in the project area with sufficient detail to inform a collision risk model.	No	Yes
Pre-construction baseline level survey objectives:	Detail the abundance / distribution and behaviour of key migratory species in the project area over multiple years with statistical confidence (power analysis) to detect change.	No	Yes

The known distribution of migratory fish in the major rivers in Wales is detailed in Clarke *et al.* (2021b). In summary; Atlantic salmon, sea trout, European eel and river and sea lamprey are widely distributed in Welsh rivers and adjacent estuaries. In contrast, smelt is only present in North Wales, with one known spawning location in the River Conwy. Twaite shad is known to spawn in the rivers Severn, Usk, Wye and Tywi. There is no evidence of allis shad spawning in Welsh rivers. There is, however, a lack of knowledge on migratory fish distribution in Welsh marine waters.

Migratory fishes that have high fidelity to specific rivers systems/spawning areas and create discrete populations, such as Atlantic salmon, sea trout and shads, might be particularly affected by localised impacts as they are likely to migrate through RAs, both on exit and return to river systems, especially multiple spawners, such as sea trout and twaite shad (Clarke *et al.*, 2021b). Species utilising surface and mid waters, both on exit and return to river systems, especially multiple spawners, such as sea trout and twaite shad (Clarke *et al.*, 2021b) are also more likely to be affected than, for example, adult eels which are bottom dwellers, although are known to make vertical diel movements during their spawning migrations (Righton *et al.*, 2016). See Table 4.3 for main available information for each fish species of interest and existing knowledge gaps relevant for the tidal sector.

Table 4.3: Summary of the available information per species of interest and existing knowledge gaps relevant for the tidal sector. U/S and D/S = upstream (from the sea into rivers and freshwater) and downstream (from freshwater to the sea) migration, respectively. 1 SW represents one sea winter salmon.

Species	Spawning strategy[1]	Home fidelity[1]	Migration time	Spawning time	Existing data (mainly from fresh and transitional waters)	Knowledge gaps in marine waters[1]
Atlantic salmon	Anadromous, semelparous (iteroparity occurs in some populations[2]).	High	U/S autumn/early winter (usually multi winter fish) and spring (1 SW fish)[3] D/S spring (smolts)[3,4,] and autumn (parr)[3].	Late autumn / early winter[4].	Historical commercial fisheries, recreational fisheries, counter and trap data, WFD surveys, salmon specific monitoring, tracking studies.	Migration pathways (some evidence available for smolts), abundance, residence time.
Sea trout	Anadromous, iteroparous.	High	U/S spring/ summer and autumn/ winter (adults)[3] D/S Late autumn/winter (kelts)[3] and spring smolts)[3,4].	Late autumn / winter[4].	Commercial and recreational fisheries, counter and trap data, WFD surveys, salmon specific monitoring.	Migration pathways, abundance, residence time.
European eel	Catadromous, semelparous.	None	U/S winter/ spring (glass eels)[5] D/S autumn (silver eels)[6].	Winter / early spring[6].	Historical glass eel fisheries, WFD surveys, eel specific surveys, power station intakes	Migration pathways, abundance, residence time.

Species	Spawning strategy[1]	Home fidelity[1]	Migration time	Spawning time	Existing data (mainly from fresh and transitional waters)	Knowledge gaps in marine waters[1]
Allis shad	Anadromous, semelparous.	High	U/S spring (adults)[7] D/S autumn/winter (juveniles)[8].	Spring[7]	WFD surveys, MPA specific surveys, power station intakes.	Migration pathways (some evidence available), presence / absence, abundance, residence time, swimming speed.
Twaite shad	Anadromous, iteroparous.	High	U/S spring (adults)[7] D/S Spring/early summer (adults)[7] and autumn/winter (juveniles)[8].	Spring / early summer[7].	WFD surveys, MPA specific surveys, power station intakes, tracking studies.	Migration pathways, presence / absence, abundance, residence time.
Sea lamprey	Anadromous, semelparous.	Low or none	U/S spring (adults)[9] D/S autumn (juveniles)[9].	Late spring / early summer[9].	WFD surveys, MPA specific surveys, power station intakes, counter and trap data.	Migration pathways, presence / absence, abundance, residence time, swimming speed, swimming depth.
River lamprey	Anadromous, semelparous.	Low	U/S autumn (adults)[9] D/S autumn (juveniles)[9].	Early spring[9].	WFD surveys, MPA specific surveys, power station intakes, counter and trap data.	Migration pathways, presence / absence, abundance, residence time, swimming speed, swimming depth
European smelt	Anadromous, iteroparous.	Unclear	U/S autumn - early spring (adults)[10]	Early spring[10].	WFD surveys, power station intakes.	Migration pathways, fidelity, presence / absence, abundance,

Species	Spawning strategy[1]	Home fidelity[1]	Migration time	Spawning time	Existing data (mainly from fresh and transitional waters)	Knowledge gaps in marine waters[1]
			D/S spring (adults)[11].			residence time, swimming speed, swimming depth.

[1]Clarke *et al.*, 2021b. Anadromous = Fishes that live in the sea and return to freshwater to spawn; Catadromous = Fishes that live in freshwater but enter the sea to spawn; Semelparous = Fish species which spawn once and then (usually) die; Iteroparity = Fish species that are repeat spawners. [2]Bordeleau *et al.*, 2020; [3]Klemetsen *et al.*, 2003; [4]Milner *et al.*, 2003; [5]ICES, 2020; [6]Righton *et al.*, 2016; [7]Maitland and Hatton-Ellis, 2003; [8]Aprahamian *et al.*, 2003;[9]Maitland, 2003; [10]Colclough and Coates, 2013; [11]Moore *et al.*, 2016.

4.2.2. How many data are needed?

There are no specific guidelines on how many data are required to characterise or set baselines for migratory fish. Exact evidence requirements will be specific to the nature, location and scale of future developments. Recent tidal stream projects in the UK (Section 2.1.1), demonstrated that detailed information on the presence, distribution and abundance of migratory fish is not always a necessity for a tidal stream EIA. However, the ecology, conservation value, and sensitivity, are likely to be key factors in determining the appropriate level of data for any prospective tidal stream development.

It should be noted that some of the most critical evidence gaps concerning migratory fish are related to nearfield interactions with tidal energy devices (see Section 2). Assessments of significant impacts can sometimes be accomplished by considering worst-case assumptions (i.e. assuming some level of species presence and effects) and determining if, even with an unrealistic worst-case whether significant impacts would be expected. In other cases specific detailed collision risk models may be required to predict the numbers of fish which may encounter a tidal energy device, the mortality expected, and where possible present that as a proportion of the reference population. ABPmer (2010) reviewed the collision risk of fish with tidal devices and noted that along with features of the devices and the nature of their operation, characteristics of the receiving environment (i.e. the baseline conditions) of fish distribution, behaviour and abundance are needed for a collision risk model.

All the identified key migratory fish species (see Section 3.1) are listed under Section 7 of the Environment (Wales) Act 2016 and regarded as of 'principal importance' for the purpose of maintaining and enhancing biodiversity in Wales. Four of the species (allis shad, twaite shad, river lamprey and sea lamprey) are specifically designated as features of MPAs (Figure 4.1).

In the Northern region, North and West Anglesey, Far west – offshore waters and West coast of Llyn Peninsula RAs do not overlap with any designated sites with migratory fish as their qualifying feature. However, species such as river lamprey, sea lamprey, Atlantic salmon, sea trout, twaite shad, smelt, and European eels to are likely to pass through these areas during their seaward/inland migrations (ABPmer and Welsh Government, 2021). Some migratory fish are also likely to use the area for feeding. The Far west – offshore waters and West coast of Llyn Peninsula RA have no overlap with migratory species MPAs, although again this does not mean migratory fish would be absent.

In the Southwest region (West coast of Pembrokeshire RA) the main potential ecological constraint in terms of migratory fish are the Cardigan Bay / Bae Ceredigion Special Area of Conservation (SAC), with river and sea lamprey as qualifying features, and Pembrokeshire Marine/ Sir Benfro Forol SAC, which has sea lamprey, river lampreys, allis and twaite shad as qualifying features (ABPmer and Welsh Government, 2021). Furthermore, the area is likely to be important for fish migrating to and from the River Teifi MPA. To the southeast of the West coast of Pembrokeshire RA is Milford Haven Waterway, an important migratory corridor for migratory fishes such as Atlantic salmon, European eel, shad, and sea lamprey.

Most of the Southern region (South coast of Wales RA) does not overlap with migratory fish species MPAs, apart from Severn Estuary on the eastern edge with twaite shad, sea and river lamprey as qualifying features. In addition, many upstream freshwater sites are MPAs with migratory fish as qualifying feature, including Atlantic salmon, twaite shad and lamprey in the rivers Usk and Wye. Therefore , the mouth of this estuary represents an important corridor for many of this migratory fish species (ABPmer and Welsh Government, 2021). There is also the Carmarthen Bay and Estuaries SAC and Burry Inlet Ramsar site which have sea lamprey, river lamprey, allis and twaite shad as qualifying features, located between West coast of Pembrokeshire and South coast of Wales RAs.

