Assessment of Risk to Diving Birds from Underwater Marine Renewable Devices in Welsh Waters

Phase 1 - Desktop Review of Birds in Welsh Waters and Preliminary Risk Assessment

On Behalf of

The Welsh Assembly Government

Date: 28th February 2011
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Executive Summary

S.1 This report reviews potential risk to diving birds from marine underwater renewable energy devices (MUREDs). The review is based on the results of desktop research into device type and diving bird ecology, and also includes examination of existing Environmental Impact Assessments (EIAs) of MUREDs, together with research from the European Marine Energy Centre (EMEC).

S.2 MUREDs considered in this report fall into two broad designs: tidal stream and wave power. Tidal stream devices are similar to submerged wind turbines and harness the energy of fast ocean currents around headlands, inlets and channels. The four categories of tidal stream device are: horizontal axis turbine, vertical axis turbine, oscillating hydrofoil and turbines which exploit the Venturi effect. Wave power devices are positioned on or near the sea surface and are driven by wave motion. The six categories of wave power device are: attenuators, point absorbers, oscillating wave surge converters, oscillating water columns (OWCs), overtopping devices and submerged pressure differentials.

S.3 A literature review presents the underwater ecology of 35 diving bird species occurring in Welsh waters. Species population and distribution are discussed, along with foraging range, foraging depth, dive profile, underwater vision and prey preferences. Species discussed are of conservation importance at an international or national scale due to their relative abundance in Welsh waters, their citation in internationally or nationally designated sites, or their legal protection status.

S.4 Of these 35 species, five have relatively high abundance in Welsh waters (≥10% of the Great Britain and Ireland breeding or non-breeding population): Manx shearwater *Puffinus puffinus*, common scoter *Melanitta nigra*, lesser black-backed gull *Larus fuscus*, northern gannet *Morus bassanus* and great cormorant *Phalacrocorax carbo*; three have a medium relative abundance (between 5 to 10%): herring gull *Larus argentatus*, razorbill *Alca torda* and common tern *Sterna hirundo*. All others have relatively low abundance (<5% of the GB/Ireland breeding or non-breeding population).

S.5 Potential risks to diving birds posed by these MUREDs are: direct habitat loss; displacement; risk of collision; risk of entrapment; and impacts arising from disturbance or displacement of prey. Risk also increases with the size of device array – the greater the rotor-swept volume of water, the greater the risk. Risk also varies with exposure of the devices' moving parts: where moving parts are fully exposed risk will be higher than

where they are partially enclosed. Risk of entrapment exists where devices comprise chambers or reservoirs. The large diameter horizontal axis turbines have variable blade tip speeds (these can be quite high, with a similar operational rpm to wind turbines[1]), unlike hydrofoils and most wave power devices which move at more predictable speeds, these fast moving blades may present a high risk when encountered by diving birds. Noise from construction activities such as pile-driving, and during operation may cause disturbance to birds. Underwater turbines may also lead to 'barotrauma' in birds, caused by sudden changes in pressure, potentially resulting in direct mortality or drowning.

S.6 Physical, direct exposure to these risks will depend on the spatial distribution of foraging birds and the depth at which MUREDs are placed. Diving birds are also at risk of indirect, negative 'bottom-up' impacts from effects on prey. Prey depletion due to collision or displacement could reduce birds' food resources and drive them to seek out alternative foraging grounds. Alternatively, prey aggregations around devices could attract birds, potentially increasing their exposure to certain types of risk.

S.7 Risk will be determined by species' foraging depth (including mean and maximum dive depth), allocation of underwater time budgets to different depths in relation to positioning of devices, dive duration, dive shape (V or U-shaped), and type of entry to the water (surface or plunge). Prey preference is another key influence, for example benthic foragers, e.g. eider *Somateria mollissima*, would only be at risk where devices occur in waters within their dive depth capacity, whilst beyond this depth risk will be negligible. Diurnal foraging routine may also influence risk: nocturnal foragers, e.g. razorbill, are considered to be at greater risk due to reduced visual ability, than diurnal foragers, e.g. Balearic shearwater *Puffinus mauretanicus*.

S.8 This report therefore presents an extensive literature review of the underwater behaviour of diving birds. The aim is to inform assessment of the suite of species that are most at risk from the potential impacts of a specific wave or tidal development in Welsh offshore waters. Once identified, this suite of species would form the list of target bird species for baseline surveys during the EIA process. The trialling of survey methodologies appropriate for the collection of baseline EIA ornithology data is being undertaken as part of the second phase of this project.

[1] British Wind Energy Association, http://www.bwea.com/ref/faq.html#fast

S.9 Any proposed development will require a detailed impact assessment, considering site and species specific characteristic of the proposal. However, using general aspects of seabird species ecology we present an overview of the potential level of impact for Welsh seabird species to MUREDs. Wave devices located at the sea surface have the potential to impact most seabird species. Sub-surface wave devices and tidal stream devices will only have the potential to impact on species capable of diving to the depths at which such devices are placed.

S.10 A table of risk level for each Welsh seabird species in relation to generic wave and tidal devices is provided. The risk level was assigned based on details of ecology and distribution in Welsh waters. Of the 35 species included in this report, 28 were assigned a low level of potential impact, while 7 were given a medium level of potential impact. This approach would be appropriate for making an initial assessment of risk for a proposed development and could be used to guide more detailed studies for species identified as being at higher risk.

S.11 To date, there are no documented instances of collisions between diving birds and MUREDs, to the knowledge of the authors. Only a small number of devices are installed however, and the likelihood of recording a collision event is extremely low. Due to lack of specific avian data for MUREDs currently undergoing testing, together with substantial knowledge gaps in the literature on diving bird populations, distribution and underwater ecology, the authors conclude that caution should be exercised during deployment. The research has, however, helped to identify the species most at risk, the potential risks from different devices, and information gaps that need to be resolved to better predict potential impacts of MUREDs on diving birds.

Contents

Quality Management i

Executive Summary iii

Contents vi

1 Introduction 1

2 Renewable Devices and Their Risk to Diving Birds 2

- **2.1 Introduction** 2
- **2.2 Tidal Stream Devices** 2
- **2.3 Wave Power Devices** 9
- **2.4 Risk to Diving Birds** 12

3 Literature Review of Diving Bird Underwater Ecology 19

- **3.1 Species Investigated and Population Abundance in Welsh Waters** 19
- **3.2 Species Conservation Importance** 20
- **3.3 Species Sensitivity** 37
- **3.4 Species Accounts** 37

4 Location of Renewable Devices and Risk to Diving Birds 77

- **4.1 Risk in Relation to Dive Depth** 77
- **4.2 Risk in Relation to Diurnal Routines** 83
- **4.3 Risk in Relation to Foraging Range** 86
- **4.4 Synthesis of Risks to Seabirds** 88

5 Review of EIAs of Marine Underwater Renewable Energy Devices 93

- **5.1 Introduction** 93

6 European Marine Energy Centre (EMEC) Studies 97

- **6.1 Introduction** 97
- **6.2 Sub-Surface Interactions: Sonar System** 97
- **6.3 Wildlife Displacement: Observations Programme** 98

6.4 Acoustic Emissions 98

6.5 Camera Observations of Interactions with Wave Power Devices 99

6.6 Targeted Future Research 99

7 Conclusions 101

7.1 Reported Collisions and Expected Frequency 101

7.2 Collisions and Other Effects 102

7.3 Marine Devices and their Risk Characteristics 102

7.4 Risk Factors in Relation to Species Size and Behaviour 103

7.5 Risk Associated with Conservation of Birds in Welsh Waters 103

7.6 Framework for Identifying Risks to Seabirds from Proposed MUREDs 105

7.7 Knowledge Gaps and Areas for Future Research 105

References 107

Websites 121

Glossary 122

Abbreviations 123

Tables and Figures

Tables

Table 1 The 35 diving bird species investigated in this report, listed in order of relative population abundance in Welsh waters. 24

Table 2 Summary of dive depth behaviour for each of the 35 diving bird species investigated in this report 78

Table 3 Summary of reported diurnal and nocturnal routines of diving behaviour for each of the 35 diving bird species investigated in this report 84

Table 4 Mean and maximum foraging ranges of seabird species (km)............ 87

Table 5 Risk categories (low/medium/high) for each seabird species in Welsh waters based on current understanding of ecology............ 90

Figures

Figure 1 Example of Horizontal Axis Turbine (SeaGen, courtesy of Marine Current Turbines Ltd.) 3

Figure 2 Example of Vertical Axis Turbine – Canada's New Energy Corporation (EnCurrent) (courtesy of New Energy Corp: www.newenergycorp.ca/)............ 4

Figure 3 SPAs (with a marine component) and SSSIs around North Wales............ 22

Figure 4 SPAs (with a marine component) and SSSIs around South Wales. 23

Figure 5 Mean and maximum dive depths for the diving bird species investigated in this report. 82

Appendices

Appendix 1	Characteristics and Relevant Technical Specifications of Marine Devices under Development or Deployed
Appendix 2	Diving Bird Population Estimates
Appendix 3	European Populations of the 35 Diving Bird Species Investigated in the Review

1 Introduction

1.1.1 The Welsh Assembly Government commissioned a review of potential risk to diving birds from MUREDs. The project comprises two phases. This Phase 1 Report presents a desk-based literature review of the nature of the devices and the ecology of the diving birds; specifically, it collates all existing, relevant information surrounding potential encounters between the two. A Phase 2 Report (RPS, 2011 *in prep.*) will present the methods, results and conclusions of field-based trials of methods designed to collect site-specific baseline data suitable to assess the potential impacts of these developments on birds.

1.1.2 The report is structured in the following way:

- Information is provided on the range of tidal stream and wave power MUREDs currently at various stages of development from prototype to deployment;
- Risks to diving birds from these device types are summarised in terms of the devices modes of operation;
- The importance of location of deployment is discussed; and
- A literature review of the diving bird species likely to occur in Welsh waters is presented, including information on species population and distribution, foraging radii, diving behaviour and prey species preferences.

1.1.3 A review is then provided of information from existing EIAs and relevant research from EMEC. Taking all the above information into account, preliminary conclusions are made regarding risk factors associated with MURED type and species' ecology, and the scale of possible effects on diving bird populations.

2 Renewable Devices and Their Risk to Diving Birds

2.1 Introduction

2.1.1 EMEC, based in Orkney, Scotland, list on their website[2] all known MUREDs, categorised into 53 tidal stream and 95 wave powered devices (Appendix 1; Tables 1.C and 1.D). A selection of MUREDs currently under development in the UK by EMEC is presented below. Descriptions of these technologies are taken from information provided by manufacturers and/or developers. A summary of the specific characteristics of these tidal stream and wave device technologies is also included in Appendix 1; Tables 1.A and 1.B, together with a preliminary assessment of the theoretical level of bird collision risk posed by these devices, based on our current understanding of how these devices operate. The generic operations of tidal stream and wave devices, together with specific details on example technologies deployed or under development, are briefly discussed in the following sections.

2.2 Tidal Stream Devices

2.2.1 Tidal stream MUREDs are generally fully submerged and are driven by the natural ebb and flow of coastal tidal waters. Fast sea currents are often magnified by topographical features such as headlands, inlets and straits, or by the shape of the seabed when water is forced through narrow channels. The occurrence of such features is therefore a key influence determining where tidal devices can yield greatest energy generation. Tidal stream devices are broadly similar to submerged wind turbines, however due to the higher density of water than air, the blades can be smaller and turn more slowly than wind turbines, yet still deliver a significant amount of power. To increase the flow and power output from the turbine, some designs include concentrators (or shrouds) around the blades to streamline and concentrate flow towards the rotors. Tidal streams have the potential to provide a completely sustainable source of energy which can be captured and converted into electricity by a tidal energy converter (TEC).

The Four Categories of Tidal Energy Converter (TEC)

Horizontal Axis Turbine

2.2.2 These MUREDs extract energy by using moving water to turn horizontally-mounted turbines. The moving parts of the turbine may be open (effectively a wind turbine under water) or contained in ducts to create secondary flow effects by concentrating the flow and producing a pressure difference (see also Venturi Effect below). All designs present risks of accidental collisions for birds, fish and mammals unless the turbine mechanisms are protected by a physical barrier or some other deterrent. An example of a horizontal axis turbine design is shown in Figure 1 below.

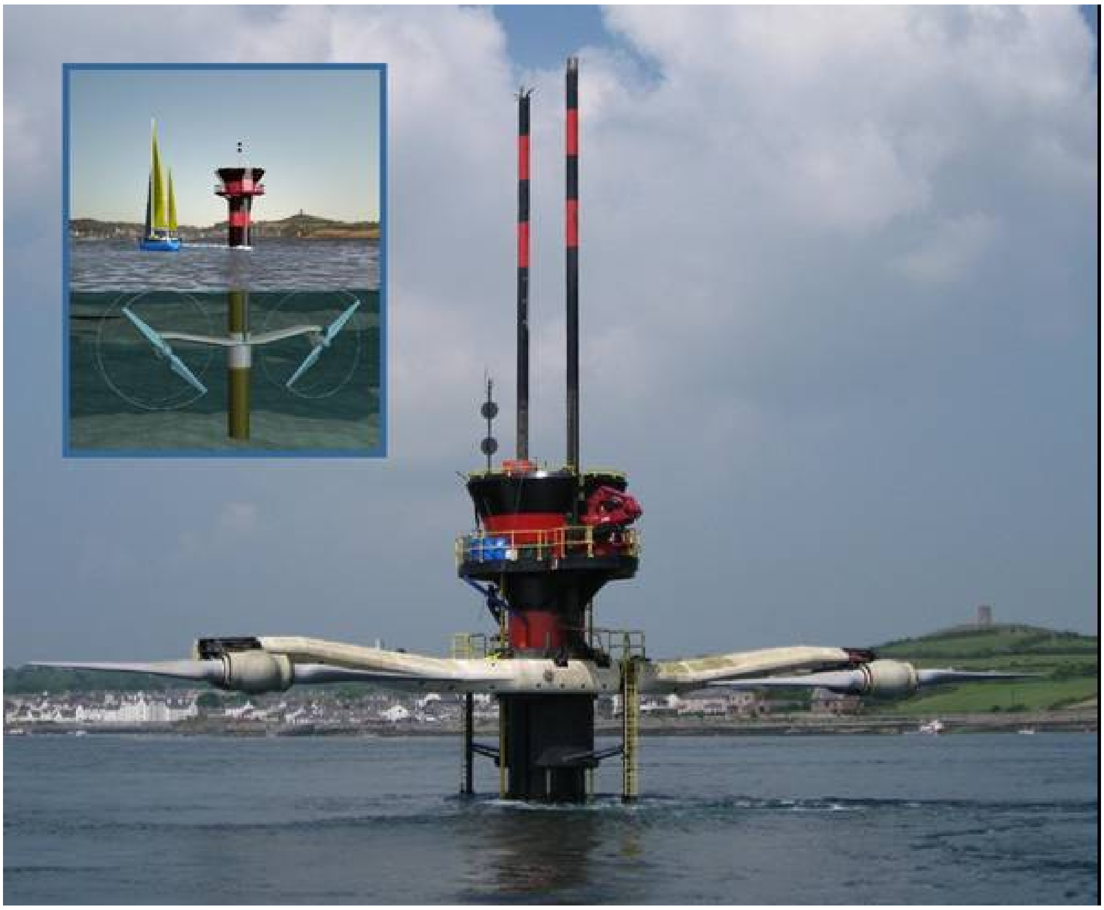

Figure 1 Example of Horizontal Axis Turbine (SeaGen, courtesy of Marine Current Turbines Ltd.)

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[2] www.emec.org.uk/wave_energy_developers.asp, www.emec.org.uk/tidal_developers.asp

Vertical Axis Turbine

2.2.3 These MUREDs extract energy in a similar way to the horizontal axis turbine except the turbine is mounted on a vertical axis. The moving parts may be open providing a collision risk to birds, fish and mammals. An example of a vertical axis turbine design is shown in Figure 2) below:

Figure 2 Example of Vertical Axis Turbine – Canada's New Energy Corporation (EnCurrent) (courtesy of New Energy Corp: www.newenergycorp.ca/)

Oscillating Hydrofoil

2.2.4 A hydrofoil attached to an oscillating arm receives motion from the tidal currents flowing either side which results in lift. This motion can then drive fluid in a hydraulic system to be converted into electricity. The moving parts may be open providing a collision risk to birds, fish and mammals. An example of an oscillating hydrofoil design is shown at www.pulsegeneration.co.uk/?q=node/25.

Venturi Effect

2.2.5 Housing MUREDs in a duct has the effect of concentrating the flow past the turbine. The funnel-like collecting device sits submerged in the tidal current. Turbines are driven directly by the flow of water, or indirectly by the induced pressure differential of the system. The suction caused by the flow of water through the ducts presents some risk of accidental incursions of birds, fish and mammals into the mechanism. An example of a Venturi Turbine is shown at www.lunarenergy.co.uk/productOverview.htm.

Examples of TECs Currently Deployed or Under Development

SeaFlow and SeaGen, manufactured by Marine Current Turbines (MCT) Ltd.

2.2.6 SeaFlow was a prototype project, involving a full-scale, single rotor, 300kW experimental horizontal axis tidal turbine that was installed 3km off Lynmouth on the North Devon coast in 2003 (it has since been decommissioned in c.2007). The system was the world's first tidal turbine. The single rotor was 11m across and comprised two blades. The rotational speed was 23 revolutions per minute (rpm) and the system was installed in a mean water depth of 25m. It was constructed with a monopile base.

2.2.7 SeaGen is a 1.2MW TEC (horizontal axis type) currently operational in Strangford Lough, Northern Ireland. It was installed in 2008. It consists of twin axial flow rotors mounted on wing-like extensions either side of a tubular steel monopole 3m in diameter. Each axial flow rotor is 16m in diameter and consists of two blades. The rotational speed is 15rpm and blade tip velocities reach 10-12ms^{-1} (Royal Haskoning Ltd., 2005). The system operates in water depths of 20-40m.

Open-Centre Turbine, manufactured by OpenHydro

2.2.8 The open-centre turbine is a horizontal axis type device deployed directly on the seabed which makes it invisible from the surface. OpenHydro became the first company to install a tidal turbine at the EMEC facility off Orkney in 2006. The design consists of 16 blades contained within an outer casing and a large open centre. Currently, OpenHydro is planning to install an array of turbines off the Channel Islands, which would generate 3GW of electricity. They have recently also installed a 1MW turbine in the Bay of Fundy, Newfoundland (2009).

RITE Project Kinetic Hydropower System, manufactured by Verdant Power

2.2.9 The Roosevelt Island Tidal Energy (RITE) Project is being operated in New York City's East River and consists of an array of horizontal axis turbines. A prototype was installed for testing in 2002. The demonstration phase of the project was completed in 2008 and the next phase (during 2009 to 2012) is to build a commercial 1MW array. The demonstration involved six full-scale turbines in array, mounted on monopiles, and stands as the world's first grid-connected array of tidal turbines. The system uses three-bladed turbines, 5m in diameter, each with a capacity of 35kW, with a rotational speed of 32rpm and a blade tip speed of 7.6ms^{-1} (Verdant Power). The system is invisible from the surface. During the next phase of the RITE Project, turbines will be mounted on tri-frames with three turbines per mount.

Gorlov Helical Turbine, manufactured by GCK Technology Inc.

2.2.10 This is a vertical axis turbine system. It is designed for hydroelectric applications in free flowing low head water courses but can also be used in the marine environment. There is no information regarding any commercial installations[3]. Turbines are 1m in diameter, 2.5m in height and comprise three blades. Turbines rotate at twice the velocity of the water current flow. Turbines can be installed in water as shallow as 1.2m and can be suspended off a barge or attached to the sea-floor.

Enermar Project, manufactured by Ponte de Archimede International

2.2.11 This project employs a Kobold turbine (vertical axis type). Testing has taken place off Italy (in the Straits of Messina between 2001 and at least 2004) and China, but there is no information regarding any commercial installations[4]. The Kobold turbine is a rotor mounted on a vertical shaft. Rotors are 6m in diameter, equipped with three blades with a span of 5m. Rotational speed is 5rpm. The system is moored in water depth of 18-25m and consists of a buoyant support platform with the turbine attached, moored by four anchoring blocks.

Hydrokinetic Turbine, manufactured by Hydro Green Energy

2.2.12 Hydro Green Energy's hydrokinetic power turbine arrays are composed of horizontal axis type turbines suspended from the surface by attachment to the underside of a

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[3] www.gcktechnology.com/

[4] www.dpa.unina.it/adag/eng/renewable_energy.html

floating raft. The current-driven turbines operate in river (in-stream, free-flow, open-river or hydrokinetic run-of-river), ocean (ocean power) and tidal settings (tidal power).

Rotor diameter is 12ft (approx. 4m), rotation speed is 21rpm and blade tip speed is 3.67ms^{-1} (Hastings Hydrokinetic website[5]). There are hydrokinetic projects underway in Mississippi and Alaska.

Clean Current Tidal Turbine, manufactured by Clean Current Power Systems

2.2.13 This is a bi-directional ducted horizontal axis turbine. A demonstration turbine was installed off Race Rocks Ecological Reserve, Canada in 2006 (since when improvements have been made and the turbine was re-deployed in 2008). The turbine is designed with a large hole in the centre of the rotor (>4m in diameter), which in theory will allow any animal or bird entering the duct to swim through unharmed. Rotational speed varies between 20 and 70rpm (Clean Current Website[6]).

Pulse Generator, manufactured by Pulse Tidal Ltd.

2.2.14 This is an oscillating hydrofoil type device, a prototype of which was deployed in the Humber Estuary close to Immingham during 2009. It is planned to install a fully commercial version at the same location in 2012. The Pulse Generator has the capability to work in shallow water and was designed primarily to harness the tidal power in near shore areas. The technology is based on twin hydrofoils, each 12m long, positioned across the tidal flow; these oscillate up and down in a vertical sweep of 5m, with an average speed of movement through the water of 2ms^{-1} (Thomson *et al*., 2007[7]). It is anticipated that small mobile pressure fields and eddies will be generated around the device during operation. The MURED will protrude 5m above the water during high tide and 12m during low tide.

Stingray, manufactured by The Engineering Business Ltd.

2.2.15 Stingray is an oscillating hydrofoil type device. A prototype was tested off the Shetlands during 2002 to 2003. Future plans for the Stingray include a 5MW pre-commercial array, to be connected to a local power distribution system, in order to test an innovative system for smoothing the flow of electricity from the oscillating devices.

[5] www.power-technology.com/projects/hastingshydrokinetic/specs.html
[6] www.cleancurrent.com/technology/environment.htm

Stingray employs a hydroplane on a mechanical articulated arm, typically situated in any water depth up to 100m. The design uses the flow of the tidal stream over the hydroplane to create an oscillating motion that causes hydraulic cylinders to drive a motor that, in turn, drives an electrical generator. The whole MURED is anchored to the seabed and orientated in the main direction of tidal flow.

Rotech Tidal Turbine (RTT), manufactured by Lunar Energy

2.2.16 The RTT is a bi-directional horizontal axis turbine housed in a symmetrical Venturi duct (an open cylinder). Deployment of this TEC (a joint project with E.ON) is planned for St. David's Head, Pembrokeshire, with the aim of installing a small array by 2014/2015.

2.2.17 The Venturi effect draws ocean currents into the RTT to capture and convert energy into electricity. Use of a gravity foundation allows the RTT to be deployed with little or no seabed preparation, at depths in excess of 40m.

Neptune, manufactured by Aquamarine Power

2.2.18 Neptune is composed of two horizontal axis tidal turbines mounted on a single monopole and situated at 30m depth. It is planned to test this TEC *in situ* at EMEC off Orkney. The device features bi-directional (flood and ebb) generation and the design makes use of technology from the wind turbine industry. At 2.4MW, Neptune is one of the most powerful marine turbines under development.

Evopod, manufactured by Ocean Flow Energy

2.2.19 Evopod is a semi-submerged, floating, tethered tidal energy capture horizontal axis type device. A 1:10 scale version is currently undergoing sea trials in Strangford Lough, Northern Ireland. There are plans to test a larger 1:5 scale version in the near future. It uses a simple but effective mooring system that allows the free floating device to maintain optimum heading into the tidal stream.

DeltaStream, manufactured by Tidal Energy Ltd.

2.2.20 The DeltaStream generates electricity from three separate horizontal axis turbines mounted on a 30m wide frame. It is planned to test this TEC off the north

[7] The River Humber (Upper Burcom Tidal Stream Generator) Order Environmental Statement. www.pulsegeneration.co.uk/files/environmentstatement.pdf

Pembrokeshire coast[8]. It is a nominal 1.2MW unit which sits on the seabed without the need for a positive anchoring system and can operate at any depth. The frame's low centre of gravity prevents the device from overturning or sliding.

TGL Turbine, manufactured by Tidal Generation Ltd.

2.2.21 The TGL turbine is a 1MW fully-submerged horizontal axis tidal turbine designed for deployment at depths of 30m. The prototype design consists of slow-moving rotors mounted on a tower and is currently being developed at EMEC off Orkney.

2.3 Wave Power Devices

2.3.1 Wave power devices are driven by wave motion and therefore positioned on or near the sea surface. Wave size is determined by wind (speed, period and fetch), seafloor bathymetry (which can focus or disperse wave energy) and currents. Waves have the potential to provide a sustainable source of energy which can be captured and converted into electricity by wave energy converters (WECs). WECs have been developed to extract energy from the shoreline out to the deeper waters offshore. See the EMEC website[9] for animations of devices for illustrative purposes.

The Six Categories of Wave Energy Converter (WEC)

Attenuator

2.3.2 An attenuator is a floating device which works perpendicular to the wave direction and effectively rides the waves. Movements along its length can be selectively constrained to produce energy.

Point Absorber

2.3.3 A point absorber is a floating structure which absorbs energy in all directions through its movements at or near the water surface. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors.

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[8] Non-technical EIA summary at www.tidalenergyltd.com
[9] www.emec.org.uk/wave_energy_devices.asp

Oscillating Wave Surge Converter

2.3.4 These devices extract energy from wave surges and the movement of water particles within them. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water through the waves.

Oscillating Water Column (OWC)

2.3.5 The OWC is a partially submerged, hollow structure. It is open to the sea below the waterline, enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a turbine, which usually has the ability to rotate regardless of the direction of airflow. The rotation of the turbine is used to generate electricity.

Overtopping Device

2.3.6 These devices rely on the capture of wave water, which is held in a reservoir above sea level before being returned to the sea through conventional low-head turbines, generating power. An overtopping device may use collectors to concentrate the wave energy.

Submerged Pressure Differential

2.3.7 These devices are typically located near to the shore and are attached to the seabed. Wave motion causes water to rise and fall above the device, inducing a pressure differential within the device. The alternating pressure pumps fluid through a system to generate electricity.

Examples of WEC Currently Deployed or Under Development

Wave Dragon, manufactured by Wave Dragon ApS, Denmark

2.3.8 The Wave Dragon is an ‘overtopping’ device which captures and holds seawater at a higher level than the surrounding water and thus drives underwater turbines. The Wave Dragon is currently at prototype stage and has undergone testing off the Pembrokeshire Coast since summer 2008. The project is currently seeking formalising prior to deploying a full scale demonstrator planned for 2011/2012.

Limpet, manufactured by Wavegen

2.3.9 The Limpet, already deployed on the coast of Islay off the west coast of Scotland, is an onshore OWC. It was constructed in 2000/01 and continues to operate; supplying the national grid as well as providing a test bed for future power take-off systems. Waves surge into a chamber open to the sea and force air through a Wells turbine, which then generates power from air flowing in either direction. As the waves recede, air is drawn back into the chamber via the turbines, generating more power. There is a grill across the front of the air chamber which prevents foreign objects entering the device.

Pelamis, manufactured by Pelamis Wave Power Ltd.

2.3.10 Pelamis is categorised as an attenuator. A prototype was installed at EMEC off Orkney in 2004 and upgraded in 2007. This WEC has also been commercially deployed off the north coast of Portugal; however technical issues have rendered the project inoperative since April 2009. It is a semi-submerged, articulated structure composed of cylindrical sections linked by hinged joints. The wave-induced motion of these joints is resisted by hydraulic rams, which pump high-pressure fluid through hydraulic motors via smoothing accumulators. The hydraulic motors drive electrical generators to produce electricity. Power from all the joints is fed down a single umbilical cable to a junction on the seabed. Several devices can be connected together and linked to the shore through a single seabed cable.

Oyster, manufactured by Aquamarine Power

2.3.11 The Oyster is a hydroelectric wave power converter (oscillating wave surge converter), designed to capture the energy in amplified surge forces in near shore waves. A 315kW prototype began testing at EMEC off Orkney in 2009. The system consists of a pump fitted with double acting water pistons, deployed near-shore in water depths of 2-10m. Each passing wave activates the pump which delivers high pressure water via a sub-sea pipeline to the shore. Onshore, high pressure water is converted to electrical power using hydroelectric generators. When deployed in multiple megawatt arrays, several near shore pumps will feed a single onshore hydroelectric generator, attached to a pipeline.

PowerBuoy, manufactured by Ocean Power Technologies (OPT)

2.3.12 The PowerBuoy is a point absorber type of device. Various prototypes of this WEC have been ocean tested off Hawaii, Santona (Spain) and New Jersey since 2008, and began operating at EMEC (off Orkney) in 2009. OPT plans to set up another testing facility off the coast of Hayle (Cornwall). They are also planning to set up two commercial ‘wave parks’ off the coast of Oregon, USA. The PowerBuoy extracts energy from ocean waves through a power take-off connected between a floating buoy which rises and falls, and a conventional mooring system. A 10MW power station would occupy approximately 12.5 ha (0.125 km^2) of ocean space.

Seawave Slot-cone Generator (SSG), manufactured by WaveEnergy AS, Norway

2.3.13 The SSG is an overtopping device. WaveEnergy have been operating a prototype off Norway since 2005. The SSG utilises three reservoirs placed on top of each other. The potential energy of incoming waves is stored in these reservoirs. Water captured in the reservoirs then runs through a multi-stage turbine. The use of multiple reservoirs results in high overall efficiency. The SSG is a concrete structure in which the turbine shaft and the gates controlling the water flow are virtually the only moving parts of the system. The multi-stage turbine uses different heights of water head on a common turbine wheel. The multi-stage technology minimises the number of start/stop sequences on the turbine, even if only one water reservoir is supplying water to the turbine, resulting in a high degree of utilisation.

2.4 Risk to Diving Birds

2.4.1 As can be seen from Section 2.2 and 2.3 and Appendix 1, there are a large number of MUREDs under development and/or potential deployment. There is a wide variation in the design of these devices and most are still at the developmental stage. By necessity this means that it is not possible to be specific about any negative (or positive) impacts on diving birds. However, with the caveat that each device in each different location will need individual rigorous assessments, it is useful to discuss theoretical potential impacts.

2.4.2 The MUREDs reviewed above pose six theoretical categories of risk to diving birds, inherent to their mode of operation or construction:

- Direct loss of habitat for diving birds due to installation of devices;
- Displacement of birds from the development area;
- Direct risk of collision between diving birds and moving parts of the device;
- Direct risk of entrapment within enclosed parts of the device;
- Direct impacts of construction/operational noise and pressure changes;
- Indirect impacts due to construction/maintenance/operational disturbance; and
- Indirect impacts due to habitat loss for prey, depletion (as a result of collision), displacement or aggregation of prey.

2.4.3 The potential theoretical risk from most of the categories mentioned above may increase with the scale of the project, i.e. the larger the array of renewable devices, the greater the rotor swept volume of water and therefore greater potential risk to diving birds. However, it is not yet known which one of the two factors: i) the size, or ii) speed, of the rotors will present a greater potential risk to birds.

Habitat Loss

2.4.4 Installation of MUREDs would result in an area of sea/seabed being lost from the foraging range of diving birds and physically prevent dives taking place in part of the water column. The extent of direct habitat loss, while dependent on the size of installation, is typically likely to be comparatively low in comparison to the overall foraging range of an individual, and so for the diving bird species discussed in this report, the potential for a significant direct effect resulting from such direct loss is considered to be very low.

Displacement

2.4.5 The effects of displacement on bird populations would be similar to direct habitat loss, albeit with the potential to occur over larger areas. The extent of displacement would probably also be both species and device specific. However, unlike direct habitat loss, there is also scope for the zone of displacement to contract over time, as birds become habituated to novel devices in their foraging areas (e.g. Madsen and Boertmann, 2008).

Risk of Collision

2.4.6 Potential collision risk will vary between renewable devices according to the extent to which turbine blades or oscillating arms are exposed to the surrounding water.

2.4.7 Horizontal axis turbines are renewable devices that resemble wind turbines. They could have the same type of collision effect on underwater wildlife, including diving birds, as wind turbines have on birds above the water's surface. Large diameter horizontal axis turbines will have high or variable blade tip speeds (e.g. 15 rpm, 10-12ms^{-1}, SeaGen), unlike hydrofoils and most wave power devices, which will move at more predictable speeds. Some of these devices are mounted on towers which are anchored or monopiled into the seabed so that the rotors sit just below the water surface. Therefore in these cases the fast-moving blades of horizontal axis turbines will be the first parts of the device to be encountered by birds diving from the surface. Other horizontal axis devices are mounted in frames that sit on the seabed, which due to their position in the water column may present less of a risk to diving birds (but may still pose a hazard to fish and mammals).

2.4.8 The more exposed the moving parts, the greater the theoretical possibility of diving birds swimming into their path, and the greater the potential risk of collision. If moving parts are partially shielded by casing then collision risk is likely to be reduced.

Risk of Entrapment

2.4.9 The potential risk to diving birds posed by OWC devices is different in that although the device has no submerged moving parts, birds may be vulnerable to becoming trapped in the turbine chamber and injured or killed by the powerful propulsion of water within. As is the case for the Limpet, which has a grill across the front in order to prevent foreign objects entering the chamber, the risk of this occurring can be reduced by having a physical barrier.

Impacts of Noise and Pressure Changes

2.4.10 The potential impact of operational noise on the animals that utilise MURED sites will be most significant during construction and subsequent maintenance activities (Madsen *et al*., 2006). Developments capable of floating or resting on the seabed rather than being fixed on the seabed would minimise the impact of noise during the construction process, as pile driving would be unnecessary. The machinery involved in pile driving has the potential to cause auditory damage to wildlife in the vicinity, for example pile driving for a 1.5MW wind turbine produces a sound pressure level of 228 $dB_{0\text{-}p}$ re 1μPa at 1m (Thomsen *et al*., 2006). This could cause disturbance to birds in the vicinity (Habib *et al*., 2007). There are various mitigation options available to minimise the potential impact of piling on seabirds. This aspect of MURED installation is common to offshore wind farm installation and since this is well covered in assessment approaches for this much more established area of renewable developments is not considered in further detail here.

2.4.11 Recent research on bats suggests that sudden changes in pressure can cause barotraumas (Baerwauld *et al*., 2008). Birds were considered less susceptible to barotrauma because of their different respiratory system, however the possibility of direct mortality or drowning as a result of these effects cannot be ruled out. The situation underwater is also unknown.

Indirect Impacts of Disturbance to Diving Birds

2.4.12 There may be indirect impacts at MURED sites due to construction, maintenance or operational disturbance through a number of mechanisms. This may either be due to a reaction of the birds themselves (which may be only temporary) or in combination with impacts on their prey species (see also next section). In order to assess the potential impacts of disturbance on diving birds, the presence of breeding colonies and favoured feeding areas along with the foraging ranges and behaviour of the relevant species would have to be taken into account.

Indirect Impacts on Diving Birds through Impacts on their Fish Prey

2.4.13 Waters off the Welsh coast are important spawning and nursery grounds for many pelagic fish species, including herring *Clupea harengus*, whiting *Merlangius merlangus*, plaice *Pleuronectes platessa*, sole *Solea solea*, pilchard (family: Clupeidae), Atlantic mackerel *Scomber scombrus* and sandeel (genera: *Hyperoplus, Gymnammodytes* or *Ammodytes*). These fish species are an important prey base of piscivorous diving birds.

2.4.14 Given that birds will only come into potential conflict with MUREDs when diving for prey, understanding the distribution and behaviour of prey species is critical in assessing the potential risk to diving birds from devices.

2.4.15 Diving birds may be at risk from indirect negative impacts as a result of impacts to their fish prey through the following scenarios:

- Local fish prey could become depleted or displaced by the deployment of MUREDs, reducing the resources of the area and causing diving birds to seek alternative foraging grounds;
- Fish prey could habituate to MUREDs and aggregate around the structures, attracting diving birds and increasing risk to the birds; and
- Fish could be vulnerable to collision with MUREDs (e.g. horizontal axis turbines), or entrapment within reservoirs (e.g. overtopping devices), attracting diving birds to trapped fish, or fish carrion, and increasing risk to the birds.

2.4.16 A wide range of fish species has been recorded in areas of strong tidal current, specifically, sea bass *Dicentrarchus labrax*, herring, pollock *Pollachius pollachius*, bib *Trisopterus luscus*, Atlantic salmon *Salmo salar* and various wrasse species (family: Labridae). Some have been recorded in the Menai Straits – a narrow stretch of shallow tidal water separating Anglesey from mainland Wales where tidal currents can reach 8 knots during a spring tide (Brazier *et al*., 1999), while others have been recorded elsewhere in strong tidal areas of northwest Wales (Moore, 2004) (see ABPmer, 2010).

2.4.17 Tidal streams are also important migratory routes for pelagic fish, e.g. herring and cod *Gadus morhua* (Lacoste *et al*., 2001; Righton *et al*., 2007). Migrating fish travelling in tidal streams are therefore likely to be funnelled through tidal rapids where other fish and marine mammal predators (Righton *et al*., 2007; Pierpoint, 2008) – and possibly also diving birds, may congregate to ambush them (ABPmer, 2010).

2.4.18 These fish species are therefore at greatest risk from tidal stream MUREDs, which are most likely to be deployed in areas of strong tidal currents. Diving birds foraging for these fish species in tidal streams are likely to be vulnerable to impact by the reduced resources or increased collision risk described in the scenarios above.

2.4.19 High energy, wave-exposed areas support fish assemblages tolerant of strong hydrodynamic conditions. Fish species recorded in the vicinity of the Wave Dragon project of the Pembrokeshire coast for example, included pollock, wrasse, goby (family: Gobiidae) and various flat fish species, together with occasional pelagic species such as Atlantic mackerel and herring. These fish species are therefore at greatest risk from wave power MUREDs which are most likely to be deployed in such high energy areas. Diving bird species foraging for these species in wave-exposed areas are therefore likely to be susceptible to impact by the reduced resources or increased collision risk described in the scenarios above.

2.4.20 It is possible that fish will avoid arrays of MUREDs due to high noise emissions (ABPmer, 2010). Noise levels for the activities associated with MUREDs are generally lower than other anthropogenic noise sources in the sea, specifically shipping, dredging, piling and seismic surveys. The maximum estimated source level of a single tidal turbine device based on existing available information is 175dB, while the maximum estimated source level for a single wave device is slightly quieter at 164dB (ABPmer, 2010). The levels of noise produced by MUREDs are below the level that might cause physical damage to fish. Nonetheless, fish may be deterred. Avoidance will be species-specific, depending on hearing ability and tolerance. Fish may also be able to hear device arrays from some distance and widely avoid the areas. This suggests high noise levels, although potentially reducing local fish prey resources and causing diving birds to seek alternative foraging grounds, may likewise prevent diving birds from using the area and lowering risk to the birds. The indirect effects of prey displacement are much harder to predict and will depend on the extent to which prey shift their distributions. It is possible that under certain circumstances breeding birds will need to extend the range over which they forage. This aspect will need to be addressed on a case by case basis, and is expected to be very difficult to predict prior to device installation.

2.4.21 The review by ABPmer (2010) suggests that fish with good hearing sensitivity, such as herring, would exhibit avoidance to a single tidal turbine device, around 300m from the point source of the noise. Fish with average hearing sensitivity, such as salmon, would show signs of avoidance around 30m and 200m in shallow and deep water respectively. Finally, fish with low hearing sensitivity, such as elasmobranchs and flatfish, would only have a minor avoidance reaction to the device within a few metres in shallow water and around 30m in deep water. Electro-magnetic fields around cables may also affect fish distributions, particularly elasmobranchs, although this would probably only extend over a few metres and the effects appear to be unpredictable (Gill *et al.,* 2009).

2.4.22 The noise levels of wave devices are lower than that of tidal turbines and as such, avoidance distances would be less (ABPmer, 2010). Fish with good hearing sensitivity would show avoidance around 90m and 260m from a single wave device in shallow and deep water respectively. Fish with average hearing sensitivity would only show avoidance around 10m and 130m in shallow and deep water respectively. Finally, fish with low hearing sensitivity would only have a minor avoidance reaction to the device within a few metres in shallow water and around 30m in deep water. Thus, a strong avoidance reaction to MUREDs would only be evident in hearing specialists (ABPmer, 2010).

2.4.23 Fish have been found to aggregate around artificial structures such as oil platforms, marinas, pontoons, sunken vessels and monopiles of offshore wind turbines. Fish aggregate around such structures for food, shelter, resting, reproduction, and for spatial reference in an otherwise barren environment. It seems likely that MUREDs will offer similarly suitable structures for fish. Given the lack of studies relevant to MUREDs, the degree to which fish would aggregate is uncertain, and a cautionary approach would seem most prudent with regard to the degree to which diving birds may be subsequently impacted.

2.4.24 Overall, the paucity of data on the impacts of MUREDs on fish leads to similar uncertainly surrounding indirect prey-related impacts on diving birds. Reduced fish prey resources and increased collision risk are the most likely main impacts on diving birds. However, further research on the deterrence of noise and the attraction of devices as places of shelter, together with a cautionary approach to deployment, are recommended.

Potential Positive Impacts on Diving Birds

2.4.25 There are also theoretical positive effects of MUREDs on seabirds, particularly if fishing activities are excluded from the site of any energy generating system. Although in the short term this might not be important, it could have longer term benefits (Inger *et al*., 2009). There are also the possible benefits of roosting/resting sites above the water surface and increased habitat complexity leading to fish recruitment. Of course any benefits would have to be offset by the potential risk of collision; but all potential impacts (negative and positive) are theoretical at this stage.

3 Literature Review of Diving Bird Underwater Ecology

3.1 Species Investigated and Population Abundance in Welsh Waters

3.1.1 The following section describes both the spatial distribution and underwater ecology of all diving bird species likely to be regularly present in Welsh waters, and therefore potentially at risk from underwater marine renewable devices.

3.1.2 Field and laboratory studies from the literature, representing several decades of research, were reviewed for data on:

- Species population and distribution;
- Foraging radius from the breeding site;
- Foraging locations during the non-breeding season;
- Depth of feeding;
- Dive profile;
- Underwater vision; and
- Prey species preferences.

3.1.3 Species selection was based on an initial list of the 119 species which make significant use of the marine environment around the UK (and Gibraltar), from the Marine Natura Project Group (now Marine Protected Areas Technical Group) (JNCC, 2007). Eventual inclusion was limited to diving bird species regularly found in Welsh waters that depend wholly or mainly on the marine environment for their survival.

3.1.4 From a review of species ecology (e.g. Snow and Perrins, 1998), this was limited to the families Anatidae (ducks, geese and swans), Alcidae (auks), Laridae (gulls), Sternidae (terns), Sulidae (gannets), Phalacrocoracidae (cormorants), Hydrobatidae (storm petrels), Procellariidae (fulmar and shearwaters), Podicipedidae (grebes) and Gaviidae (divers). As some proposed MURED types are found at or just under the surface, species that just break the water layer (e.g. shallow plunge diving by gulls) were included.

3.1.5 Determination of species occurrence in Welsh waters was based on (i) species distribution maps e.g. from Mitchell *et al*. (2004) and Stone *et al*. (1995b) and (ii) boat- and land-based surveys carried out on behalf of the Welsh Assembly Government by

RPS since 2009 at two sites on the Welsh coast (RPS, 2011 *in prep*.). The sites at which the surveys were conducted were ones identified as suitable for MURED developments; in Ramsey Sound, Pembrokeshire and off Carmel Head, Anglesey. The surveys used methods adapted from wind farm assessments (Camphuysen *et al*., 2004, MacLean *et al.,* 2009), with modifications to improve their suitability for underwater devices. Hence the focus was shifted from flying birds to diving species. Further details are provided in the accompanying field methods report (RPS, 2011 *in prep.*).

3.1.6 Based on these criteria, a total of 35 species of diving bird were investigated. These are listed in Table 2, and throughout this report, in order of relative population abundance in Welsh waters. Relative population abundance is based on percentage occurrence in Wales, of the UK or Great British and Irish population estimates (depending on available data; see Appendix 2). Population estimates were obtained from two main sources: Mitchell *et al*. (2004) and Baker *et al*. (2006), and are presented in Table 1 and in individual species accounts. Supplementary information on national population estimates and a table showing the populations of these species in a European context are presented in Appendix 2.

3.1.7 Species which have >10% of UK/GB populations in Wales are classified as having a relative high abundance. Those with 5% to 10% of UK/GB populations are classified as having a medium relative abundance, and species with Welsh populations ≤5% of UK/GB populations have a relatively low abundance.

3.2 Species Conservation Importance

3.2.1 The relative abundance in Welsh waters may only partly describe how sensitive a species is in relation to the conservation status of its national and international populations. A species found in Welsh waters may, for example, be inherently rare worldwide, or be at the extremities of its current breeding range. As such, an assessment must refer to the conservation importance of a species, based on its UK and European legal protection status and qualification for inclusion in nearby designated sites: Special Protection Areas (SPAs), Marine SPAs and Sites of Special Scientific Interest (SSSIs) (see Figure 3 and Figure 4 for locations).

3.2.2 Selection of conservation importance level was based on the following criteria:

- International: Inclusion in the EC Wild Birds Directive Annex I[10], and/or qualification species of an SPA or Marine SPA[11]; or
- National: Cited species of a SSSI with a coastal component (where known)[12], and/or inclusion in Schedule 1 of the Wildlife and Countryside Act 1981 as amended[13], and/or included in Section 42 of NERC Act 2006[14].

3.2.3 In the case of the Balearic shearwater, the species is included in the 2010 IUCN Red List Category (as evaluated by BirdLife International) as being Critically Endangered. Importance level for each species is presented in Table 1. Species investigated are all of conservation importance at least a national level. A list of Welsh SPAs and SSSIs with a coastal component is shown in Appendix 3.

[10] The EC Wild Birds Directive places legal obligations on governments to protect the most important European species both on land and in the marine environment. It requires Member States to provide for the protection, management and control of all naturally occurring wild birds and to take special measures for the protection of migratory birds.

[11] SPAs are identified and classified under the Wild Birds Directive. European Member States have an obligation to select sites for those bird species included in Annex I of the Directive and also for regularly occurring migratory species. For the marine environment, these include marine bird species, such as divers, grebes and seaducks. SPAs in Wales are classified by the Welsh Ministers in light of recommendations made by the Countryside Council for Wales (CCW).

[12] SSSIs are notified by the CCW under the Wildlife and Countryside Act 1981. These sites are notified for the purpose of protecting species, habitats and geological features of national importance. SSSIs are primarily a terrestrial designation however they can in certain circumstances extend into the marine environment.

[13] The Wildlife and Countryside Act 1981 prohibits the intentional killing, injuring or taking of any wild bird and the taking, damaging or destroying of the nest (whilst being built or in use) or eggs. It prohibits possession of wild birds (dead or alive) or their eggs. There are additional penalties for offences relating to birds on Schedule 1 and, in addition, it is an offence to disturb Schedule 1 birds at nest or the dependent young of Schedule 1 birds.

[14] Section 42 of the Natural Environment & Rural Communities Act 2006 lists species of principal importance for conservation of biological diversity in Wales.

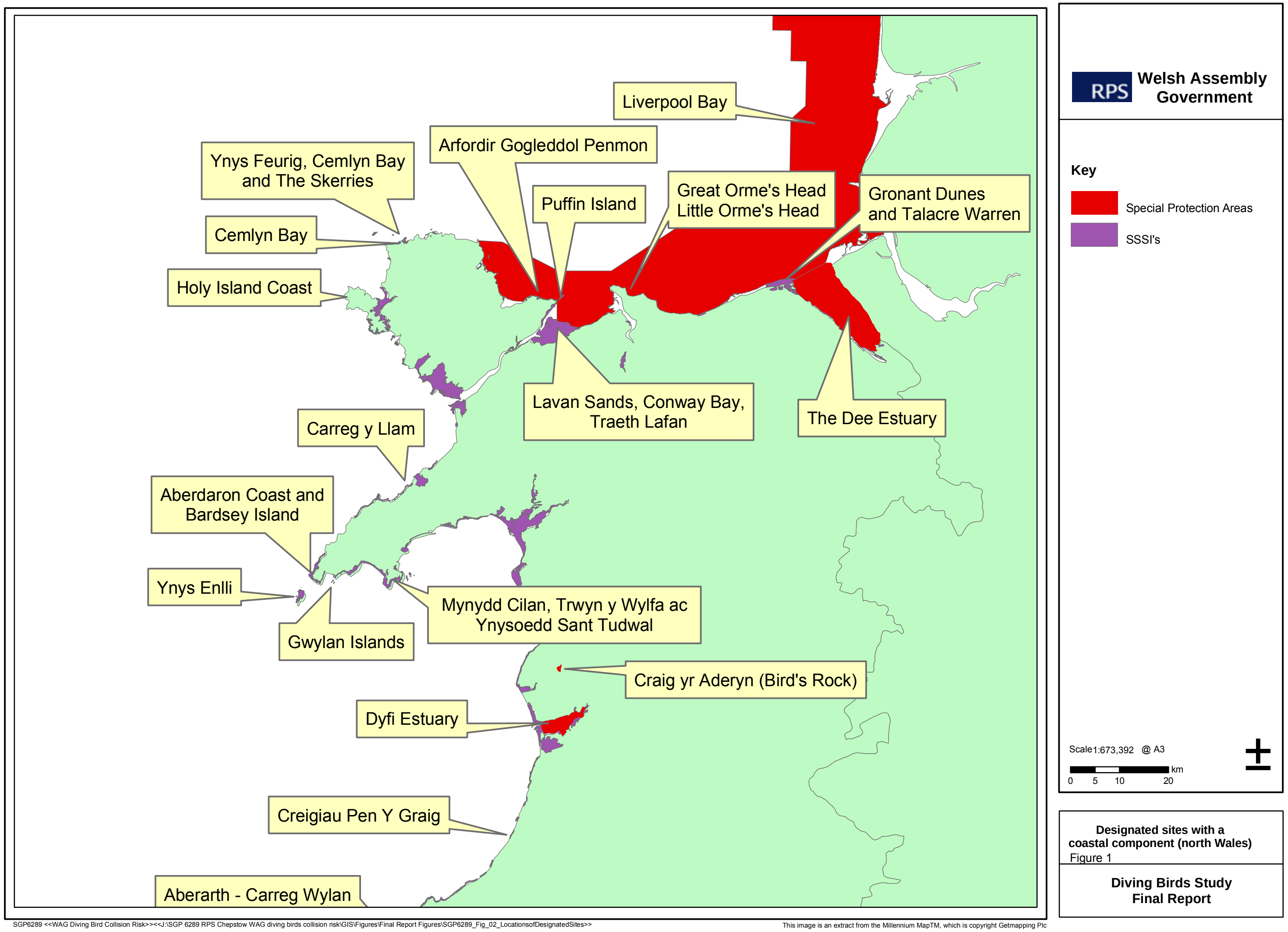

Figure 3 SPAs (with a marine component) and SSSIs around North Wales

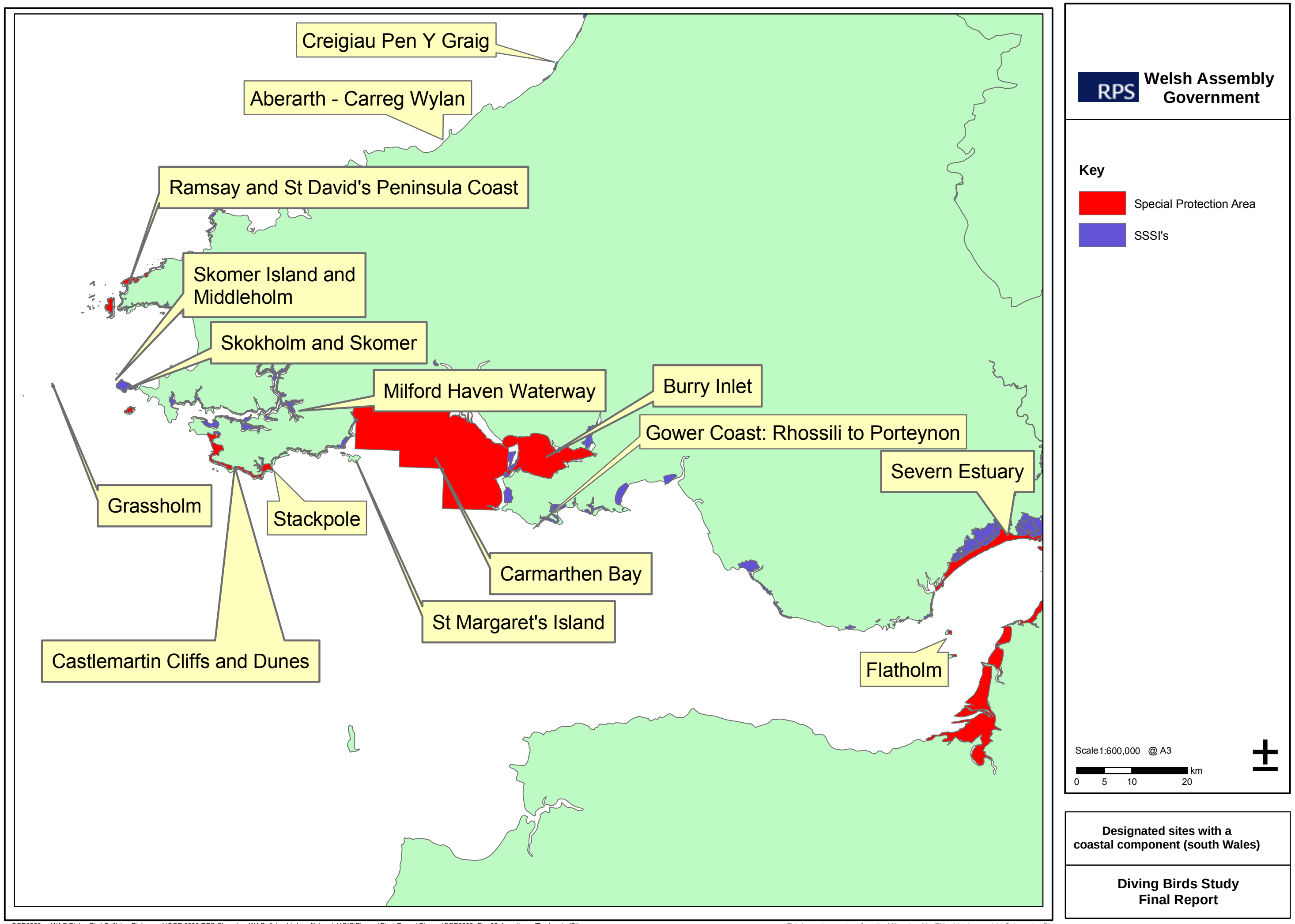

Figure 4 SPAs (with a marine component) and SSSIs around South Wales.