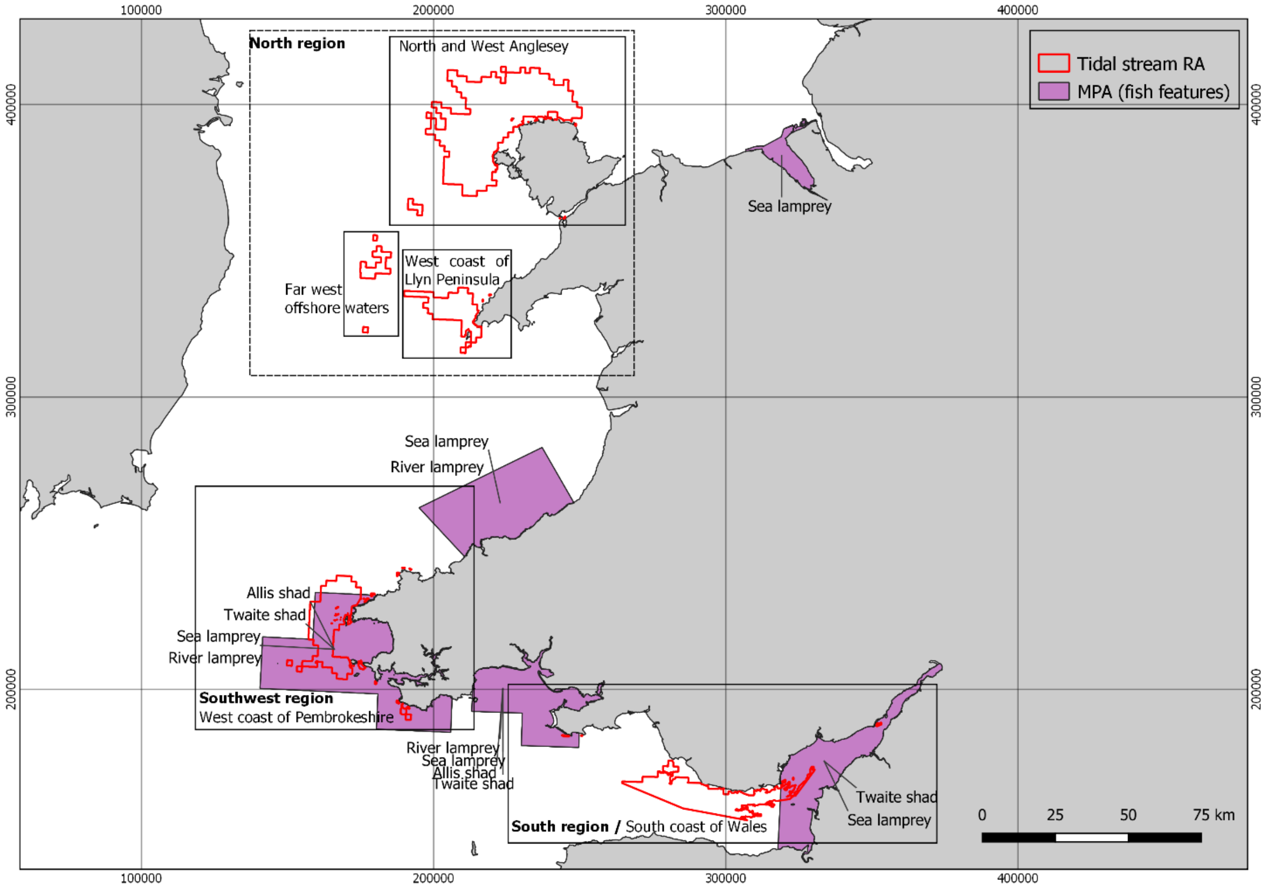

Figure 4.1: MPAs with migratory fish as qualifying features.

4.2.2.1. New data required

Migratory fish in the marine environment are a key feature in the Welsh marine area, as evidenced by the MPAs and individual species' conservation status. Current EIAs (Section 2.1.1) rely on broad descriptions of species ranges and migratory periods to assume presence at particular times of year on a precautionary basis. Information on important areas for migratory fish has previously been inferred through a 1 km seaward extension of Welsh estuaries as one can assume that coastal waters adjacent to these areas should have those species present (ABPmer and Welsh Government, 2021). Note, however, that this approach is not based on evidence.

As there are very few data on migratory fish in the marine environment which are relevant to tidal stream developments (see Section 4.2.1), any further data collected would be valuable to the tidal stream sector, particularly evidence of absence for key species in key areas, or knowledge of seasonal presence and relative abundance. Additional data could range from high level screening of species using eDNA techniques to highly detailed tagging and tracking of key species.

4.3. Marine mammals

4.3.1. Existing data

There are many existing data available for marine mammals in the Welsh marine area, however, the type, spatial and temporal resolution vary significantly. Furthermore, while there are several broadscale datasets of marine mammal distribution, they are not typically detailed enough (i.e. the spatial and temporal resolution) to inform EIA characterisation and assessments (e.g. collision risk modelling). This means that existing data are valuable for planning, policy and screening and scoping, and prospective developers of tidal stream projects can use this to gain an indication of the potential environmental risk for marine mammals. However, for most tidal stream projects site specific survey data would currently be expected. While some data will be useful for strategic objectives, additional data would be needed (Table 4.4).

The SMMNR project (ABPmer, 2019, 2020) identified 36 datasets for marine mammals, however, only three of these were considered high scoring by the SMMNR project for tidal stream sector use. Notable existing marine mammal data which would be valuable to support tidal stream projects are Small Cetaceans in European Atlantic waters and the North Sea ‘SCANS-III’ (Hammond *et al.*, 2021), the atlas of the marine mammals of Wales (Baines and Evans, 2012), cetacean distribution maps (Waggitt *et al.*, 2019) and seal density at sea (Sea Mammal Research Unit (SMRU) and Marine Scotland, 2017). A particular example of marine mammal data gathered with the specific intention of informing characterisations for tidal stream projects is described in Gordon *et al.* (2011). While highly focused on tidal stream areas, the project was spatially limited and only collected data for two months. Therefore, while providing an example of appropriate survey techniques, it does not provide much up to date data of use for future tidal stream projects. There are also data (PAM data of cetacean detections) available from the Sustainable Expansion of Applied Coastal and Marine Sectors ‘SEACAMS 1 & 2’ projects, which are expected to be published in the near future (Bangor University, 2022).

Table 4.4: Marine mammals - strategic evidence objectives and data gaps.

Stage	Marine mammals	Suitable existing data?	Additional data required?
Planning and Policy level	Confirm the presence / absence of marine mammals in the RAs.	Yes	No*
Site Selection, scoping and screening level	Confirm the presence / absence seasonal occurrence and abundance / distribution of marine mammals in the Ras.	Partial	Yes
Site characterisation level	Confirm the presence / absence seasonal occurrence and abundance / distribution of marine mammals in the RAs. Also confirm specific functional use of the area (e.g. feeding, breeding, diving depth, prey species, residence time, individual 'turnover' etc) with sufficient detail to inform a collision risk model.	No	Yes
Pre-construction baseline level survey objectives:	Detail the abundance/distribution and behaviour (e.g. feeding, residence time etc) of marine mammals in the project area with statistical confidence (power analysis) to detect change.	No	Yes

* Additional data would enhance the current evidence base to enable more informed planning and policy decisions; however, existing data are available.

Key marine mammal species in the Welsh marine area are; bottlenose dolphins, harbour porpoise, short-beaked common dolphin, Risso's dolphin, minke whale and grey seals (Clarke *et al.*, 2021a). See Table 4.5 and Table 4.6 for the main marine mammal occurrence in the identified tidal RAs.

Table 4.5: Marine mammal occurrence in tidal RAs (ABPmer and Welsh Government, 2021).

Tidal resource area	Marine mammals present	Occurrence
North & West Anglesey	Harbour porpoise Bottlenose dolphins Risso's dolphins Short-beaked dolphins Minke whale Grey seals	High Common Low Low Low Common
Far West-offshore waters	Minke whale Common dolphin Risso's dolphin Bottlenose (offshore ecotype)	Common Common Common Common
West coast of Llyn Peninsula	Harbour porpoise Minke whales Risso's dolphins Bottlenose dolphins Grey seals	High Low Low Low High
West coast of Pembrokeshire	Grey seals Bottlenose dolphins Risso's dolphins Minke whale Short-beaked common dolphin	High Common Common Low Low
South coast of Wales	Harbour porpoise Bottlenose dolphins Risso's dolphins Minke whale Short-beaked common dolphin Grey seals	High Low Low Low Low Common/Low

Table 4.6: Core datasets used for determining marine mammal occurrence in RAs (ABPmer, 2019).

Derived dataset	Core dataset	Confidence
Grey Seal at sea	Russell *et al.* (2017)	High
Atlas of marine mammals of Wales	Baines and Evans, (2012)	High
Cetacean distribution	Waggitt *et al.* (2019)	High
Seal pupping and haul out sites	Baines *et al.* (1995); Westcott and Stringell, (2004); Strong *et al.* (2006); Clarke *et al.* (2020)	Medium

4.3.2. How many data are needed?

There are well established guidelines of the amount of marine mammal data needed for tidal stream projects. Furthermore, a great deal has been learnt from the development of the offshore wind industry in relation to marine mammal assessments in recent years. The principle guidance, Sparling *et al.* (2015) describe the considerations for data collection. It can also be seen from recent tidal stream projects (see Section 2.1.1) that two years of monthly observation data have been collected specific to the proposed development site to inform EIA characterisations and assessments.

Marine mammals are likely to be a significant concern for any offshore tidal stream development, regardless of the location relative to MPAs due to their highly mobile nature and high conservation value. However, all RAs except the Southern region / South coast of Wales RA overlap with an MPA for at least one marine mammal species (Figure 4.2).

For the policy, planning and screening and scoping stages information on the presence/absence and relative importance of areas for marine mammal species are needed, and these data, are largely already available.

However, for EIA characterisations for tidal stream energy projects collision risk modelling will typically be required. Collision risk modelling requires data on encounter rates to be predicted, often based on density estimates for the species being considered (Sparling *et al.*, 2015). Furthermore, it is important to understand the individual turnover of animals at a site (i.e. are the same individuals reoccurring over a period) as this influences the probability of an individual having an encounter with device, while this may be difficult to measure in practise, photo identification can be used to identify particular individual animals. Diving depth and behaviour may also be important data, although this information is not collected with traditional observation techniques, and while tagging and tracking are viable options for seals, these techniques are not used for cetaceans in the UK given the necessity of capturing animals at sea to tag them. There do not appear to be any examples outside the UK where tagging of small cetaceans has been routinely carried out.

4.3.2.1. New data required

As described in Section 4.3.1, there are reasonably good data for broadscale distribution and abundance of marine mammals, and these data (and the ongoing national projects) provide excellent data for planning, policy, and screening and scoping. However, these broadscale data are generally not considered sufficient for individual project assessments. The typical requirement at a project level is two years of monthly observation data (Sparling *et al.*, 2015). The purpose of these site specific surveys is to, at a fine scale, describe the abundance, distribution and temporal variability of marine mammals at the location, and make observations as to the behaviour of animals if possible (e.g. feeding, transiting, surfacing etc.).

Given the availability of some existing data (but noting there is a shortfall of high spatial and temporal resolution data in the tidal stream RA), data that are needed are for the presence, abundance and distribution (and behaviour) specific to the RAs, and ideally to a resolution suitable for EIA characterisations (i.e. full coverage, monthly for at least two years). Options for collecting these data are discussed in Section 5.