Table 1 The 35 diving bird species investigated in this report, listed in order of relative population abundance in Welsh waters.

Species	Annex I	Schedule 1	Section 42	SPA/ SSSI Qualifier	Season	Overall Population Estimate (UK/GB and Irish)[15]	Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]	Relative Population Abundance in Welsh Waters[17]	Importance
1. Manx shearwater *Puffinus puffinus*				Aberdaron Coast and Bardsey Island SPA Skokholm and Skomer SPA Ynys Enlli SSSI Skokholm SSSI Skomer Island and Middleholm	Breeding	332,267 AOS* (GB and Irish)	168,133 AOS (51%)	**High**	International
2. Common scoter *Melanitta nigra*		✓	✓	Carmarthen Bay Marine SPA Liverpool Bay SPA	Breeding	160 pairs (GB and Irish)	None	None	n/a
					Winter	50,000 individuals	21,779 (2006/2007)	**High**	International

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[15]Refer to individual species accounts for references for these data. AOS: Apparently occupied sites; AON: Apparently occupied nests; AOB: Apparently occupied burrows.

[16]Assessed from various sources (Austin, 2008; Mitchell, 2004 and RSPB website).

[17]This assessment is based on the proportion of the UK/GB population that is found in Welsh offshore waters. A high significance is given to Welsh populations >10% of UK/GB populations, a medium significance is given to Welsh populations between 5% and 10% of UK/GB populations, and a low significance is given to Welsh populations ≤5% of UK/GB populations.

Species	*Annex I*	*Schedule 1*	*Section 42*	*SPA/ SSSI Qualifier*	*Season*	*Overall Population Estimate (UK/GB and Irish)*[15]	*Welsh Population Estimate (Welsh % of UK/GB and Irish population)*[16]	*Relative Population Abundance in Welsh Waters*[17]	*Importance*
						(UK)	(44%)		
3. Lesser black-backed gull *Larus fuscus*				Skomer Island and Middleholm SSSI Aberarth – Carreg Wylan SSSI Flatholm SSSI Skomer and Skokholm SPA (assemblage)	Breeding	116,684 AON (GB and Irish)	20,722 AON (17.7%)	**High**	National
4. Northern gannet *Morus bassanus*				Grassholm SPA and SSSI	Breeding	259,311 AOS/AON* (GB and Irish)	39,000 AOS/AON (12%)	**High**	International
5. Great cormorant *Phalacrocorax carbo*				Puffin Island SPA and SSSI The Dee Estuary SPA (winter and breeding assemblage) Mersey Narrows and North Wirral Foreshore SPA (assemblage) Arfordir Gogleddol	Breeding	13,500 AON (GB and Irish)	1,699 AON (12%)	**High**	National
					Winter	24,200 individuals (UK)	Not available, likely to be ≤3,000 individuals (12%).	Unknown	National

Species	*Annex I*	*Schedule 1*	*Section 42*	*SPA/ SSSI Qualifier*	*Season*	*Overall Population Estimate (UK/GB and Irish)*[15]	*Welsh Population Estimate (Welsh % of UK/GB and Irish population)*[16]	*Relative Population Abundance in Welsh Waters*[17]	*Importance*
				Penmon SSSI Craig gr Alderyn (Bird's Rock) SSSI Dee Estuary SSSI Gronant Dunes and Talacre Warren SSSI Little Orme's Head SSSI Creigiau Pen y Graig SSSI Newborough Warren – Ynys Llanddwyn SSSI, St. Margaret's Island SSSI Gwylan Islands SSSI					
6. Herring gull *Larus argentatus*			✓	Skokholm and Skomer SPA (assemblage) Breeding seabird colony feature of: Skomer and Middleholm	Breeding	149,177 AON (GB and Irish)	13,974 AON (9.4%)	Medium	National

Species	Annex I	Schedule 1	Section 42	SPA/ SSSI Qualifier	Season	Overall Population Estimate (UK/GB and Irish)[15]	Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]	Relative Population Abundance in Welsh Waters[17]	Importance
				SSSI Skokholm SSSI Stackpole SSSI Castlemartin Cliffs Dunes SSSI					
7. Razorbill *Alca torda*				Skokholm and Skomer SPA Gower coast to Porteynon SSSI Great Orme's Head SSSI Skokholm SSSI Skomer and Middleholm SSSI Breeding seabird colony feature of: Skomer and Middleholm SSSI Skokholm SSSI	Breeding	216,000 individuals (GB and Irish)	12,638 individuals (6%)	Medium	International

Species	*Annex I*	*Schedule 1*	*Section 42*	*SPA/ SSSI Qualifier*	*Season*	*Overall Population Estimate (UK/GB and Irish)[15]*	*Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]*	*Relative Population Abundance in Welsh Waters[17]*	*Importance*
				Stackpole SSSI Castlemartin Cliffs Dunes SSSI					
8. Common tern *Sterna hirundo*	✓			Ynys Feurig, Cemlyn Bay and The Skerries SPA The Dee Estuary SPA and SSSI The Skerries SSSI Ynys Feurig SSSI Cemlyn Bay SSSI Breeding seabird colony feature of: Shotton Lagoons and Reedbeds SSSI	Breeding	15,000 AON (GB and Irish)	674 AON (5%)	**Medium**	National
9. Common guillemot *Uria aalge*				Skokholm and Skomer SPA (assemblage) Seabird feature of: Carreg Y Llam SSSI	Breeding	1,559,500 individuals (GB and Irish)	57,961 individuals (4%)	**Low**	National

Species	*Annex I*	*Schedule 1*	*Section 42*	*SPA/ SSSI Qualifier*	*Season*	*Overall Population Estimate (UK/GB and Irish)*[15]	*Welsh Population Estimate (Welsh % of UK/GB and Irish population)*[16]	*Relative Population Abundance in Welsh Waters*[17]	*Importance*
				Castlemartin Cliffs and dunes SSSI Gower to Porteynon SSSI Great Ormes Head SSSI Skomer and Middleholm SSSI Skokholm SSSI. Breeding seabird colony feature of: Skomer and Middleholm SSSI Skokholm SSSI Stackpole SSSI Castlemartin Cliffs and dunes SSSI					
10. Northern Shoveler *Anas clypeata*				The Severn Estuary SPA (assemblage) Burry Inlet SPA	Winter	15,200 individuals (UK)	509 individuals in Severn Estuary and Burry Inlet (>3.3%)	Unknown	National

Species	*Annex I*	*Schedule 1*	*Section 42*	*SPA/ SSSI Qualifier*	*Season*	*Overall Population Estimate (UK/GB and Irish)*[15]	*Welsh Population Estimate (Welsh % of UK/GB and Irish population)*[16]	*Relative Population Abundance in Welsh Waters*[17]	*Importance*
				(assemblage) Malltraeth Marsh SSSI (breeding) Valley Lakes SSSI (wintering) Llyn Alaw SSSI (severe weather) Llyn Trafwll SSSI (severe weather)					
11. European Storm-petrel *Hydrobates pelagicus*	✓			Skokholm and Skomer SPA Skokholm SSSI Skomer Island and Middleholm SSSI	Breeding	82,820 AOS (GB and Irish)	2,805 AOS (3%)	Low	International
12. Arctic tern *Sterna paradisaea*	✓			Ynys Feurig, Cemlyn Bay and The Skerries SPA and SSSI	Breeding	56,000 AON (GB and Irish)	1,705 AON (3%)	Low	International

Species	Annex I	Schedule 1	Section 42	SPA/ SSSI Qualifier	Season	Overall Population Estimate (UK/GB and Irish)[15]	Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]	Relative Population Abundance in Welsh Waters[17]	Importance
13. European shag *Phalacrocorax aristotelis*				N/A	Breeding	32,500 AON (GB and Irish)	914 AON (3%)	Low	National
14. Sandwich tern *Sterna sandvicensis*	✓			Ynys Feurig, Cemlyn Bay and The Skerries SPA The Dee Estuary SPA and SSSI (passage) Cremlyn Bay SSSI	Breeding	14,500 AON (GB and Irish)	450 AON (3%)	Low	International
15. Little tern *Sternula albifrons*	✓	✓		Gronant Dunes and Talacre Warren SSSI	Breeding	2,000 AON (GB and Irish)	75 AON (3%)	Low	International
16. Atlantic puffin *Fratercula arctica*				Skokholm and Skomer SPA Gwylan Islands SSSI (feature) Skokholm SSSI Skomer Island and Middleholm SSSI	Breeding	600,750 AOB* (GB and Irish)	10,328 AOB (2%)	Low	International
17. Black-legged				Skokholm and Skomer	Breeding	415,995 AON	7,293	Low	International

Species	Annex I	Schedule 1	Section 42	SPA/ SSSI Qualifier	Season	Overall Population Estimate (UK/GB and Irish)[15]	Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]	Relative Population Abundance in Welsh Waters[17]	Importance
Kittiwake *Rissa tridactyla*				SPA (assemblage) Breeding feature of: Aberarth – Carreg Wylan SSSI Great Orme's Head SSSI		(GB and Irish)	(<2%)		
18. Black headed gull *Larus ridibundus*			✓	N/A	Breeding	141,890 AON (GB and Irish)	1,986 AON (1.4 %)	Low	National
					Winter	1,697,797 individuals	Unknown	Unknown	Unknown
19. Northern fulmar *Fulmarus glacialis*				Breeding seabird colony feature of: Stackpole SSSI Castlemartin Cliffs and Dunes SSSI Skomer and Skokholm SSSI Skomer and Skokholm SPA (assemblage)	Breeding	538,000 AOS (GB and Irish)	3,474 AOS (<1%)	Low	National
					Winter	1.7 million individuals (UK)	Unknown	Unknown	Unknown
20. Roseate tern *Sterna*		✓	✓	Ynys Feurig, Cemlyn Bay,	Breeding	790 AON	2 AON	Low	International

Species	Annex I	Schedule 1	Section 42	SPA/ SSSI Qualifier	Season	Overall Population Estimate (UK/GB and Irish)[15]	Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]	Relative Population Abundance in Welsh Waters[17]	Importance
dougallii				The Skerries SPA The Skerries SSSI Ynys Feurig SSSI		(GB and Irish)	(<1%)		
21. Black guillemot *Cepphus grylle*				Arfordir Gogleddol Penmon SSSI	Breeding	42,683 individuals (GB, Irish & Isle of Man)	28 individuals (<0.1%)	Low	National
22. Balearic shearwater *Puffinus mauretanicus*	✓		✓	N/A	Passage	1,200 individuals (UK)	Regular passage recorded through Welsh waters, minimal data	Unknown	International (IUCN Red-listed)
23. Greater scaup *Aythya marila*		✓		N/A	Winter	9,200 individuals (UK)	Concentrated on Dee Estuary on Welsh/English border	Unknown	National
24. Common eider *Somateria mollissima*				N/A	Breeding	31,800 pairs (GB and Irish)	Small numbers breed at Ynys Seiriol / Puffin Island (up to 30 pairs)	None	n/a
					Winter	80,000 individuals (UK)	Occurs along south Wales coast	Unknown	Unknown
25. Common goldeneye				N/A	Breeding	200 pairs	None	None	n/a

Species	*Annex I*	*Schedule 1*	*Section 42*	*SPA/ SSSI Qualifier*	*Season*	*Overall Population Estimate (UK/GB and Irish)*[15]	*Welsh Population Estimate (Welsh % of UK/GB and Irish population)*[16]	*Relative Population Abundance in Welsh Waters*[17]	*Importance*
Bucephala clangula						(UK)			
					Winter	35,000 individuals (UK)	Not available but widely distributed	Unknown	Unknown
26. Red-necked grebe *Podiceps grisegena*				N/A	Winter	200 individuals (UK)	Very low numbers	Unknown	Unknown
27. Slavonian grebe *Podiceps auritus*	✓	✓		N/A	Breeding	40 pairs (UK)	None	None	n/a
					Winter	775 individuals (UK)	Not available but occurs widely in low numbers. Lavan Sands in Wales is of UK importance	Unknown	International
28. Black-necked grebe *Podiceps nigricollis*				N/A	Breeding	50 pairs (UK)	None	None	n/a
					Winter	120 individuals (UK)	Not available but occurs in South Wales	Unknown	Unknown
29. Red-breasted				Lavan Sands SSSI	Breeding	2,550 pairs	Not available but widely	Unknown	Unknown

Species	Annex I	Schedule 1	Section 42	SPA/ SSSI Qualifier	Season	Overall Population Estimate (UK/GB and Irish)[15]	Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]	Relative Population Abundance in Welsh Waters[17]	Importance
merganser *Mergus serrator*				Traeth Lafan SSSI		(GB and Irish)	distributed along coast		
					Winter	10,500 individuals (UK)	Not available but widely distributed along coast. Lavan Sands in Wales is of UK importance	Unknown	National
30. Great northern diver *Gavia immer*	✓	✓		N/A	Winter	2,750 individuals (UK)	Not available but widespread along coast in low numbers	Unknown	International
31. Black-throated diver *Gavia arctica*	✓	✓		N/A	Breeding	175 pairs (GB and Irish)	None	None	n/a
					Winter	700 individuals (UK)	Occurs rarely in Welsh waters	Unknown	International
32. Red-throated diver *Gavia stellata*	✓	✓		Liverpool Bay SPA (wintering)	Breeding	1,200 pairs (GB and Irish)	None	None	n/a
					Winter	5,000 individuals (UK)	Not available but occurs widely around coast particularly north west Wales	Unknown	International
33. Little grebe				N/A	Breeding	13,800 pairs (GB)	Not available	Unknown	**n/a**

Species	Annex I	Schedule 1	Section 42	SPA/ SSSI Qualifier	Season	Overall Population Estimate (UK/GB and Irish)[15]	Welsh Population Estimate (Welsh % of UK/GB and Irish population)[16]	Relative Population Abundance in Welsh Waters[17]	Importance
Tachybaptus ruficollis									
34. Great crested grebe *Podiceps cristatus*				Lavan Sands and Conwy Bay SPA Wintering feature of: Traeth Lafan SPA and SSSI Dee Estuary SSSI	Breeding	12,150 pairs (GB and Irish)	*Not on coastal waters in breeding season*	None	n/a
					Winter	19,000 individuals (UK)	Widely distributed. Lavan Sands in Wales is of UK importance	Unknown	National
35. Sooty shearwater *Puffinus griseus*				N/A	*Passage only – minimal data available*			Unknown	Unknown

3.3 Species Sensitivity

3.3.1 There will likely be considerable overlap between the proposed location of MUREDs and seabird foraging areas. Locations suitable for tidal stream devices are also likely to be sites favoured by particular fish species, which in turn will attract seabird species which prey on those fish species. Diving birds are therefore potentially at risk from the processes described in Section 2.4. Species sensitivity will depend on:

- The extent of overlap between MUREDs and diving bird foraging areas on the surface;
- The extent of overlap between MUREDs and diving bird foraging areas below the surface;
- The foraging ecology of diving bird species at risk, including diving depth and swim speed;
- Diurnal routine of foraging;
- Seasonality of species presence; and
- The extent to which the species is attracted to the development, e.g. for perching/nesting/foraging (underwater structures may act as reefs, attracting prey species).

3.3.2 In assessing risk, the species accounts focus on the potential risk of collision or entrapment, which will be dependent on foraging ecology and the importance of population distributions at different times of year. There are, however, large knowledge gaps in the ecology of many of the species investigated in this report, specifically on diving depth, diurnal routines, underwater vision and the ecology of younger age classes.

3.3.3 Further work on species specific sensitivity has been conducted by the Wildfowl and Wetlands Trust (WWT, 2010). To estimate sensitivity scores, two life history traits were considered; adult survival and habitat flexibility. The results of this exercise were used to inform the species sensitivities reported here.

3.4 Species Accounts

3.4.1 This section describes diving bird foraging ecology relevant to risk from MUREDs. For ease of comparison, dive depths and durations, as well as swim speeds, have been rounded up to the nearest metre (m), second (s) and metres per second (ms^{-1}), respectively.

3.4.2 The following literature review sets out to be as thorough as possible in depth and breadth, drawing on any scenario considered relevant in assessing risk to diving birds from renewable devices. The review bears significant limitations, however. Data are patchy, with some species studied far better (e.g. gannet) than others (e.g. red-breasted merganser). The most accomplished divers (i.e. the auks, family: Alcidae) yielded far more dive data than surface feeding species (i.e. the terns, family: Sternidae). Only limited UK studies were available. Also the majority of data refer only to breeding adults on their breeding grounds during summer months. Thus data from closely related species are used where data on species of interest are lacking, and study sites across the world are included to substantiate UK studies. As complete a picture as possible is presented, albeit with knowledge gaps and a composite of data on species and location (see Appendix 2 for information sources).

3.4.3 This review is a necessary first step in appreciating the complexity of the issues involved in assessing any potential impacts on diving seabirds and their ecology. Accurate risk assessments require site-specific data on MURED technology and depth positioning, together with species abundance and ecology. Such well-linked data are not yet available and will be dependent on full-scale device testing and monitoring, which are largely still in progress for many projects. Properly conducted studies prior to consent, during construction and during operation using standardised methodologies are necessary to plug gaps in our knowledge of the effects of these devices.

1. Manx Shearwater *Puffinus puffinus*

Population and Distribution

3.4.4 The Manx shearwater breeding population of Great Britain and Ireland is approximately 332,500 pairs (Mitchell *et al*., 2004). The species breeds on a few islands off the west coast, in particular Skomer off Wales and Rum off Scotland. The Manx shearwater does not winter in UK waters, however during spring and autumn passage migrants disperse along much of the UK coast (Snow and Perrins, 1998).

Foraging Distance during Breeding Season

3.4.5 Manx shearwaters are principally offshore foragers. Between May and June foraging tends to be restricted to continental shelf areas west of Scotland and in the Celtic and Irish Seas, often around the main colonies of Skomer, Skokholm and Rum (Webb *et* *al*., 1990, Stone *et al*., 1995b). There is a seasonal trend, with Manx shearwaters recorded feeding in the central Irish Sea in April and May, whereas later in the season they tend to be concentrated in waters to the south and west of the Isle of Man, and particularly in the Celtic Sea in August (Stone *et al*., 1994). Overall, densities are generally greatest in waters less than 100m deep (Stone *et al*., 1995a).

3.4.6 In general, rafting birds most commonly forage within 15km of the breeding site; birds on feeding forays, however, may travel up to 100km (Ratcliffe *et al*., 2000). Surveys of Manx shearwater around Rum during chick-rearing (in August 1988) found the majority feeding within 50km of the breeding colonies (Harrison *et al*., 1994). Maximum foraging ranges from Skomer are much larger than this, being in excess of 400km (Guilford *et al*., 2008). The species will also gather in non-foraging flocks (Wilson *et al*., 2009).

Depth of Feeding

3.4.7 Manx shearwaters feed at the sea-surface, either making plunge dives from a height of 1-2m, or making shallow, wing-propelled dives to catch prey items.

3.4.8 Current research into the diving behaviour of Manx shearwater has not yet been published (Votier pers. comm.), but research on the closely-related wedge-tailed *Puffinus pacificus* and Audubon's shearwaters *P. iherminieri* revealed mean dive depths of 14m (maximum 66m), and 15m (maximum 35m) respectively (Burger, 2001). Keitt *et al*.'s (2000) study of black-vented shearwater *P. opisthomelas* recorded a slightly deeper mean dive depth of 21m (maximum 52m), whilst sooty shearwater *P. griseus* have been recorded diving to 67m (Weimerskirch and Sagar, 1996).

Dive Profile

3.4.9 The Manx shearwater forages by plunge diving (Martin and Brooke, 1991), generally during the day. The closely-related Audubon's shearwater has been recorded diving for up to 20s (Snow and Perrins, 1998).

Underwater Vision

3.4.10 Martin (1998) describes the anterior eye structure and retinal visual fields of two species from the same order (procellariiformes) as the manx shearwater, the grey-headed *Diomedea melanophris* and black-browed *Thalassarche melanophris* albatross. The study found the eyes to be of an 'amphibious optical design' suggesting albatross vision to be well-suited for the visual pursuit of active prey beneath the water. The corneas are relatively flat and hence of low refractive power. In the air the binocular fields are relatively long and narrow, upon immersion, however, they are abolished. In an earlier study, Martin and Brooke (1991) found the Manx shearwater to also have corneas of a low refractive power. It is probable, therefore, that many procellariids, including the Manx shearwater, have vision well-adapted to underwater foraging.

Prey-Species Preferences

3.4.11 Manx shearwater diet includes small squid, small fish such as herring, spratt and sardines, cephalopods, small crustaceans, and surface floating offal (Snow and Perrins, 1998).

2. Common Scoter *Melanitta nigra*

Population and Distribution

3.4.12 The common scoter breeding population of Great Britain is approximately 95 pairs (Baker *et al*., 2006), while the breeding population of Ireland is approximately 65 pairs (Snow and Perrins, 1998). The species breeds inland. The UK population increases during the winter to approximately 50,000 individuals (Baker *et al*., 2006), foraging off western Ireland and much of the British coast except for the west coast of Scotland and the Bristol Channel. Winter flocks of common scoter occur in Carmarthen and Cardigan Bays, along the Moray Firth and the north Norfolk coast (Holt *et al*., 2009).

Foraging Distance during Breeding Season

3.4.13 Common scoter breed inland and are therefore not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.14 The common scoter forages on the seabed within water depths of 3m – 20m (Kaiser *et al*., 2006).

Dive Profile

3.4.15 No information available.

Underwater Vision

3.4.16 No information available.

Prey-Species Preferences

3.4.17 The common scoter feeds mainly on molluscs, in particular bivalves (Kaiser *et al*., 2006).

3. Lesser Black-backed Gull *Larus fuscus*

Population and Distribution

3.4.18 The coastal-breeding lesser black-backed gull population of Great Britain and Ireland is approximately 91,323 AON with 20,682 AON in Wales (Mitchell *et al*., 2004). The species is a colonial nester, frequently occurring with other gull species. The colony at Skomer was formerly the largest in Britain and Ireland, but has been overtaken by those at South Walney (Cumbria) and Tarnbrook Fell (Lancashire). Once breeding is complete, the majority of birds migrate along the western seaboard of Europe to Iberia and North Africa, although increasing numbers are remaining within their breeding range throughout the year.

Foraging Distance during Breeding Season

3.4.19 Very little is known about the foraging behaviour of the species, and although more marine than the closely-related herring gull, quantitative data are limited (Kim and Monaghan, 2006). Ratcliffe *et al*. (2000) suggest that most foraging takes place within 15km.

Depth of Feeding

3.4.20 Methods of obtaining food include dipping-to-surface (contact type), surface-plunging, and shallow plunge-diving for up to two seconds (Snow and Perrins, 1998). Strann and Vader (1992) observed plunge-diving for sea urchins, blue mussels and other marine invertebrates in shallow water (less than about 1m deep).

Underwater Vision

3.4.21 Håstad *et al*. (2005) found evidence of extended ultraviolet vision in gulls (Laridae), which may have an adaptive value, such as improved foraging efficiency in dip or plunge diving, as fish can possess ultraviolet markings during courtship. The authors did however conclude that it is more probable that this trait is associated with their terrestrial foraging habits rather than piscivory.

Prey-Species Preferences

3.4.22 Black-headed gulls are omnivorous and much food is taken from scavenging (e.g. food waste from boats) or kleptoparasitism (stealing food caught/killed by another animal). Evidence has shown that fish, marine crustaceans and marine molluscs make up the majority of prey items.

4. Northern Gannet *Morus bassanus*

Population and Distribution

3.4.23 The northern gannet breeding population of Great Britain and Ireland is approximately 259,500 pairs (Mitchell *et al*., 2004). The species breeds in large colonies, in particular Ailsa Craig (southwest Scotland), Hermaness (Shetland), Bass Rock (Firth of Forth), St. Kilda (off northwest Scotland) and Grassholm (Wales) (Mitchell *et al*., 2004). The majority of the northern gannet population does not winter in UK waters; however, birds can occur in the vicinity of colonies and along coasts throughout the year.

Foraging Distance during Breeding Season

3.4.24 The northern gannet is a pelagic feeder during the breeding season, commonly foraging within 100km of the breeding site (Tasker *et al*., 1985c, Ratcliffe *et al*., 2000). Maximum foraging distances have been estimated at 900km for birds breeding on Grassholm, Pembrokeshire (Votier *et al*., unpublished); and 128km for Shetland-breeding birds, with the majority foraging within 37km (Garthe *et al*., 1999). Gannets from the Bass Rock, Firth of Forth are frequently recorded feeding at the Wee Bankie (approximately 33km away) or off Fife Ness around 20km away (Wanless *et al*., 1998). The maximum recorded foraging distance from the Bass Rock was 540km (Hamer *et al*., 2000). Satellite-tracked gannets from Great Saltee (Co. Wexford, Ireland) tend to forage within 100km of the coast (Hamer *et al*., 2000).

Depth of Feeding

3.4.25 Northern gannet dive records range from a mean depth of 5m (maximum 22m) (Garthe *et al*., 2000) to 20m (maximum 34m) (Brierley and Fernandes, 2001). Dive depths tend to be deeper around midday and shallower around dawn and dusk (Garthe *et al*., 1999; Lewis *et al*., 2002). This is likely due to changes in light penetration into the water column through the diel cycle, i.e. low light penetration at dawn and dusk may force gannets to dive at shallower depths during these periods.

Dive Profile

3.4.26 Northern gannets are plunge divers, entering the water at considerable speeds. They are also wing-propelled divers underwater. Garthe *et al*. (1999) documented dive durations of 1–8s off Shetland while Garthe *et al*. (2000) found dive durations of 8–38s in the vicinity of Shetland/Orkney.

3.4.27 Garthe *et al*. (2000) documented the northern gannet in the vicinity of Shetland/Orkney performing extended, deep, U-shaped dives as well as rapid, shallow, V-shaped dives. Short, shallow dives were usually V-shaped, whilst dives deeper than 8m and longer than 10s were usually U-shaped, including a period at constant depth. The authors hypothesised that the extended, deep, U-shaped dives were directed at schools of capelin *Mallotus villosus* and the rapid, shallow, V-shaped dives were directed at larger pelagic fish and squid. Moreover, these V-shaped dives allowed the birds to surprise their pelagic prey which may be critical if the maximum swim speed of the prey species exceeds the maximum dive speed of the birds. Brierley and Fernandes (2001) suggest that the northern gannet can swim beyond the initial plunge dive to retrieve prey.

Underwater Vision

3.4.28 No information available.

Prey-Species Preferences

3.4.29 The northern gannet forages primarily on lipid-rich pelagic fish up to 30cm in length such as mackerel, herring and sandeel (Hamer *et al*., 2000; Snow and Perrins, 1998), but also forages extensively for fishery discards (Votier *et al*., unpublished).

5. Great Cormorant *Phalacrocorax carbo*

Population and Distribution

3.4.30 The great cormorant breeding population of Great Britain and Ireland is approximately 13,500 pairs (Mitchell *et al*., 2004). The UK winter population is estimated at 24,200 individuals (Baker *et al*., 2006). The species mainly occurs in rocky coastal areas, lagoons and estuaries, with foraging divided between freshwater and marine habitats. Two subspecies occur in the UK, the endemic *P.c. carbo* and continental *P.c. sinensis*. *P.c. sinensis* is increasing in the UK and tends to breed predominantly inland, whereas *P.c. carbo* is mostly coastal (Mitchell *et al*., 2006). *P.c. carbo* will also exploit inland lakes and fish farms. Both subspecies probably have a largely coastal distribution in the winter.

Foraging Distance during Breeding Season

3.4.31 Great cormorants typically forage inshore within 15km of the breeding site (Ratcliffe *et al*., 2000). Grémillet (1997) studied 89 foraging trips of eight pairs of cormorants at the Chausey Islands in France. The maximum feeding range recorded was 35km from the colony, but these represented less than 5% of the total. The majority (c65%) of the trips were within 5km of the colony, and a further 20% were within 10km.

Depth of Feeding

3.4.32 The great cormorant has been recorded diving to a mean depth of 6m (maximum 32m) (Grémillet *et al*., 1999).

Dive Profile

3.4.33 The great cormorant is a foot-propelled diver. In a study by Grémillet *et al*. (1999) at the Chausey Islands in France, birds dived for a mean duration of 40s (maximum 152s).

Underwater Vision

3.4.34 Research by White *et al*. (2007) concluded that the great cormorant does not have any special adaptation to underwater vision; rather, visual acuity underwater is as poor as that of humans. White *et al*. (2007) go on to suggest that cormorants use a flush-foraging or ‘heron’ strategy rather than a pursuit-foraging or ‘hawk’ strategy. The authors predict that cormorants detect prey only at short range then catch it with a rapid lunge. Although visual acuity is poor, the great cormorant’s eyes can move independently of one another to scan for escaping prey; binocular vision then permits accurate lunging. Once a prey item is caught, the great cormorant returns to the surface where the eyes can be swung forward and down to examine the prey before it is ingested.

Prey-Species Preferences

3.4.35 Cormorants feed on a wide variety of benthic and demersal prey fish, with diet varying greatly among colonies, probably as a result of differences in bottom substrate causing different availabilities of prey within their foraging ranges (Ratcliffe *et al*., 2000). The prey that predominate in most studies are flatfish, blennies, sea-scorpions and gadoids, with sandeels, salmonids, labrids and eels being important at some colonies (Ratcliffe *et al*., 2000).

6. Herring Gull *Larus argentatus*

Population and Distribution

3.4.36 The coastal-breeding herring gull population of Great Britain and Ireland is approximately 140,994 AON with 13,930 AON in Wales (Mitchell *et al*., 2004). Largest concentrations are in northern and western Scotland and northwest England, with breeding occurring in particular along rocky coastlines, although increasingly buildings in urban areas are used. Caldey Island in Dyfed is the largest colony in Wales, holding 2,134 AON. The breeding population in Britain is largely resident with movements being limited within that region or to neighbouring coastal counties.

Foraging Distance during Breeding Season

3.4.37 Ewins *et al*. (1994) concluded that the optimal foraging range for the herring gull was less than 40km from its breeding range.

Depth of Feeding

3.4.38 The herring gull uses various methods of feeding: (i) dipping-to-surface to take items on or just below surface; (ii) surface- (or sometimes shallow-) plunging, from 5–6m; (iii) surface-seizing, on occasion immersing head and front part of body; and (iv) shallow surface-diving (Snow and Perrins, 1998).

Underwater Vision

3.4.39 Håstad *et al*. (2005) found evidence of extended ultraviolet vision in gulls (Laridae), which may have an adaptive value, such as improved foraging efficiency in dip or plunge diving as fish can possess ultraviolet markings during courtship. The authors did however conclude that it is more probable that this trait is associated with their terrestrial foraging habits rather than piscivory.

Prey-Species Preferences

3.4.40 The herring gull is an opportunist, being a predator, scavenger, and food-pirate, taking a wide range of prey items. It mainly feeds in the littoral and shallow sub-littoral zones, although commonly takes foodstuffs indirectly available from man.

7. Razorbill *Alca torda*

Population and Distribution

3.4.41 The razorbill breeding population of Great Britain and Ireland is approximately 216,000 individuals (Mitchell *et al*., 2004). The species mainly breeds in large colonies off northern Scotland and to a lesser extent in Wales, southwest England, northeast England and much of Ireland. Razorbill disperse during winter although remain close to the coast in large numbers.

Foraging Distance during Breeding Season

3.4.42 During surveys around the Pembrokeshire Islands in 1990, razorbills were seen up to 25km from the colonies with the highest mean density within 5km, whereas in 1992 they were found up to 45km away (albeit in low numbers beyond 25km) with the highest densities within 10km (Stone *et al*., 1992).

3.4.43 Elsewhere, transect counts around the Isle of May found the highest concentrations of razorbills within 5km of the colony, but aggregations were also located 35km away over the Wee Bankie (Wanless *et al*., 1998). Tasker *et al*. (1987) found the highest densities were seen just 1km from Isle of May. The majority of razorbills breeding at St Kilda forage within 5km of the islands, with foraging also taking place at the Whale Rock Bank 38km away (Leaper *et al*., 1988). Benn *et al*. (1987) suggested a maximum feeding range from North Rona of 15km. Webb *et al*. (1985) recorded maximum densities of razorbills 26-28km away from the colony at Flamborough Head in June 1984, although large numbers during transect counts were also seen from the coast within 1km from the colony. Lloyd (1976; 1982) estimated that the maximum foraging ranges from Skokholm and Great Saltee, Ireland were 13km and 20km respectively.

3.4.44 Razorbills therefore forage in highest densities with 10km of breeding colonies, with the majority of foraging occurring within 40km (Ratcliffe *et al*., 2000).

Depth of Feeding

3.4.45 Razorbills off Scotland have been reported to favour shallow water areas for diving (Wanless *et al*., 1990). Breeding razorbills off Norway were recorded diving to a median depth of 25m–30m (Barrett and Furness, 1990). Similarly, chick-rearing razorbills off Iceland were observed foraging at depths rarely greater than 35m (maximum 41m) (Dall'Antonia *et al*., 2001).

3.4.46 An in-depth study of chick-rearing razorbills in the Baltic Sea (Benvenuti *et al*., 2001) found more than 50% of dive depths to be less than 15m, the most frequent depth interval to be 5m–10m, and dives rarely to exceed 40m (maximum 43m). In addition, 'nocturnal dives' after sunset and before sunrise were shallower (<20m), and those around midday were deeper, presumably due to the upward migration of prey during night-time hours (Benvenuti *et al*., 2001).

3.4.47 Documented incidental catches of razorbills in stationary gill nets on the sea floor off Newfoundland reveal the species to be capable of diving to at least 120m (Piatt and Nettleship, 1985). The species is unlikely, however, to dive much beyond this range due to diving capability being a function of body mass with a significant positive correlation noted by the authors (Piatt and Nettleship, 1985).

Dive Profile

3.4.48 The razorbill is a wing-propelled diver. Birds often forage in loose flocks and dive from the surface, often dipping the head into the water several times first (Snow and Perrins, 1998).

3.4.49 Benvenuti *et al*.'s (2001) study of chick-rearing razorbills in the Baltic Sea revealed V-shaped dives and peak diving activity around sunset and sunrise, with a sharp decline in activity between 2200hrs – 0200hrs and no activity around midnight. In contrast, the Dall'Antonia *et al*. (2001) study of chick-rearing razorbills off Iceland noted a higher frequency of (shallower) dives around midnight, but still with a V-shaped dive profile. The oblique descent and ascent of the species was also noted by Watanuki *et al*. (2006).

3.4.50 Additionally, Paredes *et al*. (2008) report on breeding razorbill off Labrador, where females executed shallower (<10m), crepuscular, W-shaped dives compared with males' deeper, diurnal, more U-shaped dives. This is likely due to differences in parental roles driving nocturnal behaviour in females, which likely prey on crustaceans during twilight, and diurnal behaviour males, which likely prey on mid-water fish during daylight.

Underwater Vision

3.4.51 No information available.

Prey-Species Preferences

3.4.52 Razorbills have a diet chiefly consisting of fish with some invertebrates (Snow and Perrins, 1998). Studies on the Isle of May showed that sandeels are the main prey fed to razorbill chicks (Harris and Wanless, 1986).

8. Common Tern *Sterna hirundo*

Population and Distribution

3.4.53 The common tern breeding population of Great Britain and Ireland is approximately 15,000 pairs (Mitchell *et al*., 2004). The species mainly breeds along coasts with shingle beaches and rocky islands, as well as inland near freshwater. Birds occur along much of the coast except southwest Scotland, southwest England and south Wales. The common tern does not winter in UK waters.

Foraging Distance during Breeding Season

3.4.54 The common tern most frequently forages within 20km – 30km of breeding site (Ratcliffe *et al*., 2000). Transects around the Isle of May found that common terns were mostly found within 10km of the colony (Wanless *et al*., 1998). Newton and Crowe (1999) found that common terns were found primarily within 10km of Rockabill, Ireland. A study cited in Cramp and Simmons (1985) found that the maximum foraging distance for common terns was 37km.

Depth of Feeding

3.4.55 There are no specific data available for common tern, but all terns plunge dive to a maximum depth of approximately 1m (Steve Votier pers. comm.).

Dive Profile

3.4.56 The common tern feeds by direct plunge-diving from the air, often preceded by hovering (Snow and Perrins, 1998).

Underwater Vision

3.4.57 No information available.

Prey-Species Preferences

3.4.58 The common tern forages chiefly on marine fish and crustaceans. It is an opportunist feeder, switching rapidly between prey types and feeding methods as circumstances change (Snow and Perrins, 1998).

9. Common Guillemot *Uria aalge*

Population and Distribution

3.4.59 The common guillemot breeding population of Great Britain and Ireland is approximately 1,559,500 individuals (Mitchell *et al*., 2004). The species breeds on cliffs, mainly in Scotland and Ireland, but also more locally in northern England, Wales and southwest England. The largest colonies within GB and Ireland are at Handa (Sutherland), Raithlin Island (Co. Antrim), Berriedale (Caithness) and Lambay Island (Co. Dublin). In Wales there are numerous colonies along the coast, with the largest colony on Skomer Island (Dyfed) (Mitchell *et al*., 2004). During winter the common guillemot is widespread offshore, chiefly over continental shelves and avoiding deep oceanic water (Snow and Perrins, 1998). Once fledged, juveniles remain pelagic for two years (Snow and Perrins, 1998).

Foraging Distance during Breeding Season

3.4.60 During a study off Skomer, Skokholm and Ramsey in June 1992 (i.e. during chick-rearing), guillemots were found as far as 55km from the colonies in the early morning, but after this time all were recorded within 30km of the colonies, with maximum densities in the 15-20km zone (Stone *et al*., 1993). In June 1990, the highest densities were recorded 40-45km from the same colonies in the morning, but no areas beyond this were surveyed so some birds may have been foraging further afield (Stone *et al*., 1992). Birkhead (1976) found that guillemots foraged to at least 10km from Skomer, and Lloyd (1982) estimated a feeding range of 20km from Great Saltee in Ireland.

3.4.61 In a study of guillemots breeding on the Isle of May during incubation in 1986, radio-tracking showed 9% of foraging trips were within 2km, 18% were between 2-7km and 73% were more than 7km (out of range) (Wanless *et al*., 1990). During chick-rearing 21% of trips were within 0-2km of the colony, 9% between 2-7km and 70% to 7km or further (Wanless *et al*., 1990). In the following year during chick-rearing 34% of trips were within 0.2km, 34% between 2-10km and only 31% beyond 10km. This suggests that the foraging range of guillemots varies among seasons and years. Those travelling out of range were likely to be foraging at offshore sandbanks. Transect counts around the Isle of May found that large numbers of birds fed on the Wee Bankie 40km away and the Marr Bank over 60km away (Wanless *et al*., 1998). Similarly Tasker *et al*. (1987) recorded two important feeding areas (Bell Rock and the Wee Bankie) within 25-30km of the Isle of May, but also noted that many guillemots foraged within 3km of the colony.

3.4.62 Similar studies of radio-tagged guillemots breeding at Sumburgh Head found they fed at sites on average 7.1km away (range 3.4-9.4km) in 1990, and on average 1.2km from the colony (range 0.1-4.8km) in 1991 (Monaghan *et al*., 1994). During the following two seasons, 1992 and 1993, radio-tracked birds foraged at mean distances of c. 1km and c. 2.5km, respectively (Monaghan *et al*., unpubl., in Ratcliffe *et al*., 2000). Wright and

Bailey (1993) found concentrations of guillemots from this colony over sandbanks within 5km of the colonies.

3.4.63 Dye-marked birds at Fair Isle were sighted feeding within 6-8km of the colony (Bradstreet and Brown, 1985). Surveys around Fair Isle in June 1980 and 1981 also found most foraging occurring within 6km of the colony (Langslow *et al*. cited in Webb *et al*., 1985).

3.4.64 In the Moray Firth in June 1982 and 1983, large concentrations of birds were seen feeding at an offshore bank 20-25km from Caithness colonies (Mudge and Crooke, 1986). Benn *et al*. (1987) found that most feeding took place within 5km of North Rona and Sula Sgeir, with adults travelling to a maximum of 15km. Large numbers of guillemots from St. Kilda were recorded feeding at a bank c. 40km away (Leaper *et al*., 1988). Almost all birds from Flamborough Head seen in June 1984 were feeding within 30km of the colony, but with some recorded up to 40km away (Webb *et al*., 1985).

3.4.65 The common guillemot therefore usually forages within 40km of the breeding site but with variations between sites and seasons.

Depth of Feeding

3.4.66 In a study of chick-rearing common guillemot off Norway (Tremblay *et al*., 2003), mean dive depth was found to be 10m, with 50% of dives less than 6m and 90% less than 22m. Tremblay *et al*. (2003) also recorded a maximum dive depth of 37m. Barrett and Furness (1990) however, report on breeding birds off Norway diving to 50m, and Daunt *et al*. (2003) observed a similar maximum depth of 53m for birds off Scotland. However, dives of less than 50m depth are probably typical (Bradstreet and Brown, 1985).

3.4.67 In contrast, Burger and Simpson (1986) found chick-rearing common guillemot off Newfoundland diving as deep as 138m. Also off Newfoundland, Piatt and Nettleship (1985) report on incidental catches of common guillemot in stationary gill nets on the sea floor, most (80%) birds were caught in nets <50m, however some were caught at 180m – the deepest that nets were set in the area. The species is unlikely, however, to dive much beyond this range due to diving capability being a function of body mass with a significance positive correlation noted by the authors (Piatt and Nettleship, 1985).

Dive Profile

3.4.68 The common guillemot is a wing-propelled diver. The Tremblay *et al*. (2003) study of chick-rearing common guillemot off Norway describes the species' dive profile as being U-shaped, with a mean bottom dive duration (during which the birds presumably feed) of 19s and an overall mean dive duration of 39s (maximum 119s). The study also observed the species' preference for diving during the flood, rather than the ebb tide.

3.4.69 The common guillemot often dips its head repeatedly into the water before diving. Birds also often feed swimming in lines, occasionally encircling and herding a shoal and catching fish at the periphery (Snow and Perrins, 1998).

Underwater Vision

3.4.70 No information available.

Prey-Species Preferences

3.4.71 The main prey of guillemots is sandeel and clupeids, with small gadoids also important at some colonies (Cramp and Simmons, 1985). Guillemots at Skomer, Wales in 1985-1987 feed chicks mainly with sprat (69%) and sandeel (21%) (Hatchwell, 1991).

10. Northern Shoveler *Anas clypeata*

Population and Distribution

3.4.72 Around 1,000-1,500 pairs breed in the UK, although in winter, numbers swell to 15,200 individuals (Baker *et al*., 2006). In southwest England/Wales, populations are more localised as suitable habitat is less widespread. Combined, the two closest SPAs where shoveler is a qualifying species (Severn Estuary and Burry Inlet) hold 509 individuals, or 3.3% of the UK population.

Depth of Feeding

3.4.73 Shovelers can collect food by (i) surface-feeding; (ii) swimming with head and neck immersed; (iii) up-ending; and (iv) diving, possibly more often than other *Anas*, but still not frequently. It dives with no forward leap, using wings underwater, in depths up to 80cm, and rarely for more than 5s (Snow and Perrins, 1998).

Foraging Distance during Breeding Season

3.4.74 In Britain, the shoveler's breeding strongholds are the Norfolk Broads, Kent Marshes and East Anglian Fens. They are generally terrestrial, inhabiting freshwater wetlands.

Underwater Vision

3.4.75 No information available, although the species is known to feed at night.

Prey-Species Preferences

3.4.76 The shoveler is omnivorous, but feeds particularly on planktonic crustaceans, small molluscs, insects and larvae, seeds, and plant debris.

11. European Storm-petrel *Hydrobates pelagicus*

Population and Distribution

3.4.77 The European storm-petrel breeding population is estimated at approximately 83,000 pairs in Great Britain and Ireland with approximately 2,800 pairs (in six colonies) in Wales (Mitchell *et al*., 2004). The species breeds on remote, often inaccessible islands, and is predominantly nocturnal around their breeding colonies. The largest colonies are in northern Scotland (such as Mousa, Shetland) and along the west coast of Ireland (such as Inishtooskert, Kerry). The largest colony in Wales is on Skokholm (Dyfed) with 2,450 pairs (Mitchell *et al*., 2004). European storm-petrels do not winter in UK waters, being completely pelagic outwith the breeding season, wintering off the coasts of western and southern Africa.

Foraging Distance during Breeding Season

3.4.78 The European storm-petrel is a pelagic feeder at all times of the year, using the shallow waters over the continental shelf as well as the deep water areas beyond, all along the north and west coasts of Britain and Ireland (Pollock *et al*., 2000a; 2000b). In general, European storm-petrels occur mostly in offshore waters >50m deep with the highest densities over >1000m depths (Stone *et al*., 1995a).

3.4.79 A study of European storm-petrels off St. Kilda found highest densities >50km from the colony in the vicinity of the edge of the continental shelf (Leaper *et al*., 1988). Foraging distances during the breeding season will depend on the distance to the continental shelf from the colony, but will regularly be >100km (Ratcliffe *et al*., 2000).

Depth of Feeding

3.4.80 European storm-petrel feed by gleaning on the surface but have also been recorded diving below the surface (Griffiths, 1981; Jensen, 1993, cited in Mitchell *et al*. 2004; Cramp and Simmons 1977). The depth of dive is likely to be only just below the surface.

Underwater Vision

3.4.81 No information available.

Prey-Species Preferences

3.4.82 The European storm-petrel forages mainly on planktonic crustacea, small planktonic fish (herring and sprat), medusae, cephalopods, and oil from fish offal (Cramp and Simmons, 1977). It also occasionally associates with fishing vessels, scavenging discards and offal, and forage in wakes of ships (Pollock *et al*., 2000a; 2000b). European storm-petrels are rarely seen feeding close inshore during the day (though it has been witnessed). Recent evidence shows they move inshore at night in order to feed on intertidal benthic crustaceans *Eurydice* spp. that migrate into the water column during nocturnal high tides (D'Elbee and Hemery, 1997). *Eurydice* spp. were found to compromise 37% of the diet of European storm-petrels breeding on two French Islands in the Bay of Biscay (D'Elbee and Hemery, 1997). This study suggests that this ability to exploit an inshore food source at night enables the species to evade avian predators which are concentrated near the coast during the day.

12. Arctic Tern *Sterna paradisaea*

Population and Distribution

3.4.83 The Arctic tern breeding population of Great Britain and Ireland is approximately 56,000 pairs (Mitchell *et al*., 2004). The species mainly breeds off Scotland, Ireland, northeastern England and north Wales, with colonies on the Farne Islands (Northumberland) and the northern isles being of particular importance. The Arctic tern does not winter in UK waters (Snow and Perrins, 1998).

Foraging Distance during Breeding Season

3.4.84 In general most observed feeding apparently takes place within 3km of the colony (Cramp and Simmons 1985). Pearson (1968) estimated that Arctic terns breeding on the Farne Islands could forage at a maximum distance of c. 20km based on a mean trip length of 50.2 mins during chick-rearing and a flight speed of $48kmh^{-1}$. The median duration of foraging trips during chick-rearing on Mousa in 1988 was 16 mins, and on Papa Westray it was 19 mins (Monaghan *et al*., 1992). These birds could not be travelling further than 15km according to the flight-speed and assumptions used by Pearson (1968) (Ratcliffe *et al*., 2000). The majority of foraging from Shetland colonies is within 10km (Wright and Bailey, 1993). The Arctic tern therefore most commonly forages within 10-15km of the breeding site, and has been recorded travelling up to 20-30km (Ratcliffe *et al*., 2000).

Depth of Feeding

3.4.85 Immersion during dives is normally just complete, i.e. less than 20cm, but will be only partial if prey visibility is restricted to the surface (Snow and Perrins, 1998).

Dive Profile

3.4.86 Arctic terns are mainly plunge divers (often preceded by hovering), but they also surface dip for floating prey or hawk for insects (Kirkham and Nisbet 1987).