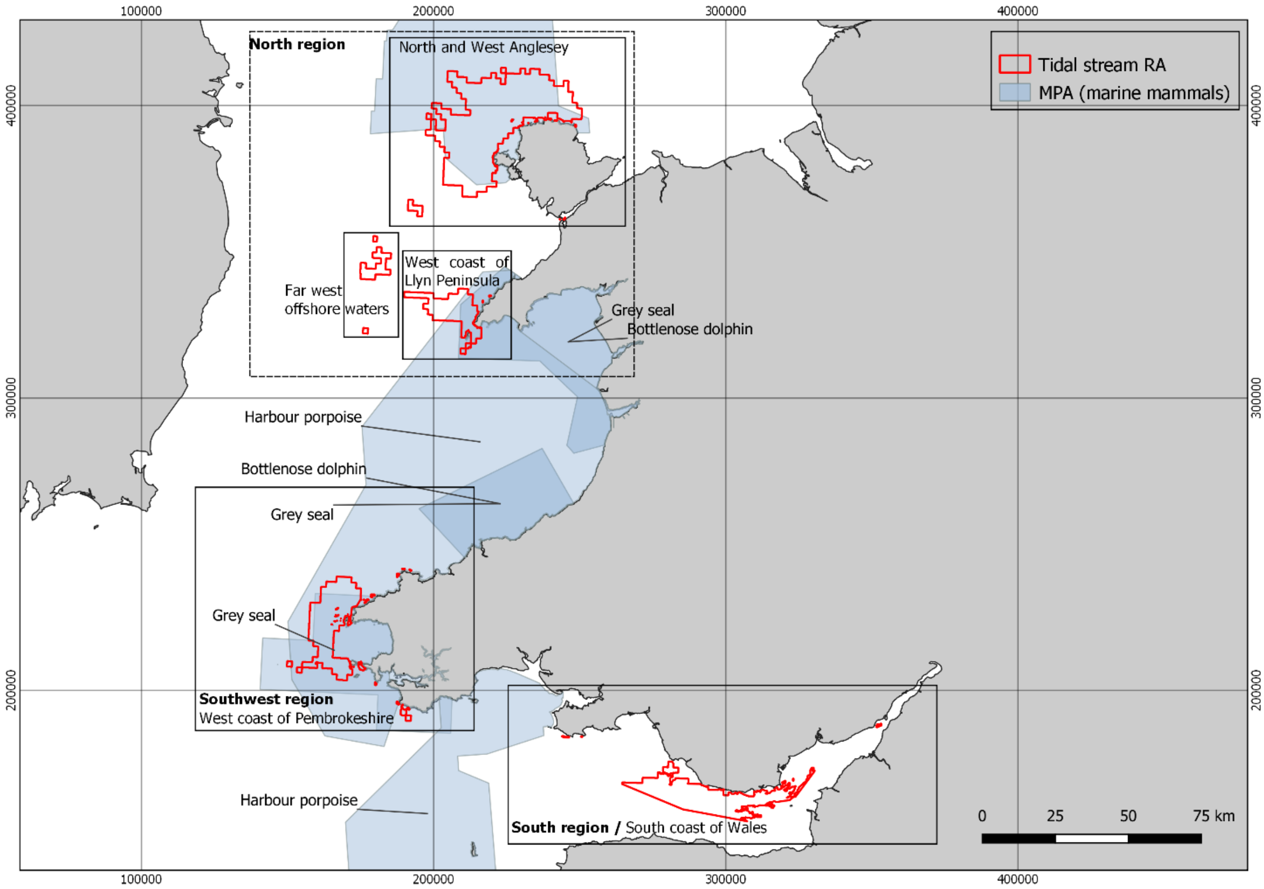

Figure 4.2: MPAs with marine mammals as key features.

4.4. Diving seabirds

4.4.1. Existing data

As with marine mammals, there are existing data on seabird distribution and abundance in the Welsh marine area. The principal data are the ‘seabirds at sea’ dataset (NRW, 2009), however these data are now over 10 years old, and have gaps in some areas, such as close to the coast. Therefore, there may be low confidence that the data represent current conditions depending on the how they are used. The recently published distribution maps and associated data in Waggitt *et al.* (2020) does offer a more recent dataset for many species. However, the authors described limitations of these data due to the broadscale approach a limitation of the modelling and input data and recommend that data are interpreted as ‘a general illustration of relative densities and broad-scale distribution over several decades’ (Waggitt *et al.*, 2019). The SMMNR project also identified 10 other seabird datasets, however only two were regarded as high scoring.

As with marine mammals, the existing data for diving seabirds provides a good broadscale picture of distribution which can inform planning, policy and screening and scoping stages (Table 4.7). However, where risks to seabirds are identified in project scoping, existing data are unlikely to be sufficient for detailed assessments and EIA characterisation purposes.

Table 4.7: Diving seabirds strategic evidence objectives and data gaps.

Stage	Diving seabirds	Suitable existing data?	Additional data required?
Planning and Policy level	Confirm the presence / absence of key seabirds in the RAs.	Yes	No
Site Selection, scoping and screening level	Confirm the presence / absence, seasonal occurrence and abundance / distribution of key seabirds in the RAs.	Partial	Yes
Site characterisation level	Confirm the presence / absence, seasonal occurrence and abundance / distribution of key seabirds in the RAs. Also confirm specific functional use of the area (e.g. feeding, breeding, diving depth, prey species etc.) with sufficient detail to inform a collision risk model.	No	Yes
Pre-construction baseline level survey objectives	Detail the abundance/distribution and behaviour (e.g. diving rate, depth etc) of diving seabirds in the project area over multiple years with statistical confidence (power analysis) to detect change.	No	Yes

The proposed RAs overlap with four MPAs, which have been designated based on the internationally important breeding colonies of these species: Skomer, Skokholm and the Seas off Pembrokeshire (Sgomer, Sgogwm a Moroedd Penfro); Grassholm MPA; Anglesey Terns (Morwenoliaid Ynys Môn) MPA; and Aberdaron Coast and Bardsey Island (Glannau Aberdaron ac Ynys Enli) MPA. These are shown in Figure 4.3 but, it should be recognised that seabirds are highly mobile and will utilise the surrounding areas.

Table 4.8 details the most conservation significant species in the proposed RAs and provides an indication of the data available.

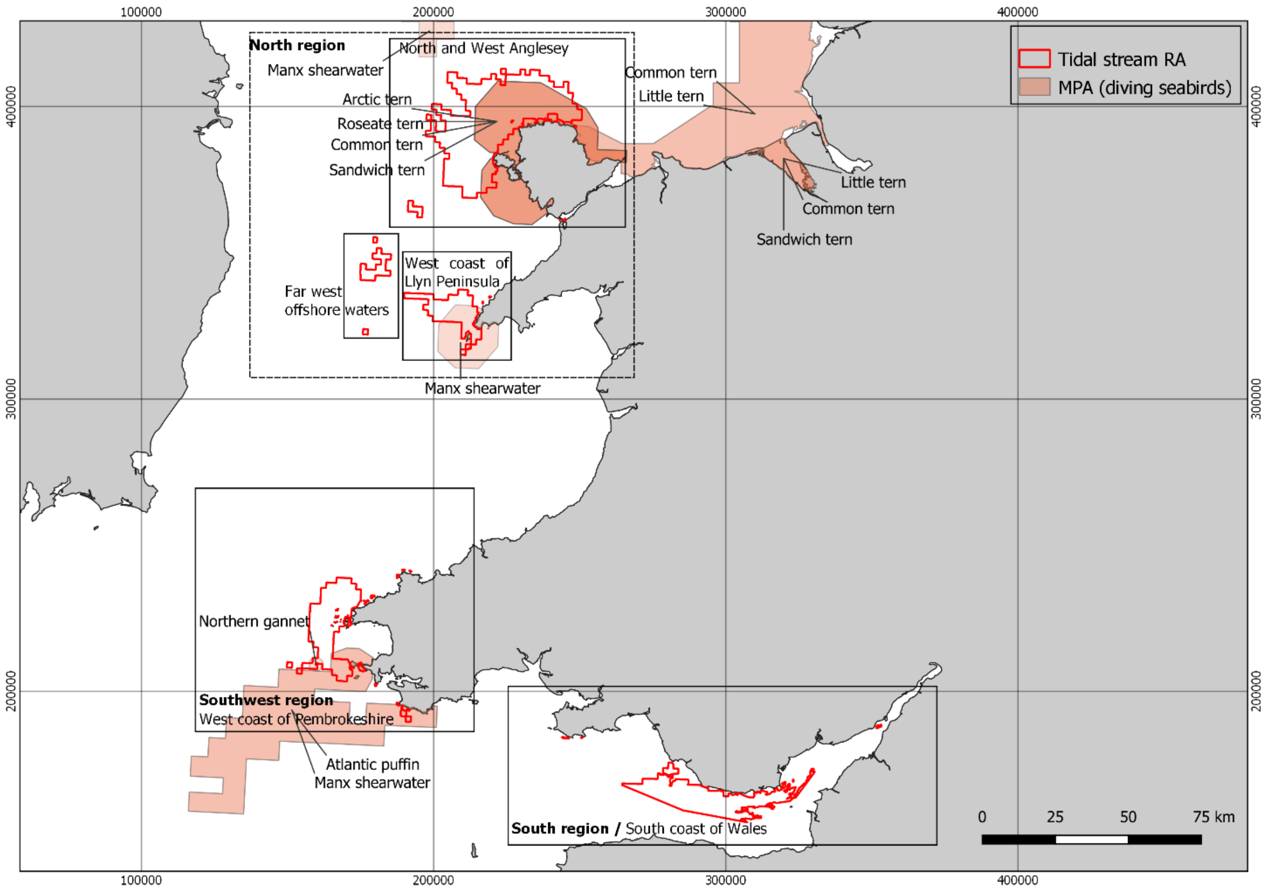

Figure 4.3: MPAs with diving seabirds as key features.

Table 4.8: Selected diving seabird species of particular conservation importance in the tidal stream RAs. Data on populations, international importance, and feature designation from JNCC (2021e) and NRW (2022).