Underwater Vision

3.4.87 No information available.

Prey-Species Preferences

3.4.88 The Arctic tern forages mainly on marine fish and crustaceans (Snow and Perrins, 1998). During a study at the Skerries, Anglesey during 1997-1999, Arctic terns fed almost exclusively on sandeels in both the courtship and chick-rearing periods, whereas those at nearby Ynys Feruig took a larger proportion of clupeids (Newton and Crowe, 1999).

13. European Shag *Phalacrocorax aristotelis*

Population and Distribution

3.4.89 The European shag breeding population of Great Britain and Ireland is approximately 32,500 pairs (Mitchell *et al*., 2004). The species mainly breeds in large colonies on Orkney, Shetland, the Inner Hebrides and the Firth of Forth and, to a lesser extent, along the coasts of Wales and southwest England, in particular Cornwall and Devon. Unlike the great cormorant, the European shag is exclusively marine.

Foraging Distance during Breeding Season

3.4.90 Radio-tagged European shags at the Isle of May (12 adults in 1987 and 7 adults in 1988) had a weighted mean foraging radius of 7km. The frequency distribution of foraging radius was, however, bimodal with most either within 2km or between 5 and 12km (Wanless *et al*., 1991b). Over 90% of foraging occurred within 13km of the colony and the maximum distance recorded was 17km (only twice).

3.4.91 Counts of European shag densities at Sumburgh Head, Shetland found consistently high densities over sandbanks within 5km of the colony (Wright and Bailey, 1993). The more distant of the two banks was only used in years when sandeel availability was low (Wright and Bailey, 1993). The small number of European shags breeding at St Kilda all appeared to forage within 2km (Leaper *et al*., 1988). Similarly, Benn *et al*. (1987) found European shags present only within 3km of North Rona and not further afield. Elkins and Williams (1974) noted that shags foraged no further than 8km from an Aberdeenshire colony during the breeding season.

3.4.92 European shags therefore most commonly forage within 5-10km of the breeding site, with the majority within 15km (Ratcliffe *et al*., 2000).

Depth of Feeding

3.4.93 Wanless *et al*. (1991b) recorded European shag off Scotland diving to mean depths of 33 to 35m (maximum 43m). Birds dived repeatedly to the same depth and spent 55% of time between 25 to 34m suggesting they were foraging close to the seabed. Daunt *et al*. (2003) observed similar results, also off Scotland, recording a maximum dive depth of 26m. In another study, Watanuki *et al*. (2005) recorded birds off Scotland diving between 10 to 43m, with dive durations of up to 97s.

Dive Profile

3.4.94 The European shag is a foot-propelled diver. Grémillet *et al*. (1998), in studying the diving behaviour of birds along the coast of France, found the species to forage in the pelagic and benthic zones. The proportions of benthic to pelagic dives varied widely between dive sequences and between individual birds, suggesting the European shag is able to exploit a wide variety of prey in varying habitats and at varying depths in the water column.

3.4.95 Wanless *et al*. (1991) found the species to forage most frequently in water of 21m – 40m depth, a substrate of gravel, sand, or rock with a patchy sediment cover. During a dive, European shag descend and ascend almost vertically relative to the sea surface.

Underwater Vision

3.4.96 No information available.

Prey Species Preferences

3.4.97 The European shag is a highly flexible forager capable of adjusting its dive pattern to accommodate the behaviour of locally-available prey. It tends to feed on benthic prey to a lesser degree than cormorants (Grémillet *et al*., 1998). Sandeels were the most important component of the diet in a review of studies in Britain (Ratcliffe *et al*., 2000).

14. Sandwich Tern *Sterna sandvicensis*

Population and Distribution

3.4.98 The Sandwich tern breeding population of Great Britain and Ireland is approximately 14,500 pairs (Mitchell *et al*., 2004). The species breeds in scattered colonies, mainly on the south and east coasts of England, north Wales, southwest Scotland and much of Ireland; colonies in Norfolk, Suffolk and Kent are of particular importance. The Sandwich tern occasionally winters in UK waters but only in very small numbers.

Foraging Distance during Breeding Season

3.4.99 The Sandwich tern most commonly forages within a few km of the breeding site, with maximum distances generally between 20 and 30km (Ratcliffe *et al*., 2000). The maximum recorded foraging distance is 67km from a colony in Scotland (Cramp and Simmons, 1985).

Depth of Feeding

3.4.100 Sandwich terns feed mainly on fish caught near the surface by plunge-diving (Cramp and Simmons, 1985). There are no specific data available for Sandwich tern, but all terns plunge dive to a maximum depth of approximately 1m (Steve Votier pers. comm.).

Dive Profile

3.4.101 The Sandwich tern hunts by plunge-diving. Dives are usually vertical, sometimes angled, and often preceded by hovering (Snow and Perrins, 1998).

Underwater Vision

3.4.102 No information available.

Prey-Species Preferences

3.4.103 The Sandwich tern chiefly preys on surface-dwelling marine fish, generally sandeels and clupeids (Cramp and Simmons, 1985).

15. Little Tern *Sternula albifrons*

Population and Distribution

3.4.104 The little tern breeding population of Great Britain and Ireland is approximately 2,000 pairs (Mitchell *et al*., 2004). The species breeds in scattered colonies, mainly on the east and south coasts of Scotland and England; colonies in Norfolk, Suffolk and Hampshire are of particular importance. The little tern does not winter in UK waters.

Foraging Distance during Breeding Season

3.4.105 Studies of little tern have found they most commonly forage within 5km of the breeding site: in Norfolk foraging occurred within 4.6km of the nest (Perrow *et al*., 2006); in the Ebro Delta in Spain, 96% of foraging activity occurred within 4km of breeding colonies (Bertolero *et al*., 2005); at Gibraltar Point, Lincolnshire, foraging was rarely >1km from the breeding colony (Davies, 1981); at a lagoon in northeast Italy 90% of foraging was within 3km and the maximum distance travelled was 6km (Fasola and Bogliani, 1990); and at a colony in Georgia the maximum feeding range was c. 4.8km (Tomkins, 1959).

Depth of Feeding

3.4.106 Little terns feed by plunge diving from a hover (Cramp and Simmons, 1985). They usually fish in very shallow water only a few cms deep often over the advancing tideline (Davies, 1981) or in brackish lagoons and saltmarsh creeks (Cramp and Simmons, 1985). There are no specific data available for little tern, but all terns plunge dive to a maximum depth of approximately 1m (Steve Votier pers. comm.).

Dive Profile

3.4.107 The little tern enters the water with a fast vertical, or near vertical, plunge-dive with partial or complete immersion (Snow and Perrins, 1998).

Underwater Vision

3.4.108 No information available.

Prey-Species Preferences

3.4.109 The little tern forages on small fish, including sandeels, and invertebrates, especially crustaceans and insects (Cramp and Simmons, 1985).

16. Atlantic Puffin *Fratercula arctica*

Population and Distribution

3.4.110 The Atlantic puffin breeding population of Great Britain and Ireland is approximately 600,750 pairs (Mitchell *et al*., 2004). The species breeds in large colonies, in particular St. Kilda (off northwest Scotland), Bempton Cliffs (Yorkshire), the Farne Islands (Northumberland), the Isle of May (Fife) and Shetland and Orkney. Around the Welsh coast the most notable colonies are on Skomer and Skokholm, Pembrokeshire, Puffin Island, Anglesey, and Lundy in the Bristol Channel. Birds are pelagic during winter months and rarely occur in coastal areas. Once fledged, juveniles remain pelagic for two years (Snow and Perrins, 1998).

Foraging Distance during Breeding Season

3.4.111 The Atlantic puffin most commonly forages within 40km of the breeding site (Ratcliffe *et al*., 2000). Atlantic puffins were found within 35-40km of Skomer and Skokholm in June 1990 and 1992, with most birds seen after 0930hrs within 10km of the colonies (Stone *et al*., 1992; 1993). Of 14 foraging trips made by a tagged Atlantic puffin breeding at the Isle of May, 9 (64%) were within 2km, 1 (7%) between 2-10km, and 4 (29%) more than 10km (Wanless *et al*., 1990). This is supported by transects around the Isle of May, which most frequently found Atlantic puffins close to the colony but that some association occurred with the Wee Bankie 40km away. The maximum distance from St. Kilda at which an Atlantic puffin with a fish was seen flying towards the colony was 40km, with many others seen feeding in the same area (Leaper *et al*., 1988).

Depth of Feeding

3.4.112 Atlantic puffins are capable of diving to 60m, although they usually forage at depths less than 30m (Piatt and Nettleship, 1985, Burger and Simpson, 1986). Breeding Atlantic puffins off Norway were recorded diving to median depths of 25m – 30m (Barrett and Furness, 1990). Piatt and Nettleship (1985) report on incidental catches of Atlantic puffin in stationary gill nets on the sea floor; birds were regularly caught in nets at 0–40m, but never in nets set deeper than 60m. On the contrary, Burger and Simpson (1986) who also report on chick-rearing Atlantic puffins off Newfoundland, found the birds to frequently forage within 60m depth (maximum 68m). Atlantic puffin are unlikely to dive much beyond this range due to diving capability being a function of body mass, with a significant positive correlation noted by the authors (Piatt and Nettleship, 1985).

Dive Profile

3.4.113 The Atlantic puffin is a wing-propelled diver (Snow and Perrins, 1998).

Underwater Vision

3.4.114 No information available.

Prey-Species Preferences

3.4.115 Atlantic puffins chiefly eat marine fish such as sandeels, sprats and other small species (Ratcliffe *et al.*, 2000). During winter, the Atlantic puffin is pelagic and forages far from the coast (Snow and Perrins, 1998).

17. Black-legged Kittiwake *Rissa tridactyla*

Population and Distribution

3.4.116 The black-legged kittiwake breeding population of Great Britain and Ireland is approximately 416,000 pairs with approximately 7,300 pairs in Wales (Mitchell *et al*., 2004). The species breeds in large colonies, in particular Bempton Cliffs and Flamborough Head (Yorkshire), West Westray (Orkney), Fowlsheugh (Grampian), St. Abbs Head area (Borders), Fair Isle (Shetland), Berriedale Cliffs (Caithness), and Handa (Sutherland) (Mitchell *et al*., 2004) and in wakes in Skomer, Skokholm and Ramsey and islands around Anglesey. The majority of the black-legged kittiwake population does not winter in UK waters, being pelagic outwith the breeding season, dispersing into the North Atlantic. However some birds do occur in the vicinity of colonies and along coasts throughout the year.

Foraging Distance during Breeding Season

3.4.117 Black-legged kittiwake is a pelagic feeder during the breeding season. Electronic logger data has shown birds frequently foraging up to 70km from the breeding site, utilising a zone of variable width up to 80-100km away from the coast (Camphuysen *et al*., 2006). Around the Welsh colonies of Skomer, Skokholm and Ramsey, high densities of kittiwakes were recorded 20-30km from the colonies in June 1990, but with some also present to the edge of the survey zone 45km away (Stone *et al*., 1992).

Depth of Feeding

3.4.118 Black-legged kittiwakes obtain prey by snatching items from the surface or splash diving just below the surface (Ratcliffe *et al*., 2000).

Underwater Vision

3.4.119 No information available.

Prey-Species Preferences

3.4.120 The black-legged kittiwake forages mainly on small epipelagic fish such as sprat and sandeel, and to a lesser extent as discards from trawlers (Cramp and Simmons, 1985).

18. Black-headed gull *Larus ridibinus*

Population and Distribution

3.4.121 In total the population of black-headed gull in Great Britain and Ireland is 141,890 AON, with 1,986 AON found in Wales (Mitchell *et al*., 2004). The species is the most widespread breeding seabird in the UK, with similar numbers on the coast and inland. In Wales, 850 AONs are coastal breeding (from 79,392 AON in Great Britain and Ireland). The majority of the breeding population is resident, with UK numbers increasing in the winter to 1,697,797 individuals (Baker *et al*., 2006).

Foraging Distance during Breeding Season

3.4.122 The black-headed gull generally forages up to 12–30km from its colony (Snow and Perrins, 1998). Very few ranged as far as 24–30km from the colony (Camargue, France), and while some flew 30–40km to a particularly favourable food source, over half of adults foraged within 10km from the colony. It is not clear how far the coastal breeding component of the population ranges, but Ratcliffe *et al*. (2000) considered foraging range likely to be within 15km.

Depth of Feeding

3.4.123 The species has a wide variety of feeding strategies, one of which is surface-plunges to take floating food, occasionally fully submerging. This is usually from c. 2m high, often after hovering, and with wings drawn into body (Snow and Perrins, 1998).

Underwater Vision

3.4.124 As with other gulls, extended ultraviolet vision may have an adaptive value, by improving foraging efficiency in dip or plunge diving as fish can possess ultraviolet markings during courtship (Håstad *et al*., 2005), although the authors are unaware of any studies to prove/disprove this hypothesis.

Prey-Species Preferences

3.4.125 Black-headed gulls are catholic in their diet, which largely reflects the location of colonies and surrounding habitat and food availability. It can be a food pirate, and at sea fish caught are usually only species of shallow water or those swimming just below surface. It also scavenges sick and dead individuals. The species may also feed on a wide range of marine invertebrates, including benthic species if disturbed (Snow and Perrins, 1998).

19. Northern Fulmar *Fulmarus glacialis*

Population and Distribution

3.4.126 The northern fulmar breeding population of Great Britain and Ireland is approximately 538,000 pairs (Mitchell *et al*., 2004). The species breeds on all suitable cliffs but mainly along the Scottish coast and in particular the northern isles as well as smaller colonies on islands around Anglesey and off Pembrokeshire. Birds are least common along the east, south and northwest coasts of England. The UK winter population increases to approximately 1.7 million individuals foraging offshore. The species is the only British seabird to occupy its nest site throughout the winter, therefore presence in inshore waters occurs year-round.

Foraging Distance during Breeding Season

3.4.127 The northern fulmar most commonly forages within 100km of the breeding site (Ratcliffe *et al*., 2000); however, breeding individuals have been known to travel up to 400km for food (Dunnet and Ollason, 1982).

Depth of Feeding

3.4.128 Northern fulmars are surface feeders, but they also splash-dive (Hudson and Furness 1988) or surface dive down to c. 3m (Hobson and Welch, 1992). Maximum recorded dive depths range from 3m (Garthe and Furness, 2001) to 4m (Snow and Perrins, 1998).

Dive Profile

3.4.129 Northern fulmars are primarily surface feeders and mostly seize prey whilst floating or swimming (Cramp and Simmons, 1977). Dives are generally shallow, with a maximum duration of 8s (Garthe and Furness, 2001) including a plunge and pursuit period (Hobson and Welch, 1992; Garthe and Furness, 2001). Diving activity occurs both during the day and at night (Furness and Todd, 2008).

Underwater Vision

3.4.130 No information available.

Prey-Species Preferences

3.4.131 The northern fulmar feeds on a wide range of fish, squid and marine invertebrates such as copepods, amphipods and, to a lesser extent, polychaetes, pteropods and cnidarians (Camphuysen and van Franeker, 1996; Phillips *et al*., 1999; Snow and Perrins, 1998). The species also frequently feeds on fish offal and marine mammal carrion (Fisher, 1952; Hobson and Welch, 1992; Camphuysen and Garthe, 1997).

20. Roseate Tern *Sterna dougallii*

Population and Distribution

3.4.132 The roseate tern breeding population of Great Britain and Ireland is approximately 790 pairs (Mitchell *et al*., 2004). The species is confined to only a few colonies, mainly off Northumberland, Anglesey and the Firth of Forth, with the bulk of the population breeding in Ireland. Passage birds occur along the south and east coasts. The roseate tern does not winter in UK waters (Snow and Perrins, 1998).

Foraging Distance during Breeding Season

3.4.133 Roseate terns breeding at Rockabill, Ireland feed primarily within 10km of the colony during chick rearing but can travel about 20km during incubation to feed over sandbanks to the south (Newton and Crowe, 1999). At Lady’s Island Lake, Ireland concentrations of roseate terns have been recorded over a reef 5km to the south (Newton and Crowe, 1999). Duffy (1986) suggested that roseate terns fed most commonly at a site 5.5km from a breeding colony at Long Island, New York, but with some travelling as far as 18km. Birds at Falkner Island, Connecticut fly to sandbanks over 25km away; and those at Bird Island, Massachusetts occasionally fly to a tide rip 30km away, although most foraged at sandbanks within 5km (Hienemann, 1992). The roseate tern therefore most commonly forages within 5-10km of the breeding site, but occasionally up to 30km (Ratcliffe *et al*., 2000).

Depth of Feeding

3.4.134 Like other tern species, roseate terns are plunge-divers. The depths they can dive tend to exceed those of other small terns as they initiate the dive from a greater altitude and fly into the water without hovering (Kirkham and Nisbet, 1987). There are no specific data available for roseate tern, but all terns plunge dive to a maximum depth of approximately 1m (Steve Votier pers. comm.).

Dive Profile

3.4.135 The roseate tern forages mainly offshore by plunge-diving from the air after flying upwind (Snow and Perrins, 1998), or by dipping (Shealer and Burger, 1993). In a radio-tracking study of the foraging habits of breeding roseate tern in Canada, Rock *et al*. (2007) found the terns to forage over shallow water less than 5m deep.

Underwater Vision

3.4.136 No information available.

Prey-Species Preferences

3.4.137 The roseate tern chiefly preys on marine fish, mostly sandeels and sprat (Snow and Perrins, 1998).

21. Black Guillemot *Cepphus grylle*

Population and Distribution

3.4.138 The number of pre-breeding black guillemots in Great Britain and Ireland is approximately 42,683 individuals (Mitchell *et al*., 2004). The species is difficult to survey as it tends to breed away from large seabird colonies, being found more on small rocky islands and rocky coasts, where their nests are hidden under boulders and in crevices. As such the census method was conducted prior to the breeding season when birds congregate close inshore for courtship and mating. The species is more sedentary than other seabirds and sheltered, shallow inshore waters provide important gathering areas for flocks of moulting black guillemots during autumn and winter (Ewins and Kirk, 1988).

3.4.139 In Wales, only 28 birds were recorded in 2000, with two known colonies; one on Anglesey and the other on Ynys Gwylan Fawr off the Llyn Peninsula in Gwynedd (Mitchell *et al*., 2004).

Depth of Feeding

3.4.140 Fish are caught by surface-diving, mostly in depths up to 20m, with a mean submersion time of 45s (Snow and Perrins, 1998). The maximum submersion duration is 50–60s, during which bird travels up to 75m or more.

Foraging Distance during Breeding Season

3.4.141 Most black guillemots feed close inshore, and BirdLife International considered that the mean foraging range was within 5km (in Langston, 2010).

Underwater Vision

3.4.142 No information available.

Prey-Species Preferences

3.4.143 Black guillemots are opportunistic feeders (mainly benthic inshore fish and crustaceans), switching between prey types as availability changes. Birds typically hunt alone but may fish shoals co-operatively (Snow and Perrins, 1998).

22. Balearic Shearwater *Puffinus mauretanicus*

Population and Distribution

3.4.144 The Balearic shearwater does not breed in the UK, however up to 5,000 individuals visit coastal areas during summer and autumn months, mainly off southern England, in particular Cornwall, Devon and Dorset, and Wales and the North Sea to a lesser extent (Wynn and Brereton, 2009). The species is principally an offshore forager.

Foraging Distance during Breeding Season

3.4.145 The Balearic shearwater does not breed in the UK and therefore is not at risk of impacts from UK MUREDs during the breeding season.

Depth of Feeding

3.4.146 Aguilar *et al*. (2003) recorded diving behaviour in chick-rearing Balearic shearwater on the Balearic Islands (Mallorca) and observed a mean dive depth of 6m (maximum 26m).

Dive Profile

3.4.147 Aguilar *et al*. (2003) also observed a mean dive duration of 18s (maximum 66s) in the Balearic shearwater. Diving was performed in short bouts. The majority of dives were V-shaped with a non-stop up and down movement at a mean velocity of $1ms^{-1}$. The birds engaged in diving activity between sunrise and sunset. Diving activity peaked in the morning, in the early afternoon, and before sunset.

Underwater Vision

3.4.148 No information available.

Prey-Species Preferences

3.4.149 The Balearic shearwater feeds mostly on small shoaling fish and squid and sometimes scavenges behind fishing vessels (Snow and Perrins, 1998).

23. Greater Scaup *Aythya marila*

Population and Distribution

3.4.150 Greater scaup do not breed in the UK, however approximately 9,200 individuals winter in UK waters (Baker *et al*., 2006), in particular areas rich in mussel beds (Snow and Perrins, 1998).

Foraging Distance during Breeding Season

3.4.151 Greater scaup very rarely breed in the UK and therefore are at minimal risk of impacts from UK MUREDs during the breeding season.

Depth of Feeding

3.4.152 Greater scaup most commonly dive between 1–5m, but are capable of diving up to 10m (Forrester *et al*., 2007).

Dive Profile

3.4.153 A laboratory study of lesser scaup *Aythya affinis* (a North American species) (Stephenson, 1994) recorded dive durations of approximately 14s for ducks diving to approximately 1.5m during feeding bouts. Bearing in mind lesser scaups are generally less coastal than greater scaups (apart from when inland waters are frozen, Snow and Perrins, 1998), it is considered likely that the two species probably exhibit slightly different feeding behaviours (although they probably occur together in mixed flocks in North America).

Underwater Vision

3.4.154 No information available.

Prey-Species Preferences

3.4.155 Omnivorous, though molluscs predominate in many Palaearctic wintering areas (Snow and Perrins, 1998).

24. Common Eider *Somateria mollissima*

Population and Distribution

3.4.156 The common eider breeding population of Great Britain is approximately 31,200 pairs (Baker *et al*., 2006), and the breeding population of Ireland is approximately 600 pairs (Snow and Perrins, 1998). The species breeds along the Scottish, Cumbrian and Northern Irish coasts (Gibbons *et al*., 1993). The UK winter population increases to approximately 80,000 individuals (Baker *et al*., 2006) foraging along much of the UK coast.

Foraging Distance during Breeding Season

3.4.157 No information available.

Depth of Feeding

3.4.158 Common eider, being foragers of benthic invertebrates, routinely forage on the seabed (Guillemette *et al*., 2004). The common eider is capable of diving to depths of 42m (Guillemette *et al*., 1993). The species does, however, strongly aggregate in shallow water, and distribution closely coincides with the highest density of prey.

Dive Profile

3.4.159 Heath *et al*. (2006) studied common eider wintering in polynyas in the Canadian Arctic where they dive to forage on benthic invertebrates. Polynyas are areas where strong tidal currents maintain open water in the sea ice and current velocity can exceed $1.5ms^{-1}$. This research highlights the powerful diving ability of common eider and suggests the species may be able to exploit prey in other regions of similarly strong tidal current.

3.4.160 While most diving birds are considered either foot- or wing-propelled, common eider use both wing and foot propulsion during diving (Heath *et al*., 2006).

Underwater Vision

3.4.161 Common eider was studied during winter months in northern Norway (Systad *et al*., 2000) where, by midwinter, day length is reduced to less than 4.5 hours of twilight. The birds were still able to forage during these low light levels, suggesting either well-developed underwater vision or strong tactile capabilities.

Prey-Species Preferences

3.4.162 The common eider is a wholly coastal and marine species, selecting foraging habitat characterised by high prey density and shallow water to minimise the time and energy requirements of diving (Guillemette *et al*., 1993). The study also found shallow reefs with patches of blue mussels *Mytilus edulis* and green sea urchins *Strongylocentrotus droebachiensis* to be favoured. The main prey items of common eider are slow-moving, benthic marine invertebrates (primarily molluscs), including mussels, urchins and starfish (Snow and Perrins, 1998).

25. Common Goldeneye *Bucephala clangula*

Population and Distribution

3.4.163 The common goldeneye breeding population of the UK is approximately 200 pairs (Baker *et al*., 2006), breeding inland. The UK winter population increases to approximately 35,000 individuals (Baker *et al*., 2006), foraging in many of Britain and Ireland's sheltered coasts (Lack, 1986).

Foraging Distance during Breeding Season

3.4.164 Common goldeneye breed inland and are therefore not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.165 Common goldeneye are capable of diving up to 4m in search of benthic prey items (Snow and Perrins, 1998).

Dive Profile

3.4.166 No information available.

Underwater Vision

3.4.167 No information available.

Prey-Species Preferences

3.4.168 Primarily molluscs, crustaceans, and insect larvae (Snow and Perrins, 1998).

26. Red-necked Grebe *Podiceps grisegena*

Population and Distribution

3.4.169 The red-necked grebe is a rare breeder in the UK, however, approximately 200 individuals winter in UK waters (Baker *et al*., 2006) along the east and south coasts from the Firth of Forth to Land's End.

Foraging Distance during Breeding Season

3.4.170 The red-necked grebe rarely breeds in the UK and therefore is at negligible risk of impacts from UK MUREDs during the breeding season.

Depth of Feeding

3.4.171 No information available.

Dive Profile

3.4.172 The red-necked grebe is a foot-propelled diver. Two studies investigated diving behaviour in this species and recorded mean dive durations ranging from 25s (maximum 50s) (Hancock and Bacon, 1968) to 29s (maximum 42s) (Simmons, 1969). Byrkjedal *et al*. (1997) observed red-necked grebes foraging along the Norwegian coast in a 'manner resembling divers (family: Gavia)'.

Underwater Vision

3.4.173 No information available.

Prey-Species Preferences

3.4.174 The red-necked grebe forages mainly on slow-moving macroinvertebrates, with fish being important only locally or temporarily, although more so in winter (Vlug, 2002).

27. Slavonian Grebe *Podiceps auritus*

Population and Distribution

3.4.175 The Slavonian grebe breeding population of the UK is approximately 40 pairs (Baker *et al*., 2006), breeding inland. The UK winter population increases to approximately 775 individuals (Baker *et al*., 2006) foraging along much of the coast, in particular the Firth of Forth, Moray Firth and Clyde Estuary in Scotland (Holt *et al*., 2009), with none known of in Wales. The Slavonian grebe is the most marine of the grebe species and forages the furthest offshore during winter.