Tidal resource area	Selected diving seabird species of key conservation importance	Reason for conservation importance
North and West Anglesey	Sandwich tern	Only colony in Wales is at Cemlyn Lagoon, 1200 pairs in 2019 (approx. 10% of UK population). Designated feature of Anglesey Terns MPA.
	Arctic tern	All four Welsh colonies are on Anglesey, totalling 3206 pairs in 2019, with the largest colonies on the Skerries off NW tip of Anglesey. Designated feature of Anglesey Terns MPA.
	Common tern	Designated feature of Anglesey Terns MPA.
	Roseate tern	Designated feature of Anglesey Terns MPA (<5 pairs, but one of only 3 UK nesting sites in 2019).
Far west offshore waters	[potential foraging area for seabirds from Anglesey and Llyn Peninsula colonies]	
West coast of Llyn Peninsula	Manx shearwater	Internationally important colony on Bardsey Island, 20675 apparently occupied nest-sites 2014-2016. Designated feature of Aberdaron Coast & Bardsey Island Special Protection Area (SPA).
West coast of Pembrokeshire	Manx shearwater	Internationally important colonies, including the world's largest colony at Skomer and Skokholm (456,000 apparently occupied nest-sites in 2018)

Tidal resource area	Selected diving seabird species of key conservation importance	Reason for conservation importance
	Northern gannet	Internationally important colony on Grassholm, 36,011 apparently occupied nests in 2015. Only nesting site in Wales. Designated feature of the Grassholm SPA, based on representing 10% of the global gannet population.
	Common guillemot	Several colonies in this region including Skomer, which holds 24% of Welsh population. One of the main species components of the ‘seabird assemblage’ qualifying feature for the Skomer, Skokholm & Pembrokeshire Coast SPA.
	Razorbill	Several colonies in this region including the colonies at Skomer/Skokholm, holding 63% of Welsh population (2018). One of the main species components of the ‘seabird assemblage’ qualifying feature for the Skomer, Skokholm & Pembrokeshire Coast SPA.
	Puffin	The colony at Skomer holds 70% of Welsh population (2000 data). A designated feature of the Skomer, Skokholm & Pembrokeshire Coast SPA as holding 1.1% of global population (1990s data).
South coast of Wales	[less significant for nesting seabirds]	

4.4.2. How many data are needed?

While there are no specific guidelines for the amount and types of seabird data needed for tidal stream projects, previous projects (see Section 4.3.1) have gathered observation surveys data for seabirds, collected to the same requirements as marine mammals. Where site specific surveys are deemed necessary this typically means monthly observations for a minimum of two years. Guidance for the offshore wind sector (Camphuysen *et al.*, 2004) also provides descriptions of well-established survey methods and data requirements, which are likely to be similar for tidal stream projects, especially for turbines in relatively shallow waters within the diving depth of seabirds.

Seabirds, especially diving seabirds are likely to be of significant concern wherever they occur and especially as there are several MPAs with diving birds as features which overlap with the tidal stream RAs as described in Section 4.4.1.

As for marine mammals, existing seabird data may, in many cases be sufficient for planning, policy and screening and scoping as there are reasonable high level distribution data for many of the key seabirds in the Welsh marine area. However, like marine mammals, encounter risk models and collision risk models are likely to be required for the EIA assessment and these need to be informed with accurate density information and reference population scales.

4.4.2.1. New data required

The broadscale data described in Section 4.3.1, although useful for planning, screening, and scoping, will likely be unsuitable for project level characterisations where risks to seabirds are identified. While there are no specific guidelines for seabird surveys, typically for offshore marine renewable energy projects the data expectations are like those for marine mammals. This is unsurprising as the risks are similar and, if visual survey techniques are used marine mammals and seabird data can be collected at the same time, using the same observers.

The data needs for seabirds are essentially the same as for marine mammals, detailed distribution, abundance (and behaviour) of seabirds in the RAs. These data would be needed with full coverage of the RAs, at minimum monthly over two years. Options to collect these data are discussed in Section 5.

5. Options and Costs

There are multiple options presented for each key feature each with an indication of the level of the cost, risk, and value of the surveys. It is not possible at this stage to provide a detailed breakdown of costs for each option as there are too many variables to account for at this stage. Costs should be regarded as indicative and be refined should options be progressed

In producing cost estimates, key factors were considered. The greatest cost in most options will be vessel costs. In all options year-round data collection is recommended. However, while small boats can be used in summer months, year-round surveys will require large vessels that can handle poor weather safely. Inevitably larger vessels cost more.

Several options presented would not be cost effective if carried out on their own but would add little additional cost to other survey work. These scenarios are indicated where relevant.

Costs for marine mammal and seabird observers can vary considerably depending on the demand across the wider offshore sector at the time of contracting. It should be noted that the large demand from the offshore wind sector, plus the impacts of Covid-19 have increased costs significantly in the last couple of years. It may be possible to reduce staffing costs by using volunteers over professionally trained observers following an agreed survey methodology.

Specific survey plans would need to be developed for any of the chosen survey options following the recommendations here and taking into consideration the data processing, storage and publishing needs described in Section 5.4. This is because there are various details for each option (e.g. survey line spacing, equipment, etc.) which need to be proposed by survey contractors along with detailed cost breakdowns. In addition, equipment may need to be purchased or rented for some options; costs will be needed to finalise cost estimates. The objectives of any chosen option need to be considered when developing a survey plan, for example, if detailed characterisation level data for marine mammals are taken forward, sufficient lining spacing, and observer replication are needed to enable density estimates from the surveys.

The indicative cost, risk and benefit of each option is discussed and classified as low, medium, high, or very high; the classifications are defined in Table 5.1.

Table 5.1: Classifications of indicative costs, risks and benefit used to assess each strategic evidence option.

Criteria	Classification
Indicative cost Defined broadly as the total survey effort based on estimated costs. Costs would typically include vessel, staff, gear and consumables. Note that costs are based on estimates of commercial work.	• Low = £0—500 k. • Medium = £500 k-£1 m. • High = £1 m-£5 m. • Very high = >£5 m.
Risk Defined as the likelihood of data of suitable quality and sufficient quantity to achieve the objectives of the survey.	• Low = good chance of success. • Medium = strong likelihood of at last partial data which will be useful. • High = strong possibility that no data of use to the tidal stream sector will be generated.
Benefit Defined as the contribution the data are likely to make to the tidal stream sector.	• Low = policy planning level only. • Medium = valuable for screening/scoping and potentially sufficient for EIA characterisations. • High = likely to be sufficient for most EIA characterisation purposes. • Very high = highly detailed sufficient for EIA characterisation and in some cases pre-construction baseline.

The final classifications for indicative cost, risk and benefit have been determined based on expert judgment and the justification for each are explained in the sections below.

5.1. Migratory fish

As described in Section 4.2.1 there are very few existing data on migratory fish at sea. However, this reflects the very significant issues of collecting data on rare and highly mobile species in the marine environment. These issues cannot be easily overcome, and while traditional fishing survey techniques could be used, it would require a tremendous amount of effort to survey the RAs to a sufficient level to capture migratory species (See section 3.1.1). While this method is not considered appropriate for wide scale surveys targeted for migratory species, it should be noted that prospective developments may be required to collect general marine fish data (particularly larger developments where collision risk may pose a viable risk to fish populations), and fishing techniques would likely be employed for such surveys. If designed with migratory fish in mind, fishing surveys targeted at a small area can be used to establish the presence (or absence with a confidence level attached) of migratory species. Specific gear may, however, be needed to target some migratory fish (e.g. glass eels).

Collection of eDNA samples from the tidal stream RAs could be a useful survey method to provide data on whether these areas are regularly used by migratory fishes, although it is difficult with current knowledge to predict the spatial and temporal sampling regime necessary to determine presence (or absence) of transiting migratory fish species at sea. It is recommended that any sampling should be conducted on at least a monthly basis and intensified during the likely seasons of species of interest being present in the marine environment (Table 4.3). An additional advantage is that the same samples could be analysed separately for wider fish communities, for cetaceans, or for other taxonomic groups, and can be stored for several years for future analyses.

The two most viable options available of collecting strategic evidence on migratory fish are eDNA and tagging. The ability of the methods to collect data capable of filling strategic evidence objectives is summarised in Table 5.2. Both methods have the potential to collect useful data, however, there are very notable limitations in terms of risk and cost. Four options, including a “do nothing” option is proposed in order of increasing estimated cost.

Option 1: No additional surveys.

The survey options for migratory fish are high to very high risk and, (for high value data), very high effort. Furthermore, it is possible that not all future tidal stream projects would require detailed migratory fish characterisation data to enable EIA conclusions. It may be more appropriate to not survey for migratory fish and instead spend money/effort elsewhere.

Option 2: eDNA.

Description: Collect several dozen samples for each RA monthly (with additional samples in peak migratory periods e.g. glass eel) for at least one, preferably 2 years.

Indicative Cost: low	**Risk:** High	**Benefit:** low-medium*
Estimated as 4 to 5 vessel days per month to collect samples. Analysis costs would depend on the laboratory, number or samples and exact procedure. Overall, costs are likely to be relatively low in comparison to other options, if the work was combined with other	Firstly, there are various options for sample collection, however, no matter the sample effort eDNA techniques would not offer evidence of absence of migratory species, and it is not able to identify the fine scale distribution or absolute abundance	If the presence of migratory fish can be demonstrated then the resulting data could be useful for high-level planning, policy and possibly screening and scoping. If migratory fish were a concern for any prospective tidal stream development, eDNA alone is unlikely to be sufficient to inform an EIA. A fully successful eDNA survey

surveys, as there is limited sample effort required.	(relative abundance may be possible between sample areas) of fish species. Secondly, the multiple variances in terms of 'when and where' the sample originated from mean that eDNA sampling can be criticised from multiple angles.	could lead to medium value data applicable to screening, scoping and broad level characterisations, however, given the difficulty in establishing evidence of absence from eDNA techniques, low value data are more likely.

Notes: To be cost-effective this work would ideally be combined with marine mammal/bird surveys. Would need a specific eDNA operator. Samples can be analysed for multiple species of interest (e.g. marine mammals, other fish etc).

*The value of this work could be increased if it were combined with other strategic evidence on migratory fish.

Option 3: Trail tagging and acoustic tracking array.

Description: The cost of a full scale tagging, and acoustic array survey would be very high. It also comes with considerable risk that sufficient data could not be collected to meet the survey objectives. A better option could be to carry out a trial tagging and tracking study at a single RA and to limit tagged fish to rivers nearby to the chosen RA. Furthermore, target species could be limited to those easiest to catch and with the highest likelihood of success, i.e. salmon (smolts) and trout (smolts and kelts) and possibly twaite shad.

Indicative Cost: high	**Risk:** high	**Benefit:** medium
Costs are likely to be >£1 m, although should be substantially less than £5 m.	**It should be noted that catching sufficient fish to make a meaningful study is challenging. There is a high risk that some or even all objectives could be unsuccessful.**	**A pilot survey has the potential to provide high value data and would, if successful inform EIA characterisations in the area targeted (and potentially be used as a proxy for other areas). However, as data would be spatially limited the overall value of classed as medium.**

Notes: Studying only one RA would mean data would not be collected at the other RAs. This could conceivably delay development at these other RAs. To mitigate against delays two approaches could be taken. Target the RA with the most potential for development or carry out a smaller, shorter study at each RA with the aim of expanding if the trial was successful.

Option 4: Full scale tagging and acoustic tracking array.

Description: Tagging of key migratory fish individuals and deployment of an array of acoustic receivers covering all RAs.

Indicative Cost: very high	**Risk:** very high	**Benefit:** high
Cost, estimated by Clarke *et al.* (2021b) is £4.3 m to £6 m. These costs while realistic should be examined in detail before further commitment to such work is considered. Commercial rates, particularly for vessel hire during winter months and in competition with other sectors such as offshore wind could drive these costs notably higher. Overall, based on indicative costs the survey effort for this option would be considered very high.	It should be noted that the programme is highly ambitious and there would be a very high risk that for some or even all species/ RAs the objectives may not be met (e.g. insufficient fish tagged, insufficient tracking data, equipment faults etc).	If successful, the data would be highly valuable for EIA characterisation and in many cases would establish a robust pre-construction baseline.

Notes: Tagging of some key species or key life stages is not viable. Therefore, data gaps would remain, even following a successful tagging project, for at minimum lamprey (sea and river) and potentially eels and salmon.

Table 5.2: Summary of strategic evidence objectives for migratory fish and methods that could fill them. (Number in brackets refers to options above).

Stage	Migratory fish	eDNA (2)	Pilot tagging and acoustic tracking array (3)	Full scale tagging and acoustic tracking array (4)
Planning and Policy level	Confirm the presence / absence of key migratory fish species in the RAs.	Partial – presence only	Yes	Yes
Site Selection, scoping and screening level	Confirm the presence / absence, seasonal occurrence and abundance / distribution of key migratory fish species in the RAs.	Partial – presence only	Yes	Yes
Site characterisation level	Confirm the presence / absence, seasonal occurrence and abundance / distribution of key migratory fish species in the RAs. Also confirm habitat utilisation (e.g. depth in the water column), and duration in the project area with sufficient detail to inform a collision risk model.	No	Yes	Yes
Pre-construction baseline level survey objectives:	Detail the abundance/distribution and behaviour of key migratory species in the project area over multiple years with statistical confidence (power analysis) to detect change.	No	No	Yes

5.2. Marine mammals

As detailed in Section 4.3.1 there are various sources of existing data for marine mammals. Currently available data are generally regarded as sufficient up to the screening/scoping stages of the EIA process. Except for very small projects, most tidal stream developments in the Welsh marine area are likely to require detailed marine mammal survey data comprising at least monthly observer data for two years.

The strategic evidence options for marine mammals are (in order of estimated indicative cost, low to high):

Option 1: No additional surveys.

Existing data are likely to be sufficient for broadscale policy and planning, although site specific surveys will in most cases be required of tidal stream developments. This is because marine mammals are likely to be a key feature in the EIA assessment, due to both potential effects/impacts at construction and operational stages.

Option 2: Land-based vantage point visual survey (coastal).

Description: land-based surveys carried out monthly for at least two years.

Indicative Cost: Low	**Risk:** Low	**Benefit:** Low
Numerous observers would be required, however, there would be no vessel costs and data processing would be minimal.	Overall there would be a low risk of the survey not meeting its objectives, however, poor weather and visibility may hamper efforts especially in winter months.	The value of these data must be considered as land-based surveys would only collect data on a very small proportion of the RAs and surrounding areas. Therefore these data are unlikely to be of benefit to many offshore tidal stream projects. This option is therefore considered to be low benefit and unlikely to have a significant benefit for the tidal stream sector.

Notes: Land-based surveys may be required in combination with boat-based surveys to ensure full coverage with the advantage that diving seabird observations can be made at the same time.

Option 3: Trial boat based visual & towed PAM survey(s).

Description: The cost of full scale surveys over all RAs would be high. It may be preferable to carry out trial surveys first. Trial surveys could be limited to a single RA. The ambition being to then expand to full scale surveys if the trial was successful. It would be recommended to carry out surveys monthly for two years to gather the most valuable data. There would be limited coastal observations for areas of restricted boat access.

As an example: survey the Southwest region only, monthly for two years. Carry out an estimated 20 x 50 km transects.

Indicative cost: medium	**Risk:** low	**Benefit:** medium

The cost of a pilot survey will vary depending on temporal and spatial coverage; however, it would likely be £500 k to £1 m (medium effort).	Boat surveys follow well established methods and there is a low risk that the survey objectives would not be met. Repeating surveys monthly for at least two years would reduce the risk of weather down time or low visibility impacting on the survey work.	Data collected would be highly valuable to the tidal sector, however, would be spatially limited and therefore this option is regarded as of medium value overall, although may be of high value for specific areas.

Notes: Studying only one RA would mean data would not be collected at the other RAs. This could conceivably delay development at these other RAs. To mitigate against delays two approaches could be taken. Target the RA with the most potential for development or carry out a smaller, shorter study at each RA with the aim of expanding if the trial was successful.

Diving seabird observations can be combined with this option for relatively little extra cost.

Option 4: Aerial survey, UAV or aeroplane.

Description: If UAV or aeroplane based digital photograph/observation surveys were undertaken it would be suggested these should be carried out monthly for a minimum of two years over the entire RAs and with a minimum 5 km buffer around the RAs.

Indicative cost: high	**Risk:** low to high	**Benefit:** medium
UAV options would require development as there are no know previous projects which have utilised UAVs for such large areas. Aeroplane observations are well established, however, relatively costly. This option would be considered high effort based on the likely costs.	Aeroplanes offer a low risk option as methods are well established and robust. UAVs would be a medium to high risk as the RA represent a very large area which may not be feasible with battery/distance limitations of most UAVs.	The spatial scale is unlikely to be sufficient to inform most EIA characterisations (Sparling *et al.*, 2015) and therefore the data are would be of medium value only to the tidal stream sector.

Notes: Diving seabird observations can also be made from aerial surveys; however, species identification is challenging.

Option 5: Static PAM.

Description: Strategically placed hydrophones (known as PODs) in each RAs would provide high resolution temporal data (and potentially spatial data if a number of hydrophones are deployed), however, only for certain cetacean species. Full coverage of all RAs is likely to be expensive due to the number of PODs required (several thousand), and potentially not feasible due to conflicts with other sea users. The volume of data and post-processing would also pose significant challenges. Therefore, strategic static PAM (i.e. a partial array) would be suggested for this option. An example survey could include 20-30 PODS or hydrophones per group in RAs deployed for a minimum of two years.

Indicative cost: high	**Risk:** medium	**Benefit:** medium
The cost of this option would depend on the survey plan; however, it could cost >£1 m so is therefore considered to be high effort.	Static PAM are considered medium risk, as a) it may be difficult to maintain the correct instrument position in high tidal velocities, and b) high tidal velocity areas may have high background noise masking cetacean vocalisations.	Data may be sufficient, for EIA characterisation for the detection of cetaceans. However, these data would be unlikely to remove the need for site specific visual surveys as the spatial scale may not be sufficient and some species are not detected by PAM. Overall the value of progressing this option would be considered medium unless combined with visual surveys (option 7).

Notes: There is the potential for conflict with other marine users and therefore consultation with stakeholders would be needed prior to deployment. This would provide high resolution temporal data on some cetaceans (however, not all species would be detected unless they vocalise). The surveys would require many PAM devices. Care would need to be taken to ensure the supplier could provide sufficient devices and the necessary support.

Option 6: Full boat based visual surveys with towed PAM

Description: For this option we would suggest full coverage of the RA with a minimum 5 km buffer around the RAs with surveys of each RA at least once per month for two years. Surveys should continue after the initial two year period (possibly at a reduced frequency or resolution) to maintain the temporal validity of these data. Coastal observations would be used for areas of restricted boat access.

Cost: high	**Risk:** low	**Benefit:** high
This option would likely require multiple vessels (one for each RA) operating for 10—20 days per month plus crew and observers. The cost for two years is estimated to be in the	This option would use well established methods and follow guidelines for surveys. Although data collection could be hampered by poor weather, repeated survey days and redundancy planning, such as back vessels and kit would	This option would, in most cases, provide sufficient data for EIA level characterisations and is therefore considered to be of high value to the tidal stream sector.

order of £5 m, so this option is ranked high.	mitigate these risks. Overall, the risks for this option are considered low.	

Notes: Diving seabird observations can be carried out in conjunction with marine mammal surveys for relatively minimal extra cost.

Option 7: Boat (with towed PAM) & static PAM

Description: Full boat based survey with towed PAM (option 6) combined with static PAM array (option 5)

Cost: very high	**Risk:** low	**Benefit:** high
Would provide efficiencies, as PODs would be serviced and data downloaded during visual surveys, however, the costs for a two year programme would be very high (>£5 m) due to the volume of survey data generated, equipment and post-processing costs.	The risk of this option would be low, as the option combines several approaches. If one approach was not successful other data could be used to fill in gaps.	This option would offer the greatest spatial and temporal resolution and is likely to be sufficient to inform EIA characterisations for most tidal stream projects.

Notes: Diving seabird observations could be carried out in conjunction with marine mammal surveys for relatively minimal extra cost. The surveys would require many PAM devices. Care would need to be taken to ensure the supplier could provide sufficient devices and the necessary support.

Seal tagging has not been proposed, as although it is a viable option which would generate useful data, tagging would only provide data for one species of interest and would not achieve the aim of addressing evidence gaps alone. The visual survey options would include observations of seals in the area being studied. Seal tagging remains a viable option for site specific data collection, if current evidence (such as existing data, or those suggested in this report) indicate seals are at high risk of potential impacts for a particular RA.

Table 5.3: Summary of strategic evidence objectives for marine mammals and methods that could fill them. (Number in brackets refers to options above).