Foraging Distance during Breeding Season

3.4.176 The Slavonian grebe breeds inland and in small numbers, and therefore is not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.177 Slavonian grebes have been recorded foraging within 3m depth on a lake in Iceland (Thorarinsson and Einarsson, 2004).

Dive Profile

3.4.178 The Slavonian grebe is a foot-propelled diver. Studies investigating dive duration in this species recorded mean dive durations of 18s (maximum 30s), 19.5s (maximum 25s) (both Ladhams, 1968), and 33.4s (maximum 39.9s) (Dow, 1964).

Underwater Vision

3.4.179 No information available.

Prey-Species Preferences

3.4.180 Chiefly arthropods (especially insects and larvae) and fish (Snow and Perrins, 1998).

28. Black-necked Grebe *Podiceps nigricollis*

Population and Distribution

3.4.181 The black-necked grebe breeding population of the UK is approximately 50 pairs (Baker *et al*., 2006), breeding inland. The UK winter population increases to 120 individuals (Baker *et al*., 2006) foraging in sheltered coasts and estuaries mainly off southern England and Wales, in particular the Fal Estuary in Cornwall and Poole Harbour in Dorset (Holt *et al*., 2009), and occurring also in South Wales.

Foraging Distance during Breeding Season

3.4.182 The black-necked grebe breeds inland, and therefore is not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.183 The black-necked grebe is a foot-propelled diver. It forages in shallow water, often collecting food by surface skimming but also diving (Snow and Perrins, 1998).

Dive Profile

3.4.184 No information available.

Underwater Vision

3.4.185 No information available.

Prey-Species Preferences

3.4.186 The black-necked grebe spends the winter in coastal habitats, where it forages on fish and crustaceans.

29. Red-breasted Merganser *Mergus serrator*

Population and Distribution

3.4.187 The red-breasted merganser breeding population of Great Britain is approximately 2,100 pairs (Baker *et al*., 2006), and the breeding population of Ireland is approximately 450 pairs (Snow and Perrins, 1998). This species breeds inland. The UK winter population, however, increases to approximately 10,500 individuals (Baker *et al*., 2006) foraging in sheltered coastal regions along much of the Great British and Irish coast (Lack, 1986).

Foraging Distance during Breeding Season

3.4.188 The red-breasted merganser breeds inland and therefore is not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.189 No information available.

Dive Profile

3.4.190 Richner (1988) documented the following behavioural characteristics of red-breasted merganser on a Scottish estuary: numbers increased as the winter progressed; numbers were highest in early morning and decreased throughout the day; spring tides were favoured over neap tides; numbers increased from low to high tide; and lower regions of the estuary were favoured over upper regions.

Underwater Vision

3.4.191 No information available.

Prey-Species Preferences

3.4.192 The red-breasted merganser feeds primarily on small fish, crustaceans and macroinvertebrates. On the coast in autumn and winter the species feeds on shrimp, sandeel, young sprat and herring; in estuaries it takes small flatfish, goby and stickleback, whilst in sealochs it feeds on a variety of seaweed associated fish (Forrester *et al*., 2007). BirdLife International[18] state that its diet consists predominantly of small, shoaling marine or freshwater fish, as well as small amounts of plant material and aquatic invertebrates such as crustaceans (e.g. shrimps and crayfish), worms and insects.

30. Great Northern Diver *Gavia immer*

Population and Distribution

3.4.193 The great northern diver does not breed in the UK, however, approximately 2,750 individuals winter in UK waters (Baker *et al*., 2006). The species forages along much of the British and Irish coast with the exception of the southeast and Bristol Channel. Largest numbers occur off the northern and western isles of Scotland and the Cornish coast.

Foraging Distance during Breeding Season

3.4.194 The great northern diver does not breed in the UK and therefore is not at risk of impacts from UK MUREDs during the breeding season.

Depth of Feeding

3.4.195 The great northern diver has been caught in fishing nets in Lake Superior in the US at depths of up to 60m (Schorger, 1947).

Dive Profile

3.4.196 No information available.

Underwater Vision

3.4.197 No information available.

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[18] http://www.birdlife.org/datazone/species/index.html?action=SpcHTMDetails.asp&sid=500&m=0

Prey-Species Preferences

3.4.198 The great northern diver forages both inshore and far out to sea where its diet consists mainly of fish, but also includes crustaceans, molluscs and annelids (Barr, 1996). The species tends to feed on fish with an erratic swimming behaviour or fusiform shape, and prefers perch or centrachids to sucker or salmonid fish (Barr, 1996). Adult great northern divers in Ontario have a daily fish intake of approximately 960grams (Barr, 1996).

31. Black-throated Diver *Gavia arctica*

Population and Distribution

3.4.199 The black-throated diver breeding population of Great Britain is approximately 170 pairs (Baker *et al*., 2006), and the breeding population of Ireland is approximately 5 pairs (Snow and Perrins, 1998). The species breeds inland. The UK winter population increases to approximately 700 individuals (Baker *et al*., 2006) foraging in sheltered coastal regions along much of the British and Irish coast except for the coasts of the Irish Sea. The Moray Firth, west coast of Scotland and northeast and southwest coasts of England are of particular importance for wintering black-throated diver (Holt *et al*., 2009); rarely around the Welsh coast.

Foraging Distance during Breeding Season

3.4.200 Black-throated diver breed inland and in small numbers, and are therefore not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.201 Outside the breeding season, the great majority resort to sheltered coastal marine waters, not often being recorded far from land. The species has been recorded foraging at depths of 3–6m, with an average dive duration of 45s (maximum two minutes) (Snow and Perrins, 1998).

3.4.202 In a study of incidental catches in the Baltic Sea, stationary fishing nets at depths of 20m were found to contain black-throated diver (Dagys and Zydelis, 2002).

Dive Profile

3.4.203 The black-throated diver feeds by surface diving, using the feet for propulsion and occasionally also the wings (Snow and Perrins, 1998).

Underwater Vision

3.4.204 No information available.

Prey-Species Preferences

3.4.205 The black-throated diver feeds chiefly on fish (Snow and Perrins, 1998).

32. Red-throated Diver *Gavia stellata*

Population and Distribution

The red-throated diver breeding population of Great Britain is approximately 1,200 pairs (Baker *et al*., 2006), breeding inland, while the species rarely breeds in Ireland (Snow and Perrins, 1998). The UK winter population increases to approximately 5,000 individuals (Baker *et al*., 2006) foraging in sheltered coastal regions along the east coast of Britain and more patchily along the west coast, with concentrations off the west coast of Scotland and around northwest Wales (Holt *et al*., 2009).

Foraging Distance during Breeding Season

3.4.206 Red-throated divers breed inland and therefore are not at risk of impacts from MUREDs during the breeding season. In a study of incidental by-catch in the Baltic Sea, stationary fishing nets at depths of 20m were found to contain red-throated divers (Dagys and Zydelis, 2002).

Dive Profile

3.4.207 The red-throated diver feeds by foot-propelled surface diving (Snow and Perrins, 1998).

Underwater Vision

3.4.208 No information available.

Prey-Species Preferences

3.4.209 The red-throated diver feeds chiefly on fish, but diet also includes molluscs and crustaceans (Snow and Perrins, 1998).

33. Little Grebe *Tachybaptus ruficollis*

Population and Distribution

3.4.210 The little grebe breeding population of Great Britain is approximately 13,000 pairs (Birdlife International, 2004), and the breeding population of Ireland is approximately 2,500 pairs ((Birdlife International, 2004). Little grebe make less amrked movements between breeding and wintering areas than other European grebes. Not normally seen in significant numbers on the sea, although may move to sheltered estuaries and harbours during severe winters (Snow and Perrins 1998).

Foraging Distance during Breeding Season

3.4.211 Little grebe breed inland and are therefore not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.212 Little grebe typically dive to no more than 1-2m for durations of 10-25secs (Snow and Perrins, 1998).

Dive Profile

3.4.213 Typically makes shallow dives, or feeds from surface.

Underwater Vision

3.4.214 No information available.

Prey-Species Preferences

3.4.215 Diet consists of insects (inc. larvae) molluscs, crustaceans, amphibian larvae and small fish (Snow and Perrins, 1998).

34. Great Crested Grebe *Podiceps cristatus*

Population and Distribution

3.4.216 The great crested grebe breeding population of Great Britain is approximately 8,000 pairs (Baker *et al*., 2006), and the breeding population of Ireland is approximately 4,150 pairs (Snow and Perrins, 1998), breeding inland. The UK winter population increases to approximately 19,000 individuals (Baker *et al*., 2006), including birds foraging in sheltered coasts and estuaries along much of the coast except northern Scotland.

Foraging Distance during Breeding Season

3.4.217 The great crested grebe breeds inland and therefore is not at risk of impacts from MUREDs during the breeding season.

Depth of Feeding

3.4.218 The great crested grebe has been recorded diving to 30m (Cramp and Simmons, 1977).

Dive Profile

3.4.219 The Wiersma *et al*. (1995) study of wintering great crested grebe found birds to increase their food intake by 1.8-fold between October and January, thus spending increasingly more time submerged during these months and diving 1.5 times deeper. Great crested grebes dived most actively during crepuscular periods. The study concluded that during winter months the species suffers from limited energetic leeway due to overall greater conductance of body heat to the surrounding water (conductance increases by a factor of 4.8 compared to air), compounded by the demand for increased food intake and time spent underwater. These high maintenance costs mean that only a rich and harvestable supply of fish can sustain the species during winter in temperate waters.

Underwater Vision

3.4.220 No information available.

Prey-Species Preferences

3.4.221 Fish consumed by adult great crested grebes are a mean length of 10cm. Adults eat longer fish during the breeding season than during the autumn. Juveniles are fed on fish about 8cm long. Research also showed that grebes are capable of swallowing both large and small fish whilst submerged (Gwiazda, 1997).

3.4.222 A study by van Eerden *et al*. (1993) on a lake in The Netherlands found a lower density threshold of exploitable smelt *Osmerus eperlanus* biomass of approximately 30kg/ha spatially determined the grebes' fishing areas. The vertical movements of the smelt also constrained the grebes temporally; allowing only crepuscular foraging. The study also found a lower fish size threshold of 6.5cm.

35. Sooty Shearwater *Puffinus griseus*

Population and Distribution

3.4.223 The sooty shearwater does not breed in the UK, but visits coastal regions in summer and autumn months in varying numbers each year. Largest numbers are usually recorded in the North Sea and southwest England with only very small numbers, usually in single figures, reported from the Welsh coast.

Foraging Distance during Breeding Season

3.4.224 The sooty shearwater does not breed in the UK and therefore is not at risk of impacts from UK MUREDs during the breeding season.

Depth of Feeding

3.4.225 The sooty shearwater feeds largely from the surface or by short, shallow plunge dives (Snow and Perrins, 1998), although a maximum depth of 68m has been documented (Shaffer *et al*., 2006).

Dive Profile

3.4.226 No information available.

Underwater Vision

3.4.227 No information available.

Prey-Species Preferences

3.4.228 A truly pelagic species, the sooty shearwater feeds predominantly on cephalopods, fish and crustaceans (Snow and Perrins, 1998; Shaffer *et al*., 2006).

4 Location of Renewable Devices and Risk to Diving Birds

4.1 Risk in Relation to Dive Depth

4.1.1 Risk will be influenced by species' typical foraging depth and by the typical spatial distribution of foraging birds. Depth distribution depends on maximum foraging depth. Shallow divers spend most of their time near the sea surface and progressively less time at depth. Deep divers however, show a bimodal depth distribution with peaks of time spent at the sea surface and at deep depths, and less time spent at intermediate depths. Thus, risk with depth will reflect how the species' underwater time budget is allocated to different depths in relation to positioning in the water column of the renewable device in question. Risk will also be influenced by the distribution of foraging behaviour, which may be concentrated in flocks/rafts or may be more widely spaced.

4.1.2 Data from the literature review on dive depth behaviour are summarised in Table 2 and Figure 5. Data are patchy, with some species far better studied (e.g. common guillemot and European shag) than others (e.g. red-breasted merganser and black-necked grebe). In some cases, no dive depth data were found e.g. Manx shearwater. In this case, data for other shearwater species were included as a surrogate indicator. It should be noted that available data mostly refer to breeding birds, on breeding grounds, during the summer. It may therefore not be relevant to extrapolate these findings to non-breeding birds, other foraging grounds or behaviour during different seasons. Findings may also be specific to the local habitat (prey/water depth) of the study site (and in some cases only laboratory studies were available).

Table 2 Summary of dive depth behaviour for each of the 35 diving bird species investigated in this report[19]

Species[20]	Mean Dive Depth	Maximum Dive Depth	Dive Duration	Dive Entry and Shape	Prey Type
1. Manx shearwater	14m (wedge-tailed shearwater) 15m (Audubon's shearwater) 21m (black-vented shearwater)	66m (wedge-tailed shearwater) 35m (Audubon's shearwater) 52m (black-vented shearwater) 67m (sooty shearwater)	<20s (Audubon's shearwater)	Plunge diver	Pelagic
2. Common scoter	3m – 20m (England/Wales)	Unknown	Unknown	Surface diver	Benthic
3. Lesser black-backed gull	<1m	<1m	c. 2 sec (Finland)	Surface plunging and shallow plunging	Pelagic
4. Northern gannet	5m (Newfoundland) 20m (Shetland/Orkney)	22m (Newfoundland) 34m (Shetland/Orkney)	1s – 8s (Shetland) 8s – 38s (Shetland/Orkney)	Plunge diver. Deep, extended U-shaped dives and rapid, shallow V-shaped dives (Shetland/Orkney)	Pelagic

[19]Refer to species accounts for data sources

[20]The colour coding refers to the population significance of the species in Welsh waters (see Table 1).

Species[20]	Mean Dive Depth	Maximum Dive Depth	Dive Duration	Dive Entry and Shape	Prey Type
5. Great cormorant	6m (France)	32m (France)	Mean 40s/max. 152s (France)	Surface diver	Pelagic and benthic
6. Herring gull	<1m	<1m	Unknown	Surface- (or sometimes shallow-) plunging Shallow surface diving	Benthic
7. Razorbill	50% dives <15m (Baltic) <20m during night (Baltic) 25m – 30m (Norway) <35m (Iceland)	41m (Iceland) 43m (Baltic) 120m (Newfoundland)	Unknown	Surface diver. V-shaped dives (Baltic) W- and U-shaped dives (Labrador)	Pelagic
8. Common tern	<1m	<1m	Unknown	Plunge diver	Pelagic
9. Common guillemot	10m (50% dives <6m and 90% dives <22m) (Norway) 80% dives <50m	37 (Norway) 50m (Norway) 53m (Scotland) 138m (Newfoundland) 180m (Newfoundland)	Mean 39s/max. 119s (Norway)	Surface diver. U-shaped (mean bottom dive duration of 19s) (Norway)	Pelagic
10. Northern shoveler	<0.80m	<0.80m	<5 s (UK and Germany)	Surface diver	Pelagic and benthic
11. European storm-petrel	Unknown	Unknown	Unknown	Surface gleaner and diver	Pelagic
12. Arctic tern	<0.20m	<0.35m	Unknown	Plunge diver	Pelagic

Species[20]	Mean Dive Depth	Maximum Dive Depth	Dive Duration	Dive Entry and Shape	Prey Type
13. European shag	33m – 35m (Scotland) 55% time 25m – 34m (Scotland) 10m – 43m (Scotland) Forages most frequently in water depths 21m – 40m (Scotland)	43m (Scotland)	97s (Scotland)	Surface diver. Almost vertical descent and ascent	Pelagic and benthic
14. Sandwich tern	Unknown	Unknown	Unknown	Plunge diver	Pelagic
15. Little tern	Unknown	Unknown	Unknown	Plunge diver	Pelagic
16. Atlantic puffin	75% dives <10m (laboratory) 25m – 30m (Norway)	68m (Newfoundland)	60% <40s (laboratory)	Surface diver	Pelagic
17. Black-legged Kittiwake	<1m	<1m	Unknown	Plunge diver	Pelagic
18. Black-headed gull	<1m	<1m	Unknown	Plunge diver	Pelagic
19. Northern fulmar	3m (Shetland)	4m	Max 8s (Shetland)	Plunge diver	Pelagic
20. Roseate tern	<1m	<1m	Unknown	Plunge diver	Pelagic
21. Black guillemot	10m	20m	43s (Scotland)	Surface diver	Pelagic
22. Balearic shearwater	6m (Balearic Islands)	26m (Balearic Islands)	Mean 18s/max. 66s (Balearic Islands)	Plunge diver. V-shaped dives (Balearic Islands)	Pelagic
23. Greater scaup	1m – 5m	10m	14s (laboratory)	Surface diver	Benthic
24. Common eider	Unknown	42m (Canada)	Unknown	Surface diver	Benthic
25. Common goldeneye	Unknown	4m	Unknown	Surface diver	Pelagic and benthic

Species[20]	Mean Dive Depth	Maximum Dive Depth	Dive Duration	Dive Entry and Shape	Prey Type
26. Red-necked grebe	Unknown	Unknown	Mean 25s/max. 50s Mean 29s/max. 42s	Surface diver	Benthic
27. Slavonian grebe	Unknown	3m	Unknown	Surface diver	Pelagic and benthic
28. Black-necked grebe	Unknown	Unknown	Unknown	Surface diver. Often skimming, occasionally diving	Pelagic and benthic
29. Red-breasted merganser	Unknown	Unknown	Unknown	Surface diver	Pelagic
30. Great northern diver	Unknown	60m (Lake Superior)	Unknown	Surface diver	Pelagic and benthic
31. Black-throated diver	3m – 6m	20m (Baltic)	Mean 45s/max. 120s	Surface diver	Pelagic
32. Red-throated diver	Unknown	21m	Unknown	Surface diver	Pelagic and benthic
33. Little grebe	1m - 2m	Unknown	10 – 25s	Surface diver	Pelagic
34. Great crested grebe	Unknown	30m	Unknown	Surface diver	Pelagic
35. Sooty shearwater	Unknown	68m (Pacific)	Unknown	Plunge diver	Pelagic

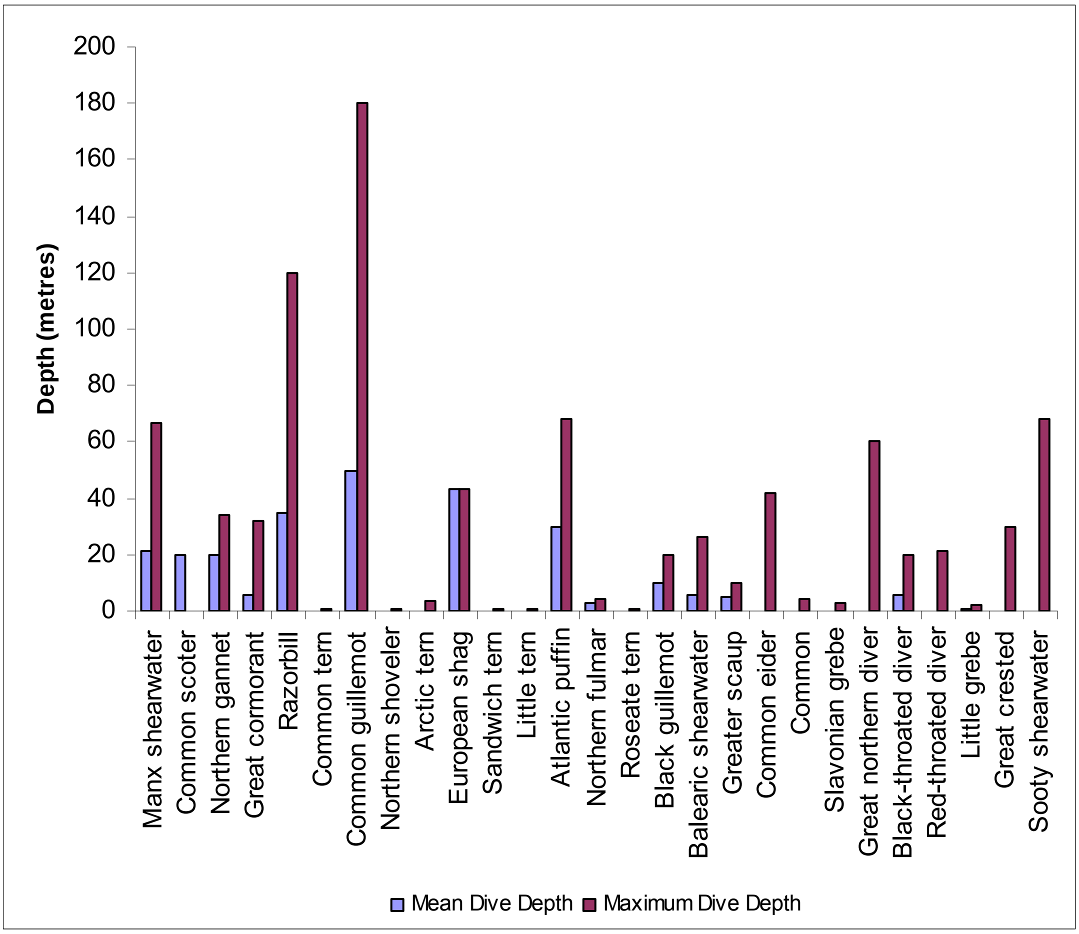

Figure 5 Mean and maximum dive depths for the diving bird species investigated in this report.[21]

4.1.3 Assessment of collision risk should take into account mean and maximum dive depths to discern the water column bands commonly occupied by species. This precautionary approach of considering maximum as well as mean dive depth is necessary given the many knowledge gaps in diving behaviour, prey species preferences, and habitat variability along the UK coast. To consider maximum dive depth in deployment decisions should reduce risk by buffering against a broader range of species' underwater behaviour – especially if this behaviour is poorly understood.

[21]The 26 species presented are those for which data were available. Blue bars show mean dive depth and purple bars show maximum dive depth. In adopting the most conservative approach, and for simplicity, the greatest mean and maximum recordings available are presented. In the absence of data for Manx shearwater, black-vented shearwater data are presented for mean dive depth and sooty shearwater data are presented for maximum dive depth.

4.1.4 Data on dive duration (Table 2) reflect dive depth as well as swimming patterns, and thus indicate the degree of lateral movement that birds may undertake. Black-throated diver, for example, has been recorded spending up to two minutes foraging underwater to a comparatively moderate depth of up to 20m. The lateral underwater movements of this species are substantial and highlight the need to incorporate lateral movement and dive duration into underwater collision risk assessments.

4.1.5 Dive shape will influence risk by affecting the time spent within particular bands of the water column, and thus the likelihood of the species encountering MUREDs positioned at particular depths. Risk will also be affected by entry to the water. Northern gannet, for example, enter the water at considerable speeds with a very small margin for error in relation to underwater structures; surface divers on the other hand exhibit a slower and more controlled pursuit behaviour which likely puts them at lower risk.

4.1.6 Prey type is a factor influencing the level of risk, whereby diving birds can be broadly distinguished as either pelagic or benthic foragers. For renewable devices positioned in water deeper than the diving capabilities of benthic foragers, underwater risk to these species will be negligible, for example common eider forage on molluscs on the seabed at depths of up to 42m, therefore beyond this depth the species may be tentatively excluded from any risk assessment. More generally, an assessment of prey species present, both benthic and pelagic, as well as seafloor substrate, will suggest which diving bird species may occur.

4.1.7 Overall, a conservative approach should be taken in positioning MUREDs at any depth, given the overall paucity of information, specifically for immature and wintering/migrating birds in Welsh waters.

4.2 Risk in Relation to Diurnal Routines

4.2.1 Risk level will also depend on diurnal foraging routines and in particular the proportion of foraging taking place at night. Species engaging in nocturnal diving are at greater risk due to reduced visibility and therefore an ability to detect moving, or other potentially dangerous structures. Alternatively any MUREDs that emit light may attract birds to congregate on or near the device, which may also pose an increased collision risk as underwater structures would remain hidden. Species that do not forage nocturnally, however, may be less vulnerable.

4.2.2 A conservative approach should be taken in positioning MUREDs within the foraging range of any diving bird species, given the overall paucity of information pertaining to diurnal routines. Care needs to be taken in interpreting findings as they are generally based on single studies.

4.2.3 Immature birds, whose poorer foraging proficiency may drive them to forage at night, may be more vulnerable than adults. Local prey may also dictate nocturnal foraging, i.e. low prey density may drive nocturnal foraging so birds can compensate, or upward migration of prey through the water column at night may drive nocturnal foraging as items become more available. For species wintering in Welsh offshore waters, reduced daylight hours during the winter may also drive species to forage in lower light levels to compensate.

4.2.4 Data from the literature review on diurnal routines of diving behaviour are summarised in Table 3. Again, it should be noted that data mostly refer to breeding birds, on breeding grounds, during the summer. Findings can therefore not necessarily be extrapolated to non-breeding birds, other foraging grounds or seasons. Findings are also likely to be specific to the local habitat (prey/daylight levels) of the study site.

4.2.5 As shown in Table 3, nocturnal foraging was only recorded in a relatively small number of the 35 diving bird species investigated. Data indicate regular dawn/dusk or night time foraging (diving) in European storm-petrel, black-legged kittiwake, northern fulmar, northern gannet, razorbill, common eider, and great crested grebe; whilst Manx and Balearic shearwaters generally forage during the day. The degree of nocturnal foraging in other species is not known. Nocturnal foraging species may be at higher risk of collision, although in some species nocturnal dives have been found to be significantly shallower than diurnal ones (e.g. razorbill; Benvenuti *et al*., 2001).