Stage	Marine mammals	Coastal visual survey (2)	Trial boat (with towed PAM) (3)	Aerial survey (4)	Static PAM (5)	Full Boat (with towed PAM) (6)	Boat (with towed PAM) & static PAM (7)
Planning and Policy level	Confirm the presence / absence of marine mammals in the RAs.	Partial – large gaps	Partial – large gaps	Yes	Yes	Yes	Yes
Site Selection, scoping and screening level	Confirm the presence / absence, seasonal occurrence and abundance / distribution of marine mammals in the RAs.	Partial – large gaps	Partial – large gaps	Yes	Yes (select species)	Yes	Yes
Site characterisation level	Confirm the presence / absence, seasonal occurrence and abundance / distribution of marine mammals in the RAs. Also confirm specific functional use of the area (e.g. feeding, breeding, diving depth, prey species, residence time, individual 'turnover' etc) with sufficient detail to inform a collision risk model.	Partial – large gaps	Partial – large gaps	No	Partial – selected species only	Yes	Yes

Stage	Marine mammals	Coastal visual survey (2)	Trial boat (with towed PAM) (3)	Aerial survey (4)	Static PAM (5)	Full Boat (with towed PAM) (6)	Boat (with towed PAM) & static PAM (7)
Pre-construction baseline level survey objectives:	Detail the abundance/distribution and behaviour (e.g. feeding, residence time etc) of marine mammals in the project area with statistical confidence (power analysis) to detect change.	No	No	No	Potentially (select species)	Potentially	Potentially

5.3. Diving seabirds

As detailed in Section 4.4.1 there are various sources of existing data for diving seabirds. However, currently available data are patchy and generally regarded as sufficient up to the EIA screening and scoping stages of the consenting process. As with marine mammals, except for very small (like single device demonstration sites) tidal stream projects, most tidal stream projects in the Welsh marine area are likely to require detailed seabird survey data comprising at least monthly observer data for two years. It should be noted that seabird observation data are typically collected at the same time as marine mammal observations and the survey methods are often similar.

The strategic evidence options for diving seabirds are (in order of estimated cost, low to high):

Option 1: No additional surveys.

Existing data are likely to be sufficient for broadscale policy and planning, although site specific surveys will, in most cases be required for tidal stream developments. Again, as with marine mammals, this is because diving seabirds are likely to be a key feature in the EIA assessment, due to both potential effects/impacts at construction and operational stages.

Option 2: Vantage point visual survey (coastal).

Description: A low effort option, which would consist of land-based surveys carried out monthly for at least two years.

Indicative cost: low	**Risk:** low	**Benefit:** low
Numerous observers would be required, however, there would be no vessel costs and data processing would be minimal.	Overall there would be a low risk of the survey not meeting its objectives, however, poor weather and visibility may hamper efforts especially in winter months.	While a relatively inexpensive and low risk option, the value of these data must be considered. Land-based surveys would only collect data on a very small proportion of the RAs and surrounding areas, and therefore these data are unlikely to be of value to many offshore tidal stream projects. These data would be low value and unlikely to have a significant benefit for the tidal stream sector.

Notes: Would be carried out in connection with marine mammal surveys.

Option 3: Trial boat based visual survey(s).

Description: The cost of full scale surveys over all RAs would be high. It may be preferable to carry out trial surveys first. Trial surveys could be limited to a single RA. The ambition being to then expand to full scale surveys if the trial was successful. It would be recommended to carry out surveys monthly for two years to gather the most valuable data. There would be limited coastal observations for areas of restricted boat access.

Cost: medium*	**Risk:** low	**Benefit:** medium
The survey should be combined with the marine mammal survey with minimal (low effort) additional costs (potentially additional observers and data processing).	Boat surveys follow well established methods and there is a low risk that the survey objectives would not be met. Repeating surveys monthly for at least two years would reduce the impacts of weather down time or low visibility.	Data collected would be highly valuable to the tidal sector, however, would be spatially limited and therefore this option is regarded as of medium value overall, although it may be of high value for specific RAs which have been surveyed.

Notes: We would suggest this option be carried out alongside marine mammal surveys.

*If combined with marine mammal surveys then additional costs for diving seabirds would be low.

Option 4: Full boat based visual surveys.

Description: For this option we would suggest full coverage of the RA with a minimum 5 km buffer around the RAs. Surveys of each area should be undertaken at least once per month for two years. We recommend surveys should continue after the initial two year period (possibly at a reduced frequency or resolution) to maintain the temporal validity of these data. There will be limited coastal observations for areas of restricted boat access.

Cost: high*	**Risk:** low	**Benefit:** high
This option would likely require multiple vessels (one for each RA) operating for 10—20 days per month plus crew and observers. The survey should be combined with the marine mammal survey with minimal (low effort) additional costs (potentially additional observers and data processing).	This option would use well established methods and follow guidelines for surveys. Although data collection could be hampered by poor weather, so repeated survey days and redundancy planning, such as back vessels and kit would mitigate these risks. Overall, the risks for this option are considered low.	This option would, in most cases, provide sufficient data for EIA level characterisations and is therefore considered to be high value for the tidal stream sector.

Notes: We would suggest this option be carried out alongside marine mammal surveys. *If combined with marine mammal surveys then additional costs for diving seabirds would be low.

Tagging of diving seabirds has not been proposed. Although it is a viable option which would generate useful data, tagging would only provide data for the tagged species of interest and would not achieve the objective or address the evidence gaps alone. The visual survey options would include observations of all seabirds, and importantly provide data for the precise area of interest within a RA (tagging studies would instead provide data on wherever the tagged animals travel to). Diving seabird tagging remains a viable option for site specific data collection, if current evidence (such as existing data, or those suggested in this report) indicate specific populations are at high risk of potential impacts in a particular RA.

Table 5.4: Summary of strategic evidence objectives diving seabirds and methods that could fill them. (Number in brackets refers to options above).

Stage	Diving seabirds	Coastal visual survey (2)	Pilot boat visual survey (3)	Full boat visual survey (4)	Tagging and tracking (5)
Planning and Policy level	Confirm the presence / absence of key seabirds in the RAs.	Partial – large gaps	Partial – large gaps	Yes	Partial – select species
Site Selection, scoping and screening level	Confirm the presence / absence, seasonal occurrence and abundance/distribution of key seabirds in the RAs.	Partial – large gaps	Partial – large gaps	Yes	Partial – select species
Site characterisation level	Confirm the presence / absence, seasonal occurrence and abundance/distribution of key seabirds in the RAs. Also confirm specific functional use of the area (e.g. feeding, breeding, diving depth, prey species etc) with sufficient detail to inform a collision risk model.	Partial – large gaps	Partial – large gaps	Yes	Partial – select species
Pre-construction baseline level survey objectives:	Detail the abundance/distribution and behaviour (e.g. diving rate, depth etc) of diving seabirds in the project area over multiple years with statistical confidence (power analysis) to detect change.	No	No	Potentially	Partial – select species

5.4. Strategic coordination

Any programme of strategic evidence collection is likely to require multiple surveys, with centralised coordination a key factor for success. This will mean that surveys should not be undertaken in isolation of one another but instead a programme coordinator should be appointed to ensure the overarching objectives are met from individual surveys. This approach would bring the greatest benefit to all stakeholders and enable the most widespread use of data.

There are multiple benefits of a coordinated and centralised approach such an approach provided the coordinators can cover the key requirements:

- Having centralised oversight of costs and logistics should maximise efficiencies. A practical understanding of the challenges of collection survey data in the marine environment will be needed within the coordinators.
- Coordination of the survey designs, ensuring they are robust and use recognised survey methods and that recognised data processing techniques are used, and suitable data products are produced. It will ensure that the statistical power to achieve objectives of both individual surveys and the overall aims of the programme are included in survey design.
- Coordination of data storage into the relevant storage locations. This should ensure that the data are openly available for all stakeholders to easily access in a readily useable format.

6. Making data available

Any strategic planning for evidence must carefully consider the collection, processing, archiving and publishing of data to maximise the scientific and societal outcomes. For marine survey data it is essential that both metadata (information about the data) and the data are shared as widely as possible, in a common, usable format (Bean *et al.*, 2017). The core guiding principles for scientific data governance are to ensure that data are Findable, Accessible, Interoperable and Re-useable (FAIR) (Wilkinson *et al.*, 2016). To achieve FAIR data for the themes covered in this report, the following elements should be considered.

6.1. Data Collection

The quality of evidence used for planning and consenting ultimately is derived from the quality, precision and scope of the data used. Creating data products which can be trusted to give the best advice for policy or regulatory decisions is reliant on the raw data collected being of sufficient scope, being collected in a consistent format and being processed using a transparent, reproducible method.

The Marine Environmental Data and Information Network (MEDIN) provide a number of established data guidelines (MEDIN, 2022a) for many marine themes, which can be used to ensure not only a consistent and detailed approach to data collection, but also assist with ease of data archiving when complete. In addition, the ongoing Joint Cetacean Data Programme (JNCC, 2021b) aims to create marine mammal specific data standards and is due to be reviewed by MEDIN as an additional accepted standard for the marine community. These may be of use specifically for any cetacean data collected. Delivery of data in such guidelines can be specified within tender documentation to ensure that data meets the required standards of the project.

6.2. Data Processing

Once raw data is collected it will typically need to be processed, quality assured and often turned into usable data products for use in reports and publications and to feed into geospatial data systems if relevant. The careful handling and recording of the provenance of the data along these steps are key to ensure the data and data products meet the FAIR principles. Any parties contracted to undertake processing must have suitable infrastructure, resources and expertise to suit the specific data types and this should be considered during the planning stages of any project.

Providing centralised coordination and oversight of the design and methodologies will help ensure the strategic aims of an evidence programme are met. Drawing together expertise through an advisory panel should result in improvements in data processing efficiency, result in faster delivery and more robust data outputs.

6.3. Metadata

Information which accompanies data (i.e. metadata) is essential for users to be able to interpret and reuse data. It can also ensure that any restrictions applied to the data are recorded, provide linkages which refer to other relevant data and determine custodianship to ensure that queries about the data or requests for underlying raw data can be efficiently answered by an authoritative source.

The MEDIN discovery metadata standard (MEDIN, 2022b) is long established within the marine data community and is compatible with both UK Geo-spatial Metadata Interoperability Initiative (GEMINI), Infrastructure for Spatial Information in the European Community (INSPIRE) and International Organization for Standardization (ISO) standards for spatial data. If strategic evidence options are taken forward, tender documentation can specify that metadata are recorded and provided using the MEDIN standard which can be produced using multiple tools both online and offline. The discovery metadata should, once approved, be published to the MEDIN portal (MEDIN, 2022c) in addition to any other required portals relevant to the theme in question.