Table 3 Summary of reported diurnal and nocturnal routines of diving behaviour for each of the 35 diving bird species investigated in this report

Species	Evidence of Nocturnal Behaviour
1. Manx shearwater	Generally forages during the day.
2. Common scoter	Not recorded
3. Lesser black-backed gull	Known to forage at night beside boats and in urban areas but nocturnal diving behaviour unknown.
4. Northern gannet	Dive shallower around dawn and dusk (Scotland).
5. Great cormorant	Not recorded

Species	Evidence of Nocturnal Behaviour
6. Herring gull	Known to forage at night beside boats and in urban areas but nocturnal diving behaviour unknown.
7. Razorbill	Conduct nocturnal dives between sunset and sunrise: peak diving activity around sunset and sunrise, lowest activity between 2200hrs – 0200hrs, and no activity around midnight (Baltic). Dives higher in frequency, but more shallow, around midnight (Iceland). Shallow, crepuscular dives (Labrador).
8. Common tern	Not recorded
9. Common guillemot	Not recorded
10. Northern shoveler	Probably feeds at night along shore but no evidence of diving.
11. European Storm-petrel	Known to forage at night closer inshore than during daylight.
12. Arctic tern	Not recorded
13. European shag	Not recorded
14. Sandwich tern	Not recorded
15. Little tern	Not recorded
16. Atlantic puffin	Not recorded
17. Black-legged kittiwake	Known to feed behind trawlers at night.
18. Black-headed gull	Colonies may be active at night and feeding is known to occur near man in harbours and urban areas. No evidence of diving at night.
19. Northern fulmar	Foraging during both day and night.
20. Roseate tern	Not recorded
21. Black guillemot	Not recorded
22. Balearic shearwater	No nocturnal foraging.
23. Greater scaup	Not recorded
24. Common eider	Recorded feeding during winter in northern Norway where day length is reduced to only few hours of twilight, suggesting that, under these circumstances at least, the species does forage in low light levels.
25. Common goldeneye	Not recorded
26. Red-necked grebe	Not recorded
27. Slavonian grebe	Not recorded
28. Black-necked grebe	Not recorded

Species	Evidence of Nocturnal Behaviour
29. Red-breasted merganser	Not recorded
30. Great northern diver	Not recorded
31. Black-throated diver	Not recorded
32. Red-throated diver	Not recorded
33. Little grebe	Not recorded
34. Great crested grebe	Forage most actively during crepuscular periods (Netherlands).
35. Sooty shearwater	Not recorded

4.3 Risk in Relation to Foraging Range

4.3.1 The risks posed by MUREDs in a particular area of open water are dependent on the foraging ranges of each species found in Welsh waters, especially the mean range figure within which most birds from a particular population will be expected to forage. For example, care should be taken to ensure MUREDs are only located within the foraging ranges of birds from major colonies and SPA-designated areas if it can be established that the sites in question are of little importance or where risks to these species are assessed to be low. Placing MUREDs within important foraging areas may mean that species are at elevated risk of collision with or entrapment within structures, construction and operational disturbance and indirect effects such as displacement of prey.

4.3.2 To try to assist Member States with the difficulties of defining foraging areas, given the lack of available data for seabird distributions at sea, BirdLife International has developed the International Seabird Foraging Range Database (reproduced in Langston, 2010). This has brought together all the available data on each species. As can be seen in Table 4, it gives standard radii which have been developed for foraging and maintenance activities of seabird species. Not all species are covered as yet, but the database will be extended as more information becomes available. As such, figures on gulls have been taken from Ratcliffe *et al*. (2000).

4.3.3 In general, cormorant, shag, and smaller gulls will forage within 15km of breeding grounds, whereas most terns, kittiwakes, larger gulls and auks forage within 40km. Species such as fulmar, gannet, storm-petrel and Manx shearwater are more wide-ranging, and have been recorded >100km from nest sites. Again, it should be noted that most data refer to breeding birds, on breeding grounds, during the summer. Findings can therefore not necessarily be extrapolated to non-breeding birds, other foraging grounds or seasons, particularly where sample sizes are small.

Table 4 Mean and maximum foraging ranges of seabird species (km)[22]

Species	Maximum Range	Mean Max	Mean	Sample Size
1. Manx shearwater	400	196.46	171.67	13
2. Common scoter	200	8.2	4.5	11
3. Lesser black-backed gull*	-	40	-	-
4. Northern gannet	640	308.36	140.09	62
5. Great cormorant	50	31.67	8.46	25
6. Herring gull	-	40	-	-
7. Razorbill	51	31	10.27	48
8. Common tern	37	33.81	8.67	42
9. Common guillemot	200	60.61	24.49	122
10. Northern shoveler	n/a	n/a	n/a	n/a
11. European Storm-petrel	100	-	>50	-
12. Arctic tern	20.60	12.24	11.75	19
13. European shag	20	16.42	6.53	29
14. Sandwich tern	70	42.3	14.7	17
15. Little tern	11	6.94	4.14	33
16. Atlantic puffin	200	62.2	30.35	48
17. Black-legged kittiwake	200	65.81	25.45	43
18. Black-headed gull*	40	30	15	-
19. Northern fulmar	664	311.43	69.35	51
20. Roseate tern	30	18.28	12.30	26

[22] Data taken from Birdlife International Seabird Foraging Range Database in Langston (2010) apart from * which is from Ratcliffe et al. (2000) or Snow and Perrins (1998).

Species	Maximum Range	Mean Max	Mean	Sample Size
21. Black guillemot	55	12	4.96	38
22. Balearic shearwater	200	34	29.29	7
23. Greater scaup	n/a	n/a	n/a	n/a
24. Common eider	100	38.33	9.25	10
25. Common goldeneye	n/a	n/a	n/a	n/a
26. Red-necked grebe	n/a	n/a	n/a	n/a
27. Slavonian grebe	n/a	n/a	n/a	n/a
28. Black-necked grebe	n/a	n/a	n/a	n/a
29. Red-breasted merganser	n/a	n/a	n/a	n/a
30-32. Diver Species	56	13.33	4	3
33. Little grebe	n/a	n/a	n/a	n/a
34. Great crested grebe	n/a	n/a	n/a	n/a
35. Sooty shearwater	n/a	n/a	n/a	n/a

4.4 Synthesis of Risks to Seabirds

4.4.1 The species most at risk from any particular development will depend on the combination of site and species specific factors, most notably the type of device (see Appendix 1 for theoretical potential collision risk for birds from specific devices) and the extent of the development.

4.4.2 Nevertheless, some broad generalisations regarding species specific risks due to MUREDs are possible. Most seabird species will potentially be at risk from wave devices located at or near the surface. However, the degree of risk posed by such devices will depend on the extent and nature of moving parts. By contrast, submerged wave devices and tidal devices will only pose a risk to those species capable of diving to the depths at which the devices are installed.

4.4.3 Wave devices located on the shoreline will probably pose the least risk, since these areas are typically of limited use for bird activity, either for resting or foraging. Any risks they do pose could probably be minimised through the use of mesh to prevent birds becoming trapped within any enclosed chambers (although this may have operational implications due to the need to remove debris).

4.4.4 Wave devices located beyond the zone of breaking waves will present greater hazards simply because they are likely to be located in areas frequented by seabirds. The actual degree of risk associated with such devices will depend on the type of device, and specifically the means by which they convert wave motion into electrical energy.

4.4.5 Tidal devices will only be sited at very specific locations, as determined by the available tidal resource. Therefore, the range of diving species potentially at risk from any particular development during the breeding season will be partly limited by proximity to seabird breeding colonies, as well as species specific diving ability in relation to tidal flow rates. It is worth noting that proximity to breeding sites will only be a factor during the breeding season, when breeding adults may be constrained in their foraging options. Outside the breeding season it is likely that such considerations will have a lesser impact. Other aspects to consider will includeinclude prey preferences, since rapid tidal flows are also likely to favour certain prey types (e.g. stronger swimming fish species), the relative importance of the location for foraging, the availability of alternative foraging sites and the habitat flexibility of each species.

4.4.6 An overall assessment of risk for each of the seabird species documented here is presented in Table 5. The preceding sections of this report were used to assign each species to risk categories (Low/Medium/High) in relation to the predicted risk of impacts from MUREDs in Welsh waters. The proximity to breeding colony score included consideration of species' foraging ranges. However, this was not simply based on distance, since the mere fact that a proposed development site lies within a species range is not a reliable guide to the probability of its occurrence at all locations within that distance. Hence, consideration was also given to each species' ecology.

Table 5 Risk categories (low/medium/high) for each seabird species in Welsh waters based on current understanding of ecology

Species	Probability of Interaction			Relative population abundance in Welsh waters	Proximity of breeding colonies to possible development areas	Overall risk category for Welsh population
	Wave		Tidal			
	Surface	Sub-surface				
1. Manx shearwater	H	M	L	H	H	M
2. Common scoter	H	M	L	H	L	M
3. Lesser black-backed gull	H	L	L	H	M	M
4. Northern gannet	H	H	M	H	M	H
5. Great cormorant	H	H	M	H	M	H
6. Herring gull	H	L	L	M	M	L
7. Razorbill	H	H	H	M	H	H
8. Common tern	H	L	L	M	H	M
9. Common guillemot	H	H	H	L	H	H
10. Northern shoveler	H	L	L	L	L	L
11. European Storm-petrel	H	L	L	L	M	L
12. Arctic tern	H	L	L	L	H	L
13. European shag	H	H	H	L	M	M
14. Sandwich tern	H	L	L	L	M	L
15. Little tern	H	L	L	L	M	L
16. Atlantic puffin	H	H	H	L	M	M
17. Black-legged kittiwake	H	L	L	L	M	L
18. Black-headed gull	H	L	L	L	H	L
19. Northern fulmar	H	M	L	L	M	L
20. Roseate tern	H	L	L	L	M	L
21. Black guillemot	H	H	H	L	M	M
22. Balearic shearwater	H	M	L	L	L	L

Species	Probability of Interaction			Relative population abundance in Welsh waters	Proximity of breeding colonies to possible development areas	Overall risk category for Welsh population
	Wave		Tidal			
	Surface	Sub-surface				
23. Greater scaup	H	M	L	L	L	L
24. Common eider	H	M	L	L	L	L
25. Common goldeneye	H	L	L	L	L	L
26. Red-necked grebe	H	M	M	L	L	L
27. Slavonian grebe	H	M	M	L	L	L
28. Black-necked grebe	H	M	M	L	L	L
29. Red-breasted merganser	H	M	M	L	L	L
30-32. Diver Species	H	H	H	L	L	M
33. Little grebe	M	L	ML	L	L	L
34. Great crested grebe	H	M	M	L	L	L
35. Sooty shearwater	H	M	M	L	L	L

4.4.7 Four species identified in Table 5 were assessed as being at high risk from MURED developments in Welsh waters (northern gannet, great cormorant, razorbill, common guillemot). A further eight species (or species groups) were assessed as being at medium risk (Manx shearwater, common scoter, lesser black-backed gull, common tern, European shag, Atlantic puffin, black guillemot and diver species). The populations of all other species were considered to be at low risk of impacts.

4.4.8 Not all of the high and medium risk species will be equally at risk for all possible developments, however this will only be determined through site and device specific assessment.

4.4.9 All four high risk species are named on SPA citations (Skomer and Skokholm: common guillemot and razorbill; Grassholm: northern gannet and Puffin Island: great cormorant), while the first three species are also named on several SSSI citations. Five of the medium risk species are named on SPA citations (Skomer and Skokholm: Atlantic puffin, Manx shearwater; Dee Estuary & Ynys Feurig, Cemlyn and Skerries:

common tern, Liverpool bay: common scoter and red-throated diver, Carmarthen Bay: common scoter, Aberdaron Coast & Bardsey: Manx shearwater). Many of the species also feature as components of SPA assemblages.

4.4.10 In order to produce the above assessment it was necessary to assign the level of risk for key aspects of potential interaction between seabirds and MUREDs using a simple three tier scale. While the example provided here illustrates this at a country wide level, the process would work equally well at the scale of individual developments. However, it is important to remember that this process is intended only as a first step, for highlighting risks based on the broad characteristics of species and devices. A detailed site and device specific assessment should then be undertaken, building on the outputs from the initial overview.

5 Review of EIAs of Marine Underwater Renewable Energy Devices

5.1 Introduction

5.1.1 A small number of prototype projects for MUREDs have undergone the EIA process. A summary of the findings from the relevant Environmental Statements (ESs) is provided in Table 6. Since these assessments are generally of trial developments, in many cases the small number of device deployments is given as a primary reason for a low likelihood of significant impacts on birds. It should be noted that the risk of potential impact will be higher for commercial-scale developments.

5.1.2 It is apparent from this review of ESs that very little is known about the potential for interaction between MUREDs and seabirds. In most cases no specific survey work was conducted, and the desktop assessments reached the conclusion that there would be negligible impacts as a result of device installation.

Table 6 EIAs undertaken for underwater renewable devices

Site/Device Evaluated	Date/Authors	Summary of Findings
Marine Energy Test Centre Environmental Statement, Orkney. Wave energy devices (unspecified).	July 2002, Carl Bro Ltd.	ES contains very limited information on birds and it appears no specific surveys were carried out.
EMEC Tidal Test Facility, Fall of Warness Eday, Orkney. Environmental Statement. Tidal and wave energy devices (unspecified).	June 2005, Aurora Environmental Ltd.	Limited survey and desktop study looking at numbers and distribution. The assessment concluded that residual impacts to wildlife, including diving bird populations, **were unclear due to lack of data presently available**. It also states that EMEC is currently working on establishing a monitoring programme in relation to the impacts of devices on sensitive populations; and is involved in plans with a number of other research institutions to identify the knowledge gaps and initiate research aimed at addressing these. These data will inform ESs required for specific prototype devices, and commercial scale

Site/Device Evaluated	Date/Authors	Summary of Findings
		developments in the future. (See section 6).
The River Humber (Upper Burcom Tidal Stream Generator) Order. Environmental Statement. Pulse Generation (Tidal) Ltd. (PGT). Tidal power generator.	October 2007, Institute of Estuarine and Coastal Studies (IECS), University of Hull.	Desktop study only of the avifauna using the tidal zone rather than diving birds. It concluded that there would be potential disturbance to intertidal flocks of waders during construction and de-commissioning but negligible effects during operation.
Strangford Lough (Northern Ireland) Marine Current Turbine Environmental Statement. Seagen Tidal Power generator.	June 2005, Royal Haskoning Ltd.	Diving species were considered most vulnerable due to sub-surface activity of tidal turbines. Main species groups included: terns, gannet, cormorant and shag, red-breasted merganser and auks (black guillemot, razorbill and common guillemot). Terns were considered important due to proximity of internationally/nationally important breeding colonies. **Collision risk** was determined from a combination of factors such as presence within working area, bird behaviour and hunting characteristics, current speed, and speed and depth of turbine blades below surface. Overall risk was judged to be **extremely low/potentially non-existent**. Most significant risk was assessed to be for actively hunting species being attracted to bubbles entrained in the water from the turbine blades. Deeper diving species were considered at low risk due to relatively slow rotor speed and small rotor swept area.
Wave Dragon EIA Scoping report, Milford Haven.	December 2005, Project Management Support Services Ltd.	Identified diving species as being most at risk. The site is close to some very large seabird colonies off the south coast of Wales, particularly important for Manx shearwater, lesser black-backed gull, razorbill, puffin and gannet. The scoping document concluded that due to the enclosed nature of the device, only small fish can pass through the grill above and below the turbines, and that **direct effects on birds are**

Site/Device Evaluated	Date/Authors	Summary of Findings
		likely to be small. Hence no boat-based or aerial surveys were thought necessary. The Food and Environment Research Agency (FERA) will be carrying out ornithological impact assessment for this trial[23], developing and reviewing techniques to assess the impact of the floating energy converter and its lights on breeding seabirds from nearby SPAs on the Pembrokeshire coast.
Seaflow: Development, Installation and Testing of a Large Scale Tidal Current Turbine. Lynmouth, Devon. (Includes ES non-technical summary).	October 2005. DTI document Contract T/06/0021/00/REP. Jeremy Thake, IT Power.	The ES concludes that '**the possible impacts on diving birds are considered to be insignificant, owing to the likely low intensity of use of the site**.' Subsequent monitoring has shown that other effects of the turbine are, as expected from the ES, relatively small, and therefore rather difficult to evaluate. There has been no rotor damage, which indicates that there have been no collisions with fish or sea mammals (or any other debris). Dolphins and diving birds are regularly seen around the turbine, but always at some distance.
Stingray Tidal Stream Energy Device – Phase 2. Shetland (Yell).	December 2003. The Engineering Business Ltd. Entec carried out EIA.	Environmental appraisal states that the coast of Yell contains numerous seabird colonies but the potential for disturbance during construction is reduced due to distance of unit and barge offshore. In terms of effects on diving seabirds of the operation of the unit, the depth of the unit is below the diving depth of most birds. Exceptions to this are '**deep diving species such as gannet, but given the size of Stingray not considered to be significant issue**'.
RITE (Roosevelt Island Tidal Energy) project (Verdant Energy).	USA-based project (no EIA available).	During the Phase 2 RITE demonstration, Verdant Power and its environmental consultants deployed a continuous underwater monitoring system. This

[23]http://www.fera.defra.gov.uk/showNews.cfm?id=320

Site/Device Evaluated	Date/Authors	Summary of Findings
Underwater turbines.		system's software detects, distinguishes, gauges, counts and tracks any events of fish passing near the turbine array. Key results to date are that there are no records of wildlife strikes at the RITE Project site. Fish have been observed predominantly near the shore close to the riprap adjacent the project site.

6 European Marine Energy Centre (EMEC) Studies

6.1 Introduction

6.1.1 EMEC, at its Orkney test sites, funds a number of research projects[24] relating to tidal and wave devices. These projects are mostly ongoing, and a summary of the aims and findings to date is presented below.

6.2 Sub-Surface Interactions: Sonar System

6.2.1 There are limitations to the use of video equipment to study marine wildlife interactions with MUREDs, due to turbidity and natural light constraints. The "Sub-surface Interactions: Sonar System" research project focuses on the potential to use sonar to investigate possible collisions.

6.2.2 Options for using sonar to derive more detailed, real-time images can generally be divided into scanning single-beam devices and multibeam devices. Single-beam scanners sweep an area and build up a one-dimensional profile. These are most suited to producing depth profiles from a moving vessel. Such devices are unlikely to be of use for observing rapidly moving small targets, such as diving seabirds. Multibeam sonar devices consist of parallel arrays of single beam sonar which operate together to produce images of objects in their field of view. There is a trade-off between object resolution, width of field of view and effective range. The Didson device (www.soundmetrics.com) is a high resolution multibeam sonar which produces very detailed images, within a 7° field of view. While the images obtained from this system would permit seabird identification, the effective range is limited to around 15m and is analogous to a torch beam in terms of the volume of sea scanned. CodaOctopus produce an alternative multibeam device (Echoscope) which produces lower resolution images, but has a 50° field of view and an effective range of up 25m. While this device is unlikely to offer reliable species identification, the volume of sea scanned would greatly enhance data collection.

[24] http://www.emec.org.uk/research.asp

6.2.3 The Sea Mammal Research Unit (SMRU) has carried out an initial test of the potential for the use of this kind of device, with a particular emphasis on marine mammal detection. This investigation concluded that whilst there is potential for application, manufacturers would need to make some refinements to suit the marine energy industries. If appropriate refinements were made, there is potential to record useful information from such equipment, and EMEC hopes to be involved in initial testing using the improved equipment. This method should also provide additional information about the interaction of a device with any object suspended in the flow, as well as essential data relating to interactions with wildlife, potentially including diving birds.

6.2.4 Current status (December 2010): this project is currently still under discussion and no timetable for outputs is currently available.

6.3 Wildlife Displacement: Observations Programme

6.3.1 The purpose of the wildlife observations monitoring project is to provide an overall picture of whether or not a change or displacement has occurred among the resident wildlife due to the presence and operation of renewable devices. This project focuses on marine mammals but has also recorded data on diving birds.

6.3.2 A marine wildlife monitoring programme has been initiated at EMEC's tidal test site. Methodology, timing of observations and data analysis is being overseen by the Sea Mammal Research Unit (SMRU) Ltd. The test area is regularly scanned by telescope for hour-long periods from an elevated onshore vantage point, marine mammals and birds are noted, and to date, the schedule of observations totals approximately 1,000 hours. Data from monitoring during 2005-07 have been analysed by SMRU Ltd. and the results form a baseline dataset of marine wildlife present in the area.

6.3.3 The marine wildlife monitoring programme will be ongoing until it is deemed to have provided sufficient data to enable an objective assessment of risk to be made.

6.3.4 Current status (December 2010): reports under review by SNH, summaries expected to be available in 2011.

6.4 Acoustic Emissions

6.4.1 Potential effects on some wildlife species may arise from the acoustic emissions of devices. Possible targets for such effects include sea mammals, some fish species and possibly diving birds. This is an ongoing project to monitor the baseline acoustic characteristics of an area in Orkney undergoing renewable device testing. The Scottish Association for Marine Science (SAMS) is currently developing the equipment and a suitable methodology. EMEC will then inherit the methodology and equipment, and be able to train and hire local contractors to continue data collection around deployed devices.

6.4.2 Current status (December 2010): work at the wave site is ongoing. At the tidal site work is completed and a summary report is expected in 2011.

6.5 Camera Observations of Interactions with Wave Power Devices

6.5.1 The objective of this project is to inform wave energy device operators, as well as regulatory and other decision makers, about the frequency and nature of interactions between marine wildlife (including diving birds) and those parts of devices which are on or above the sea surface. The project involves placing a dedicated high magnification camera at the existing lookout post on Black Craig, Orkney Mainland. The aim of this investigation is to provide a methodology for assessing the effects of the protruding elements of wave devices on marine mammals and birds.

6.5.2 Current status (December 2010): work soon to be completed, reporting timetable not yet confirmed.

6.6 Targeted Future Research

6.6.1 EMEC is hoping to extend to the wave site those projects already underway or under development at the tidal test site. This applies to the following potential projects at Billia Croo, Orkney:

- Risk of collision between wildlife and MUREDs: sub-surface interactions between wildlife and renewable devices will be investigated using sonar in collaboration with SMRU and the University of Aberdeen;
- Risk of damage to benthic communities: benthic ecology will be studied using a remotely-operated vehicle (ROV)/photographic footage to provide detailed visual confirmation of seabed condition; and
- Risk of impacts of acoustic emission: baseline data describing the background acoustic characteristics of the tidal test site will be gathered, in collaboration with the Scottish

Association for Marine Science (SAMS) who is developing the equipment and methodology.

7 Conclusions

7.1 Reported Collisions and Expected Frequency

7.1.1 This review has not found any reported instances of collisions between diving birds and MUREDs, either in the published scientific literature or from other sources, such as the limited monitoring and research ongoing at existing installations. However the lack of any recorded instances does not infer that such collisions will not occur. There are three main reasons for this:

- There are few such devices installed at present, and those that are installed are often prototypes. The most significant difference between prototypes and installations suitable for commercial-scale generation is scale. If collisions are infrequent they may only be detected at larger scale (i.e. multi-device arrays) installations; and
- Even in a large scale installation, there is a very low chance of recording a collision event. If the collision resulted in the death of the bird, the carcass would be expected to float, where it could be scavenged by both pelagic fish and birds. It is also likely to be removed from the site by currents. In addition, there are few opportunities to record collision because deployment of people or recording devices has been limited to date, resulting in a low probability of detection.
- There may also be commercial sensitivities involved which have prevented the release of data which could prove valuable for the entire sector.

7.1.2 Studies of onshore commercial-scale wind farms have shown that some species are at a higher collision risk than others due to their behaviour and ecology (Drewitt and Langston, 2006; Hotker *et al.,* 2006; Bright *et al.,* 2008). This review recognises that there is a theoretical risk of collision associated with underwater turbines for diving birds, that this risk is likely to vary between species, and that this is an issue which requires assessment and monitoring. One possible method for monitoring for collisions could be to use underwater cameras, mounted to provide a view of the moving parts. Such equipment would only be suitable for depths at which sufficient light was available, and would be limited to the hours of daylight. There would also be practical challenges involved in supplying power and retrieving image data. Since it would be expected that collision events would be infrequent, it is likely that long term deployments would be required.

7.2 Collisions and Other Effects

7.2.1 In the terrestrial environment, collisions are assumed to result in the death of a bird through direct physical contact, and this is supported by post-mortem of known collision victims. However there are a number of other possible mechanisms for effects on birds and other wildlife. Recent research on bats suggests that sudden changes in pressure can cause barotraumas (Baerwauld *et al*., 2008). Birds were considered less susceptible to barotrauma because of their different respiratory system, however the possibility of direct mortality or drowning as a result of these effects cannot be ruled out.

7.2.2 Disturbance and displacement effects during construction and operation may also directly affect birds' ability to forage, or indirectly by affecting prey numbers or distribution in the vicinity of MUREDs. Both these circumstances could have negative impacts on productivity during the breeding season and could also affect survival rates. Monitoring for these effects can be achieved by using various methods, as follows:

- Aerial and/or boat-based BACI (Before-After/Control-Impact) surveys on distribution, abundance, seasonality and use of proposed sites;
- Radio tagging individual birds to establish foraging destinations from breeding colonies and dispersal and migration through site;
- Targeted use of remote sensing techniques (e.g. radar, infrared video cameras, Thermal Animal Detection System (TADS)) from offshore platform;
- Recording breeding productivity rates in colonies before and after construction;
- Population analysis and habitat modelling; and
- Observing or modelling prey distribution, availability and provisioning rates.

7.3 Marine Devices and their Risk Characteristics

7.3.1 Existing available technologies fall into two categories; those that use currents to drive turbine blades directly (e.g. vertical axis turbine such as SeaGen) and devices that use marine currents to drive turbines indirectly (using hydraulic cylinders or air, e.g. oscillating hydrofoil such as Stingray). Devices which use currents indirectly have a greatly reduced or even absent theoretical collision risk. Those which use currents directly to drive turbine blades (e.g. horizontal axis turbines) need a clearer mechanism for theoretical collision risk. A detailed EIA assessment would have to take into account the design of devices, the number of devices, the array arrangement, and depth of deployment (and the populations of species present in that particular area during both the breeding and non-breeding seasons). The relationship between devices (depth and technology) and species present is very much site-specific.