Good, useable metadata will help ensure that data collected within a strategic evidence programme can easily be found by the relevant stakeholders. Doing so will maximise the use of the data in the current plans and help ensure that the data can be reused in future studies.

6.4. Data Archiving

Any data and data products collected or created must have an archive location determined to ensure an audit trail for the verification of advice and reports specific to tidal stream energy. In addition, data and data products may have a wider scientific / policy value, making the appropriate choice of data archive location even more crucial.

The key considerations for data archival are:

- Overall size of data to be retained.
- The formats in which it is to be stored and retrieved.
- The potential to restrict access to all or parts of the data.
- The ability for the data to be stored / retrieved / published from the archive.
- The length of time expected for retention (which can be forever for raw data).

Each consideration may be different for different data themes or for specific surveys. When reviewing the criteria above, it is essential that the selected data archive centre has the appropriate infrastructure, resources, and stability of funding to meet the requirements for the specific data in question. As an example, the MEDIN network provides a number of different data archive centres (MEDIN, 2022d) each with their own specialist theme, each centre varies in terms of charges and other prerequisites such as data standards used.

These might be the preferred location for the final archive of data, but any associated costs and other requirements must be considered during the project planning stages.

From the options discussed in Section 5 the most notable storage challenge is likely to be acoustical data from PAMs and PODs. Historically these types of data are often unavailable or inaccessible to external researchers because of the size of the datasets. They are typically stored on hard drives rather than web-based platforms which greatly limits access. These data are likely to require many terabytes of storage space. Setting up a storage plan from the offset will be key to ensuring there use and future reuse.

6.5. Data Publishing

To maximise the value of any data collected, the data should be made as openly available as possible. Due regard must be paid to any legal sensitivities, restrictions or terms and conditions, which should be applied to any data or data products before they are published.

It would be preferable if the selected data archive centre has the capability to publish the data, alongside any potentially relevant data products, to one or more data portals to facilitate access to and awareness of data for potential users. At the same time, the data archive centre must retain the status of the single authoritative source for the data, being able to answer queries regarding provenance, ownership and onward use (Figure 6.1).

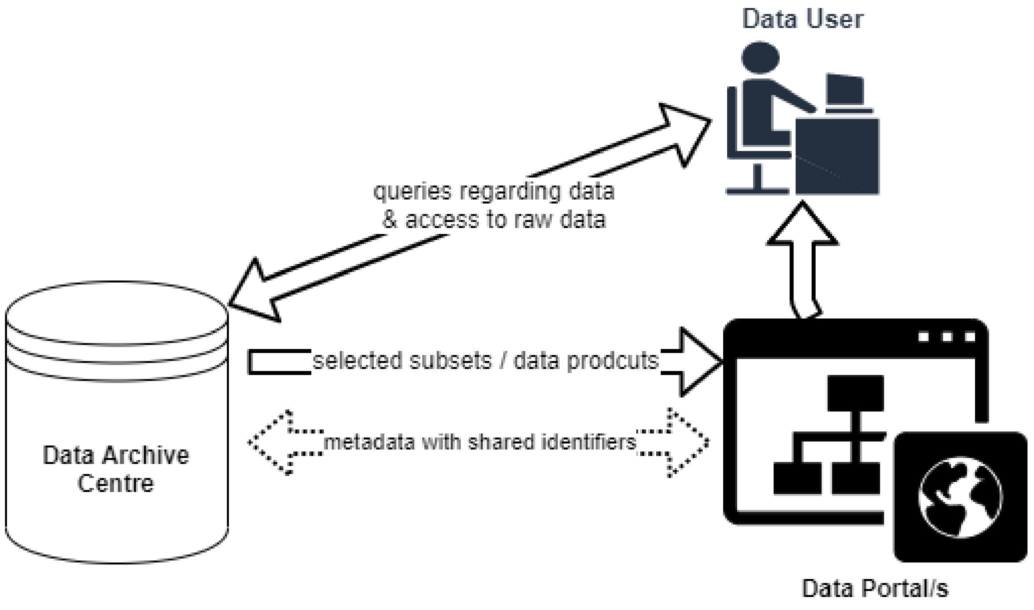

Figure 6.1: Data publishing distribution and cross linking.

The limitations of the data portal or of the data archive centre may mean that this is not possible, in which case the data provider would be responsible for ensuring data and data products are distributed to relevant data portals and metadata within them make reference to the original archived data location.

We anticipate that data products (e.g. density maps or location maps) would be published on public data portals, such as DataMapWales (https://datamap.gov.wales/) and/ or the Wales Marine Planning Portal (http://lle.gov.wales/apps/marineportal). Raw data should, however, not need to be hosted on these portals but instead be available via the data archive centre.

For practical reasons such as the size of data files or sensitivities, it may be that only specific subsets of the processed data or data products can be made available for download by the public. If this is the case, the archive centre should still publish discovery metadata describing all data retained via the MEDIN portal which allows potential users to request special access to non-published data, if they have the required access rights.

Again, assessing the data storage requirements from the offset of a strategic programme will pay dividends. Working out what to do with data when it has already been collected can lead to unexpected costs.

6.6. Data Planning

The need to plan for data gathering is essential to ensure that the data are made FAIR. Any future tenders / data gathering projects must, at the earliest stage possible, consider the entire lifecycle for all data collected and any data products create (including their archival and onward use). Any likely participating organisations (for example data processors, data archive centres and data publishers) should be consulted as early as possible to ensure that they have the resources, expertise and infrastructure to handle any elements they would be expected to contribute to. The expertise and facilities provided within the MEDIN community should be able to help make recommendations to ensure best practice is followed.

7. Conclusions

Building on the review of monitoring methodologies and technologies and recommendations in Clarke *et al.* (2021a) (Section 2.1.1) we consider the methods identified for data gathering are viable for strategic evidence in RAs in support of the tidal stream sector. In addition to the core recommendations in Clarke *et al.* (2021a) we also consider PAM (both towed and static) offers viable and reliable methods of collecting marine mammal data. While there are risks and considerations for PAM methods in high tidal velocity areas (such as background noise and equipment stability), these issues are likely to be resolvable (see section 3.2).

The options for strategic evidence presented in Section 5 are summarised in Table 7.1. Each of the options have the potential to produce data that could support the consenting of tidal energy developments in Wales and address certain critical evidence gaps that exist. There are, however, levels of cost and relative benefit that should be considered carefully.

The most significant cost relative to benefit considerations come with migratory fish. All the viable options identified are high risk (i.e. could fail to meet the objectives) as they utilise relatively new technology and/or rely on tasks which are difficult to achieve (such as tagging sufficient numbers of rare fish). However, if successful, tagging and acoustic telemetry options would provide highly valuable data, not only to the tidal stream sector but of value to all potential marine developments with an impact pathway to migratory fish, and to the general scientific community.

The main concern for migratory fish in relation to tidal stream devices is the risk of collision with the turbines. This is emphasised by the critical evidence gap described in ORJIP-OE (2020); '*The nature of any potential interactions between migratory fish and tidal turbines is uncertain'*. However, this risk is a perceived risk rather than a confirmed risk (Copping *et al.*, 2020; ORJIP-OE, 2020), with few empirical data on collision risk and mortality of marine fishes, (and also for mammals and seabirds). Indeed, Copping *et al.* (2020), in reviewing the available evidence describe, from the few existing studies marine fish, collision events are rare to non-existent. The priority of carrying out highly expensive, and high risk migratory fish studies should therefore be weighed up against focusing research efforts into qualifying and quantifying the pressure pathways between migratory fish and tidal stream devices.

There are potential non-collision risks from tidal stream devices for migratory fish, such as far-field impacts (e.g. avoidance of devices/arrays) and construction impacts. Survey evidence from acoustic telemetry studies would provide an excellent base on which to assess these risks. Whether these data are strictly needed to come to conclusions regarding the significance of impacts (i.e. EIA conclusions), though, would depend largely on the nature, location, and scale of a proposed development.

Table 7.1: Summary of survey options with effort, risk, and value for migratory fish.

Option	Indicative Costs	Risk	Benefit to tidal stream sector
Migratory Fish			
1) No survey	-	-	-
2) eDNA	Low	High	Low-medium
3) Trial tagging and acoustic tracking	High	High	Medium
4) Full scale tagging and acoustic tracking	Very High	Very High	High
Marine mammals			
1) No survey	-	-	-
2) Vantage Point surveys	Low	Low	Low
3) Trial visual/PAM vessel survey	Medium	Low	Medium
4) Aerial survey	High	Low-high	Medium
5) Static PAM	High	Medium	Medium
6) Full visual surveys (boat) with towed PAM	High	Low	High
7) Visual surveys + PAM (boat) + static PAM deployment	Very high	Low	High
Diving seabirds			
1) No survey	-	-	-
2) Vantage Point surveys	Low	Low	Low
3) Trial visual vessel surveys	Medium*	Low	Medium
4) Full visual surveys (boat)	High*	Low	High
Strategic Coordination			
Coordinated oversight of survey work and analysis	Low	Low	Very high

* Low if combined with marine mammal surveys.

For migratory fish, in particular for the tagging and acoustic telemetry option, there is an open question over the value of the data for tidal stream developments. Combined with the very high costs and high risk of this option, it is concluded that it offers limited value for money when considering the tidal stream sector only. However, the proposed programme in Clarke *et al.* (2021a) would provide nationally (possibly internationally) valuable data and should therefore be considered as a multi-sector evidence requirement and pursued with a wider purpose than tidal stream energy alone. In balancing the risks, costs and benefits, we would view such a study as a research programme, rather than a “commercial” piece of work. The suggestions for funding in Clarke *et al.* (2021b) effectively concur this conclusion.

In comparison to tagging and telemetry, eDNA studies for migratory are relatively low cost. There is still a high risk of minimal data being collected and the value to the tidal stream sector is low, as eDNA will, at best describe broad scale presence of fish in wide areas. However, eDNA could offer some data on migratory fish at sea in the Welsh marine area where at present there are none. If sample collection was combined with other surveys (for example samples collected during marine mammals/seabird visual surveys) the cost of analysing the samples and processing the results would likely be very modest. Therefore, if sample collection can be combined with other planned surveys, eDNA analysis for migratory fish should be considered largely due to the limited cost and lack of existing data.

For marine mammals and diving seabirds there are well established guidelines and precedents from previous marine renewable projects. While there are existing data for both key features, detailed occupancy and distribution data are needed for most tidal stream energy projects comprising monthly visual surveys for at least two years. Aerial survey options are viable for both marine mammals and seabirds, however, the value of the data are limited given the difficulties in identifying species from altitude. For marine mammals, PAM options are also viable (although with medium risks, due to issues with background noise and instrument stability), however, PAM alone (i.e. static PAM) would only provide data on vocalising cetaceans.

Boat-based visual surveys for marine mammals and seabirds combined with towed PAM are recommended as the most cost effective and valuable data, which could be strategically collected to address evidence gaps and support the tidal stream sector development for these key features. This is because of the generally accepted need for visual survey data for both marine mammals and diving seabirds and the efficiencies to be gained when combining these surveys, and the value to the tidal stream sector of having these data available, which could expedite the consenting process and de-risk areas for prospective developers.

In conclusion, we suggest that the most valuable and cost effective strategic evidence to support development of the tidal stream sector in Wales are boat-based visual and towed PAM surveys for marine mammals and seabirds, covering the whole RAs with extended buffers of at least 5 km. Surveys should be monthly and continue for a minimum of two years. There are numerous survey contractors with the skills to plan and carry out such surveys. Collection of eDNA samples monthly with analysis for migratory fish species would be a cost-effective add-on to this programme.

Should any of the options be taken forward we would recommended that further input is needed from specialists, particularly in statistical power to plan, design and fully cost any strategic evidence.

It is important that whichever survey options are taken forward strategic oversight is maintained to ensure data are fit for purpose, processing is to standardised methods, and data products are made available. While it may be appropriate for different survey contractors to carry out individual surveys, survey plans, data processing and data publication should be via a central organisation tasked with achieving the overarching objectives. Survey coordinators should, from the onset of any project, have a clear and agreed data plan to ensure that survey outputs are FAIR. The costs of coordination are minimal in relation to the overall surveys. The benefits to all parties are very high.

This report relates to the tidal stream sector. However, where data can be collected to support multiple sectors (e.g. offshore wind, wave, tidal range etc) the relative value of different options may change, for example, while a tagging and acoustic telemetry study for migratory fish is not currently considered value for money for the tidal stream sector, there may be value in the project overall if the outcomes are applicable and are shared between sectors.

The recommendations in this report are intended to provide advice to the Welsh Government in understanding the value of strategic evidence to the tidal stream sector and the practicalities to be considered should the Welsh Government or any other research organisation take forward the options presented in this report.

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Appendix A - Review of ORJIP Ocean Energy evidence needs

The critical evidence needs highlighted by ORJIP-OE (2020) were briefly reviewed as part of this project (an in-depth review was beyond the scope of this project). Their relevance to strategic evidence for key features of importance, assessing their status and use of key wave and tidal stream resource areas was considered. The findings of this review are presented below:

Table A.1: Review of critical evidence needs highlighted by ORJIP-OE in relation to the strategic evidence on the status of key features in and around tidal resource areas. Table adapted from ORJIP-OE (2020).

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
1. Methods and instruments to measure mobile species occupancy and behaviour in high energy environments and around marine energy devices.	Development of instrumentation to measure/determine: • Distribution and individual behaviour around tidal stream turbines (including near-field responses). • Collision events or avoidance of tidal stream turbines. • Consequences of collisions.	N/A
	Cooperation between regulatory bodies, industry and researchers to agree on a preferred suite of instruments and platforms to accelerate data collection and facilitate national and international cooperation on the development of an improved evidence base.	**Yes:** A largescale programme of strategic evidence surveys is likely to require cooperation between multiple parties.

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
	Improvement of the reliability and survivability of instruments in high energy waters, to address challenges including: • Hydrodynamic forcing. • Corrosion and biofouling. • Pressure and sealing.	**Indirectly:** large scale strategic evidence could indirectly provide funding for improvements in instrumentation reliability and servicing.
	Development of solutions to reduce electronic interference between instruments on platforms.	**Indirectly:** large scale strategic evidence could indirectly provide funding for improvements in electronic interference.
	Development of solutions to improve efficiencies in storing, processing and analysing large amounts of data generated by monitoring, including improved integration of algorithms and machine learning to recognise images of marine animals around turbines to reduce processing of large quantities of data generated by monitoring programmes.	**Yes:** Large scale strategic evidence surveys would generate a large amount of data. If these data are to be efficiently made available to researchers for suitable analysis. Storage and dissemination of the raw data will be essential for a successful development of strategic evidence. In turn this should reduce processing times. Such improvements can be carried through to monitoring stages.
	Development of reliable approaches to powering monitoring equipment to achieve a balance between conserving power and carrying out observations over long periods of time (due to the rare probability of interactions).	**Indirectly:** large scale strategic evidence could indirectly provide funding for improvements in instrument power supply.

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
2. Near-field interactions between mobile species and tidal stream turbines.	Further monitoring around operational tidal stream turbines to describe the occurrence and behaviour of marine mammals, fish and diving birds at close range to devices (1–10s of metres).	N/A
	Quantification of near-field responses (evasion) of marine mammals, fish and diving birds to devices.	**Partly:** Strategic evidence would provide data on the distribution and abundance of marine mammals, fish and diving birds in tidal stream resource areas. Being able to quantify numbers in the wider area will help validate near-field responses.
	Further research to understand the potential consequences of blade strikes and collisions including: • Lethal effects. • Occurrence and nature of the injuries.	N/A
	Links between injury and an individual's ability to survive and reproduce.	N/A
	Cooperation between government, regulatory bodies, industry and researchers to agree on a collaborative approach to gathering and sharing information on measurements of animal interactions with devices.	**Indirectly:** Lessons learned on cooperation between parties at the strategic evidence survey stage will be beneficial when sharing information on measurements of animal interactions with devices.
3. Occupancy patterns, fine-scale distribution and behaviour of mobile species	Further characterisation of marine mammal, seabird occupancy patterns and behaviour in marine energy sites including habitat use in relation to	**Yes:** Strategic evidence surveys would allow for the characterisation of marine mammal and seabird occupancy patterns in the tidal

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
in wave and tidal stream habitats.	hydrodynamic features and conditions, to understand the likely degree of spatial and temporal overlap with deployed devices and arrays.	resource areas. Depending on the level of survey effort, this should directly provide spatial and temporal coverage of these species in and around the tidal resource areas.
	Baseline fish distribution to determine which species are in vicinity of potential tidal energy sites.	**Yes:** Strategic evidence surveys have the potential to inform on the distribution of migratory fish species in the resource areas, if these species are targeted.
4. Far-field responses of mobile species to wave and tidal stream devices and arrays.	Development of methods to relate specific marine animal behavioural responses to the range of frequencies and sound levels from single wave and tidal stream devices, or the physical presence of devices.	**Partly:** Quantifying abundance and distribution of key features in the wider resource areas will help understand potential responses such as avoidance and barrier effects.
	Development of a framework for studying the behavioural consequences of radiated noise from wave and tidal stream devices, to move beyond using audibility as a proxy for behavioural response.	**Partly:** Understanding behavioural responses will likely require a greater understanding of the abundance and distribution of key features within and around the tidal resource areas.
5. Subsea acoustic profiles of wave and tidal stream sites and technologies.	Further development of instrumentation to accurately measure the noise from a range of wave and tidal stream device types and distinguish from ambient noise.	N/A

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
	Further measurements of radiated noise generated by a range of operational wave and tidal stream devices, distinguished from ambient noise, in particular across sound frequencies within the hearing range of sensitive marine animals.	**Indirectly:** By identifying which species may be present in the area.
	Measurement of radiated noise around early arrays of wave and tidal stream devices.	N/A
6. Tools for assessing and managing risk to mobile species populations for large-scale wave and tidal stream development.	Validation/revision of collision risk predictive models using empirical data and field measurements.	**Partly:** Understanding the distribution and abundance of species in an area would provide data to feed into collision risk models to understand how many animals could be at potential risk.
	Development of models or frameworks for translating individual collision risk to population level risk, and to scale collision risk from single tidal stream turbine to arrays.	**Partly:** Understanding the distribution and abundance of species would provide data to feed into collision risk models to understand how many animals could be at potential risk.
	Development of models or frameworks to predict how the underwater noise from larger arrays of devices may affect marine animals.	N/A
7. Tools for assessing effects of large-scale wave and tidal stream developments on physical processes.	Validation of predictive models for large-scale energy extraction, using empirical data and field measurements of high-resolution bathymetry and flow.	N/A

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
	Field measurements before and after deployments of large arrays to validate oceanographic models (note there is limited value in gathering data from small-scale arrays).	N/A
	Improved parameterisation of wave and tidal stream devices to represent specific designs at specific locations, to accurately model the effects they may have on oceanographic systems.	N/A
	Research to connect physical change with its ecological implications for specific species and habitats, so that any change described by model results can be translated to real-world implications.	N/A
8. Tools for assessing social and economic impacts of wave and tidal stream developments.	Development of tools and databases to classify key social and economic indicators.	**Partly:** Quantifying the distribution and abundance of key features that are relevant to social and economic ecosystem services will provide data to support assessment of any impacts.
	Identification of key questions and data needs to guide data collection efforts.	N/A
	Development of incentives to collect and share MRE data across the MRE industry.	**Partly:** Understanding the distribution and abundance of key features that are relevant to social and economic ecosystem services may help emphasise the need to share data.

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
	Creation of flexible planning approaches to address uncertainty as projects move forward and learning increases. Appropriately scale MRE project impacts and data collection efforts to avoid unnecessary requirements for data and mitigation.	N/A
9. Tools for assessing climate change impacts of wave and tidal stream developments.	Development of tools and databases to classify key climate change and carbon reduction indicators.	N/A
	Identification of key questions and data needs to guide data collection efforts.	N/A
	Development of incentives to collect and share MRE data across the MRE industry.	N/A
10. Tools and guidance for managing risk and uncertainty during the preparation of Project Environmental Management Plans (PEMPs)	Further development of Environmental Risk Management Measures Toolbox (OES Environmental and ORJIP Ocean Energy).	N/A
	Undertake a comprehensive review of the approach taken to developing PEMPs and adaptive management strategies in the wave and tidal sector to date.	N/A

Strategic Topics	Priority Actions	Relevance to Strategic Evidence
	Produce guidance on how PEMPs can be best developed in the future, drawing on experience from other sectors where relevant.	N/A
	Determine the transferability of data and experience regarding the applicability and effectiveness of management and mitigation measures applied to date.	N/A

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