7.4 Risk Factors in Relation to Species Size and Behaviour

7.4.1 A review of the factors relating to the behaviour and other attributes of diving birds has highlighted that on a theoretical basis, some species are potentially more vulnerable to collisions or other adverse effects from interactions with marine renewables devices.

7.4.2 Larger species, species that feed on benthic prey, and species capable of pursuit of prey, are all considered to be exposed to a greater theoretical collision risk.

7.4.3 For onshore wind projects, theoretical collision risk models, such as the Band model (Band, 2000), are used to estimate species-specific collision rates based on baseline flight-activity data collected at the proposed wind farm site. Two parameters that are used in this modelling process are bird length and wingspan, which highlights the influence of bird size on the probability of collision. Smaller species have an increased chance of passing between turbine blades without being struck. This is also likely to be the case in the marine environment. Theoretical collision risk with MUREDs may also be influenced by the underwater propulsion technique (i.e. use of wings or feet) used by the birds, which would need to be considered in the design of such a model for MUREDs.

7.4.4 Risk of collision is also influenced by diving behaviour. Species that dive to feed on benthic prey tend to have longer dive-periods and are thus on a theoretical basis exposed to collision for a greater period of time than those that dive and feed on prey near the surface. Species that pursue prey underwater may be exposed to a higher risk of collision which would be a major factor in terms of potential for avoidance of collision with devices. Underwater visibility may also be a factor in relation to this.

7.5 Risk Associated with Conservation of Birds in Welsh Waters

7.5.1 It is unlikely to be possible to make definitive predictions about the effects of underwater marine renewable energy devices on diving birds without further research, experience and monitoring. However, an informed approach to the EIA of these proposals will help avoid potential impacts associated with poorly sited developments.

7.5.2 In the case of onshore wind, a number of poorly sited wind farms appear to have had adverse impacts on bird and bat populations (Drewitt and Langston, 2006). These have also had associated consequences for the renewable energy industry. To avoid repeating this scenario, the EIA process needs to consider which diving birds are present, their conservation status, and how they use the potential development site. Consideration of the diving birds' prey, and the distribution of that prey both vertically in the water column and spatially will also be required. The scale of the development relative to the foraging resource affected must be taken into account, together with the diving behaviour of the birds. This combined analysis will enable the EIA process to highlight developments that pose a high risk because they are sited in important foraging areas or pose a risk to very sensitive bird populations.

7.5.3 Surveys at a proposed site can be used to collect data to characterise bird activity. The data from these surveys can then be used in conjunction with population modelling techniques to determine the likelihood of significant impacts to bird populations. These would provide an approximate equivalent output to the collision risk assessments developed for wind turbines. However, this would not include any specific modelling of interactions between turbines and birds, since this aspect will prove difficult to parameterise.

7.5.4 During the scoping stage of a wave or tidal development, it is recommended that this literature review is used to inform an assessment of the suite of species most vulnerable to potential risk from the proposed development. This process should be used to identify the target species that baseline data will be required for the EIA process. This assessment of the species at most potential risk from the development will be site-specific, depending on the design of the MUREDs and the proposed location. However, this should form only the first step in a full assessment process. This is an area of extremely active development, and new research is likely to be published on a regular basis. Comprehensive searches for the most up to date information should also be undertaken.

7.5.5 This literature review should also be used to highlight current knowledge gaps in seabird diving behaviour in order to determine where future study would best be targeted. Enhancing our knowledge of diving behaviour will allow the potential risks of MUREDS on birds to be more thoroughly examined.

7.6 Framework for Identifying Risks to Seabirds from Proposed MUREDs

7.6.1 We have provided a generic example of how to assess the risks to seabirds posed by MUREDs (Table 5). This used the information detailed in the earlier sections of the report to generate an overall assessment of risk for each species. The table presented here was derived at the level of all Welsh waters, however the basic approach would be equally suitable for estimating risks for specific developments. Indeed this form of approach, taking a 'long' list and filtering it to obtain a 'short' list of species considered to be at higher risk is commonly used in most forms of impact assessment. This desk-based assessment could be undertaken at an early stage in the development process and used to focus attention on the species of greatest concern. For example, once the species at potential risk have been identified, study effort can be directed to understanding the diving behaviour of these species at the site. The data collected could then be used to undertake specific assessments such as collision risk modelling, or the effects of construction or displacement on the populations.

7.7 Knowledge Gaps and Areas for Future Research

7.7.1 Perhaps the single most important area for future research should be aimed at improving understanding of seabird behaviour underwater. The extent to which diving seabirds are able to detect, and if necessary take avoiding action from, underwater devices is not known. The first priority in this respect will be testing approaches for observing seabirds underwater. This task can be split into various components, including testing the suitability of existing technologies for observing seabirds (e.g. sonar), methods for mounting (e.g. boat, pontoon etc.) and means for supplying power and storing/retrieving data. All of these are likely to present significant challenges.

7.7.2 Another difficulty stems from the need to determine the size of population which may be affected by a development. This will require a means to estimate turn-over rates amongst individuals at a site. It will also be necessary to estimate the colony of origin of birds observed on site, in order that the proportion of birds from any one breeding population (e.g. SPA) which visit a proposed development site can be estimated. This may involve the use of radio or GPS tags, or possibly coloured dyes, in combination with intensive observations. Such approaches will probably be difficult and labour intensive during the breeding season, but may not be possible outside the breeding season.

7.7.3 As a first step however, for proposed developments, regular, detailed and appropriately focused surveys of bird activity and behaviour should be undertaken at the site. Data obtained can be used to begin to address questions of site use, and to establish the necessity of further intensive research. Methods for undertaking these surveys have been developed and discussed in detail in the fieldwork report (RPS, 2011, *in prep.*) which complements this review.

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Glossary

Alcid	Belonging to the avian family Alcidae, or auks, that includes the razorbill, common guillemot and Atlantic puffin.
Barotrauma	Physical damage to the body caused by a difference in pressure between an air space inside the body and the surrounding fluid.
Cephalopod	Belonging to the mollusc class Cephalopoda, which includes squid, octopus and cuttlefish.
Cnidarians	Belonging to the phylum Cnidarians, that includes jellyfish and Anemones.
Crepuscular	To be active during the twilight hours of dawn and dusk.
Kleptoparasitic	To steal food from another animal that has caught or killed the food.
Pelagic	To inhabit the open oceans.
Piscivorous	To habitually feed on fish.
Procellariid	Belonging to the avian order Procellariiformes, or tube-nosed birds, that comprise petrels, prions, shearwaters and albatross.
Pteropod	Small, pelagic, swimming sea snails, also known as sea butterflies.

Abbreviations

AOS	Apparently Occupied Sites
AON	Apparently Occupied Nests
AOB	Apparently Occupied Burrows
dB	Decibel
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
MCT	Marine Current Turbines
OWC	Oscillating Water Column
RITE	Roosevelt Island Tidal Energy
rpm	revolutions per minute
RTT	Rotech Tidal Turbine
s	seconds
SAMS	Scottish Association for Marine Science
SMRU	Sea Mammal Research Unit
SPA	Special Protection Area
SSG	Seawave Slot-cone Generator
TEC	Tidal Energy Converter
TGL Turbine	Tidal Generation Ltd. Turbine
MURED	Underwater Marine Renewable Energy Devices
WEC	Wave Energy Converter

Appendices

Appendix 1

Characteristics, and Relevant Technical Specifications of Marine Devices under Development or Deployed

Appendix 1 Table 1A – Characteristics of Tidal Stream Devices

Name of Device and manufacturer	Moving Parts	Non-Moving Parts	Dimensions	Mooring Arrangements	Location Characteristics	Theoretical Potential Bird Collision Risk (Magnitude)
Stingray, The Engineering Business	The device has a moveable arm.	Moveable arm is on supporting frame which is mounted on seabed.	Height 23.6 metres. Width 15.5 metres. Arm length 11 metres. Arm operating angle ±35°.	Not physically fixed to seabed, it is designed to stay in position through a gravity base system utilising a combination of weight and earth anchors. Ballast weights can be added to base.	Placed on seabed so that hydroplane operates in mid depth of water column.	Low/non-existent
Rotech Tidal Turbine, Lunar Energy	The generator unit comprises of turbine blades within an open cylinder.	-	Duct diameter 15 metres. Duct length 19.2 metres. Turbine diameter 11.5 metres.	Gravity base system.	On seabed (>40 metres). Designated to be sited in arrays across tidal bottlenecks.	Low/medium
Neptune, Aquamarine Power	Two horizontal axis rotating turbines similar to wind	Tower rising from seabed with turbines mounted at 45° angle.	Unavailable.	-	On seabed, turbines operate at mid-depth.	Low/medium

Name of Device and manufacturer	Moving Parts	Non-Moving Parts	Dimensions	Mooring Arrangements	Location Characteristics	Theoretical Potential Bird Collision Risk (Magnitude)
	turbines in design.					
Deltastream, Tidal Energy Ltd.	Three separate horizontal axis turbines mounted on a common frame.	Single, triangular frame.	Frame 30 metre wide. 15 metre diameter rotor which is elevated between 5 to 20 metres above seabed.	Gravity base system.	On seabed.	Low/medium
TGL Turbine, Tidal Generation Ltd.	Slow moving (undefined) rotors	Foundation holds rotors in place.	The resource has four times the energy intensity of a good wind site, so tidal turbines need only a quarter of the swept area of a wind turbine.	The foundations are anchored to the seabed.	On seabed.	Low
Seagen Tidal Turbine Blades, AEL	It has two rotors (turbine blades).	Steel cross beam, to which rotors are attached. Steel cross beam is attached to a column which is sunk into ocean floor	Rotors are each 16m in diameter, no other dimensions given	Column sunk into ocean floor	Below surface, mid-depth	Low/medium
Seaflow Tidal	It has a rotor diameter	Column to which rotor	Rotor has a diameter	Column sunk into	Not stated	Low/medium

Name of Device and manufacturer	Moving Parts	Non-Moving Parts	Dimensions	Mooring Arrangements	Location Characteristics	Theoretical Potential Bird Collision Risk (Magnitude)
Turbine, AEL	of 11m	attached	of 11m, no other dimensions given	ocean floor		
Archimedes Wave Swing, AWS Ocean Energy	Passing waves move an air-filled upper casing against a lower fixed cylinder, with up and down movement converted into electricity	-	N/A for device. A 50MW farm will occupy an area around 3 nautical miles long by 2 cables wide.	The AWS is submerged at least 6m below the sea surface and moored to seabed	Seabed	Low/non-existent

Appendix 1 Table1B – Characteristics of Wave Power Devices

Name of Device and Developer	Moving Parts	Non-Moving Parts	Dimensions	Mooring Arrangements	Location Characteristics	Theoretical Potential Bird Collision Risk (Magnitude)
Wave Dragon	There are 16-24 turbines on full size version. Their design is of traditional propel type used in Hydroelectric generation, using runners within a cylinder rather than exposed turbine blades. 34cm diameter runner on test model. Variable speed of rotation. Orientation is downwards, water flows from reservoir down through turbines.	Design incorporates wave reflector arms (126 metres to 190 metres in length) focussing water towards a ramp. The resulting reservoir is 5,000 to 14,000 m^3 in capacity.	-	Tethered to steel anchor blocks.	In open sea, suspended down to mid depth in water column (down to between >20 to >30 metres).	Low/non-existent
Limpet, Wavegen	There are no moving parts underwater.	Oscillating water column is open to the sea.	-	Constructed so that it is attached to the shoreline rather than the seabed.	Placed on the shoreline to maximise the capture of wave energy and conversion to pneumatic power.	Low/non-existent
Pelamis, Pelamis	Hinged joints between cylindrical sections that	Cylindrical sections lie on surface.	Tube sections 120-150m long,	The complete machine is flexibly moored so as to	In water >50 metres deep.	Low/non-

Name of Device and Developer	Moving Parts	Non-Moving Parts	Dimensions	Mooring Arrangements	Location Characteristics	Theoretical Potential Bird Collision Risk (Magnitude)
Wave Power Ltd.	stay near the surface.	Cable carries electricity from transformer to seabed (>50m) and from there to shore.	3.5m wide.	swing head-on to the incoming waves and derives its 'reference' from spanning successive wave crests.		existent
Oyster, Aquamarine	A piston moves when the Oscillating Surge Converter is pushed by wave action.	The Oscillating Surge Converter rests on the seabed and is positioned so the top is above the water level (in water 10-12 metres).	-	-	Near the shore line in water 10-12 metres deep.	Low/non-existent
Powerbuoy, OPT	Buoy sits on surface.	Sea-floor cable	Overall height (deployed): 9 metres. Overall height (stowed): 5.6	Anchored on the sea bottom using a proprietary anchoring system that avoids any damage or threat to the	On surface.	Low/non-existent

Name of Device and Developer	Moving Parts	Non-Moving Parts	Dimensions	Mooring Arrangements	Location Characteristics	Theoretical Potential Bird Collision Risk (Magnitude)
			metres. Height above waterline: 1.7 metres. Draft: 7.4 metres. Average float diameter: 1.5 metres.	seabed or sea life.		
Buldge Wave Anaconda, Checkmate SeaEnergy	Large water filled distensible rubber tube floating just beneath the ocean surface	Tether and foundations	Perhaps 200m long and 5m diameter	Tethered to seabed by chain	Surface	Low/non-existent
C-Wave, C-Wave Limited	Two neutrally buoyant walls approximately half a wave length apart, so that while one is moving forward the other is moving back.	Tether and foundations and stable submerged steel frame	Not given	Tethered to seabed by chain	On, and just below the surface	Low/non-existent

Name of Device and Developer	Moving Parts	Non-Moving Parts	Dimensions	Mooring Arrangements	Location Characteristics	Theoretical Potential Bird Collision Risk (Magnitude)
Seawave Slot-Cone Generator (SSG)	Gates controlling the water flow.	Reservoirs and turbine encased in concrete foundations.	-	Concrete structure.	Can be situated onshore (in a coastal area where the landscape is naturally wedge-shaped); offshore as a floating or a fixed installation, (for a fixed SSG offshore installation a de-commissioned oil platform can be an option as the SSG foundation, this will prolong the utilization of the foundation and postpone the final de-commission); or as part of a breakwater.	Low/non-existent

Appendix 1 Table 1C – Tidal Stream Device Developers (source EMEC)

Company	Technology	Country Base
Aquamarine Power	Neptune	UK
Atlantis Resources Corp	Aquanator	Australia
Balkee Tide and Wave Electricity Generator	TWPEG	Mauritius
BioPower Systems Pty Ltd.	bioStream	Australia
Blue Energy	Blue Energy Ocean Turbine (Davis Hydro Turbine)	Canada
Clean Current Power Systems	Clean Current Tidal Turbine	Canada
Edinburgh Designs	Vertical-axis, variable pitch tidal turbine	UK
Edinburgh University	Polo	UK
Fieldstone Tidal Energy	Fieldstone Tidal Energy	USA
Free Flow 69	Osprey	USA
GCK Technology	Gorlov Turbine	USA
Greenheat Systems Ltd.	Gentec Venturi	UK
Hammerfest Strom	Tidal Stream Turbine	Norway
Hydro Green Energy	Hydrokinetic Turbine	USA

Company	Technology	Country Base
Hydro-Gen	Hydro-gen	France
Hydrohelix Energies	hydro-helix	France
Hydroventuri	Rochester Venturi	UK
Ing Arvid Nesheim	Waterturbine	Norway
Kinetic Energy Systems	Hydrokinetic Generator, KESC Bowsprit Generator, KESC Tidal Generator	USA
Lunar Energy	Rotech Tidal Turbine	UK
Marine Current Turbines	Seagen, Seaflow	UK
Natural Currents	Red Hawk	USA
Neo-Aerodynamic Ltd. Company	Neo-Aerodynamic	USA
Neptune Systems	Tide Current Converter	Netherlands
Neptune Renewable Energy Ltd.	Proteus	UK
New Energy Crop.	EnCurrent Vertical Axis Hydro Turbine	Canada
Ocean Renewable Power Company	OCGen	USA
Oceana Energy Company	TIDES	USA
OpenHydro	Open Centre Turbine	Ireland

Company	Technology	Country Base
Overberg Limited	Evopod	UK
Ponte di Archimede	Kobold Turbine	Italy
Pulse Generation	Pulse Generators	UK
Robert Gordon University	Sea Snail	UK
Rugged Renewables	Savonius turbine	UK
Scotrenewables	SRTT (Scotrenewables Tidal Turbine)	UK
SMD Hydrovision	TiDEL	UK
Statkraft	Tidevanndkraft	Norway
Swanturbines Ltd.	Swan Turbine	UK
Teamwork Tech.	Torcado	Netherlands
The Engineering Business	Stingray	UK
Tidal Electric	Tidal Lagoons	UK/USA
Tidal Energy Pty Ltd.	DHV Turbine	Australia
Tidal Generation Ltd.	Deep-gen	UK
Tidal Hydraulic Generators Ltd.	Tidal Hydraulic Generators	UK

Company	Technology	Country Base
Tidal Sails	Tidal Sails AS	Norway
TidalStream	TidalStream	UK
UEK Corporation	Underwater Electric Kite	USA
University of Southampton	Southampton Integrated Tidal Generator	UK
University of Strathclyde	Contra-rotating marine current turbine	UK
Verdant Power	Various	USA
Vortex Hydro Energy	VIVACE (Vortex Induced Vibrations Aquatic Clean Energy)	USA
Water Wall Turbine	WWTurbine	USA
Woodshed Technologies - CleanTechCom Ltd.	Tidal Delay	Australia / UK

Appendix 1 Table 1D –Wave Power Device Developers (source EMEC)

Company	Technology	Country Base
Able Technologies L.L.C.	Electric Generating Wave Pipe	USA
Applied Technologies Company Ltd.	Float Wave Electric Power Station	Russia
Aqua Energy / Finevara Renewables	Aqua Buoy	USA
Aquamarine Power	Oyster	UK
Atmocean	Atmocean	USA
AW Energy	Waveroller	Finland
AWS Ocean Energy	Archimedes Wave Swing	UK
Balkee Tide and Wave Electricity Generator	TWPEG	Mauritius
BioPower Systems Pty Ltd.	bioWave	Australia
Bourne Energy	OceanStar ocean power system	USA
Brandl Motor	Brandl Generator	Germany
Caley Ocean Systems	Wave Plane	UK/Denmark
Checkmate Seaenergy UK Ltd.	Anaconda	UK
College of the North Atlantic	Wave Powered Pump	Canada

Company	Technology	Country Base
Columbia Power Technologies	Direct Drive Permanent Magnet Linear Generator Buoy / Permanent Magnet Rack and Pinion Generator Buoy / Contact-less Force Transmission Generator Buoy	USA
C-Wave	C-wave	UK
Daedalus Informatics Ltd.	Wave Energy Conversion Activator	Greece
Delbuoy	Wave Powered Desalination	USA
DEXA Wave UK Ltd.	DEXA Wave Energy Converter	USA
Ecofys	Wave Rotor	Netherlands
Ecole Centrale de Nantes	SEAREV	France
Edinburgh University	Sloped IBS Buoy	UK
Embley Energy	Sperboy	UK
Energias de Portugal	Foz do Douro breakwater	Portugal
Float Inc.	Pneumatically Stabilized Platform	USA
Floating Power Plant ApS (F.P.P.)	Poseidon's Organ	Denmark
Fobox AS	FO3	Norway
Fred Olsen and Co./Ghent University	SEEWEC	Norway / EU

Company	Technology	Country Base
GEdwardCook	Syphon Wave Generator	USA
GEdwardCook	Floating Wave Generator	USA
Green Ocean Energy Ltd.	Ocean Treader WEC	UK
Greencat Renewables	Wave Turbine	UK
GyroWaveGen	GyroWaveGen	USA
Hydam Technology	McCabe Wave Pump	Ireland
Independent Natural Resources	SEADOG	USA
Indian Wave Energy Device	IWAVE	India
Ing Arvid Nesheim	Oscillating Device	Norway
Instituto Superior Tecnico	Pico OWC	Portugal
Interproject Service (IPS) AB	IPS OWEC Buoy	Sweden
JAMSTEC	Mighty Whale	Japan
Joules Energy Efficiency Services Ltd.	TETRON	Ireland
Lancaster University	PS Frog	England
Langlee Wave Power	Langlee System	Norway

Company	Technology	Country Base
Leancon Wave Energy	Multi Absorbing Wave Energy Converter (MAWEC)	Denmark
Manchester Bobber	Manchester Bobber	UK
Martifer Energia	ONDA 1	Portugal
Motor Wave	Motor Wave	Hong Kong
Muroran Institute of Technology	Pendulor	Japan
Neptune Renewable Energy Ltd.	Triton	UK
Neptune Systems	MHD Neptune	Netherlands
Norwegian University of Science and Technology	CONWEC	Norway
Ocean Energy Ltd.	Ocean Energy Buoy	Ireland
Ocean Motion International	OMI Combined Energy System	USA
Ocean Navitas	Aegir Dynamo	UK
Ocean Power Technologies	Power Buoy	UK / USA
Ocean Wave Energy Company	OWEC	USA
Ocean Wavemaster Ltd.	Wave Master	UK

Company	Technology	Country Base
Oceanic Power	Seaheart	Spain
Oceanlinx (formerly Energetech)	Denniss-Auld Turbine	Australia
Offshore Islands Ltd.	Wave Catcher	USA
Offshore Wave Energy Ltd.	OWEL Energy Converter	UK
ORECon	MRC 1000	UK
OWWE (Ocean Wave and Wind Energy)	Wave Pump Rig	Norway
Pelagic Power AS	PelagicPower	Norway
Pelamis Wave Power	Pelamis	UK
Renewable Energy Holdings	CETO	Australia/UK
Renewable Energy Pumps	Wave Water Pump (WWP)	USA
Sara Ltd.	MHD Wave Energy Conversion (MWEC)	USA
SDE	S.D.E	Israel
Sea Power International AB	Streamturbine	Sweden
Seabased AB	Linear generator (Islandsberg project)	Sweden
Seawood Designs Inc.	SurfPower	Canada

Company	Technology	Country Base
SEEWEC Consortium	FO3 device, previously as Buldra	UK
SeWave Ltd.	OWC	Faroe Islands
Sieber Energy Inc.	SieWave	Canada
SRI International	Generator utilizing patented electroactive polymer artificial muscle (EPAM™) technology	USA
Swell Fuel	Lever Operated Pivoting Float	USA
SyncWave	SyncWave	Canada
Trident Energy Ltd, Direct Thrust Designs Ltd.	The Linear Generator	UK
Union Electrica Fenosa of Spain	OWC	Spain
University of Edinburgh	Salter's Duck	UK
Vortex Oscillation Technology Ltd.	Vortex oscillation	Russia
Wave Dragon	Wave Dragon	Wales / Denmark
Wave Energy	Seawave Slot-Cone Generator	Norway
Wave Energy Centre (WaVEC)	Pico plant	Portugal
Wave Energy Technologies Inc.	WET EnGen™	Canada

Company	Technology	Country Base
Wave Energy Technology	(WET-NZ)	New Zealand
Wave Power Group	Salter Duck, Sloped IPS	UK
Wave Star Energy ApS	Wave Star	Denmark
Waveberg Development	Waveberg	Canada
WaveBob Limited	Wave Bob	Ireland
Wavegen (Siemens)	Limpet	UK
Wavemill Energy	Wavemill	Canada
WavePlane Production	Wave Plane	Denmark
WindWavesAndSun	WaveBlanket	USA

Appendix 2

Diving Bird Population Estimates

Mitchell *et al*.'s (2004) study summarises results of the book Seabird 2000, a census of all seabirds breeding in Great Britain and Ireland during 1998-2002. Counts presented, therefore, reflect only breeding adults of seabird species and refer to Great Britain and Ireland (Northern Ireland and Republic of Ireland), the Isle of Man and the Channel Islands. This report presents population counts from Mitchell *et al.* (2004) for the following diving bird species (ordered according to population abundance in Welsh waters):

- Manx shearwater;
- Northern gannet;
- Lesser black-backed gull;
- Great cormorant;
- Herring gull;
- Razorbill;
- Common tern;
- Common guillemot;
- European storm-petrel;
- Arctic tern;
- European shag;
- Sandwich tern;
- Little tern;
- Atlantic puffin;
- Black-legged kittiwake:
- Black-headed gull
- Northern fulmar;
- Roseate tern;
- Black guillemot; and
- Sooty shearwater.

Baker *et al*.'s (2006) study reviews results of the Avian Population Estimates Panel (APEP) and draws on data prior to 2002 for most species. Counts presented, therefore, reflect breeding and wintering adults of all common bird species and report on Great Britain and UK populations. Great Britain includes the Isle of Man but excludes the Channel Islands, while UK counts combine those for Great Britain with Northern Ireland. For wintering species, there is currently insufficient up-to-date data to give accurate estimates for the Welsh coast. However, these species are listed in the review as they are known to have a widespread distribution in Welsh waters or they occur in lower numbers but may be vulnerable to MUREDs. This report presents population counts (where available) from Baker *et al*. (2006) for the following diving bird species (ordered according to population abundance in Welsh waters):

- Common scoter;
- Northern shoveler;
- Greater scaup;
- Common eider;
- Common goldeneye;
- Red-necked grebe;
- Slavonian grebe;
- Black-necked grebe;
- Little grebe
- Red-breasted merganser;
- Great northern diver;
- Black-throated diver;
- Red-throated diver; and
- Great crested grebe.

European Populations of the 35 Diving Bird Species Investigated in this Review

Mitchell *et al.* (2004) present seabird population estimates in an international context (where available). BirdLife International (2000 and 2004) also provides population estimates and trends. This information is summarised in Appendix Table 2A below. Note that the figures given are for the European Union countries only:

Appendix 2 Table 2A – European[25] Populations of the 35 Diving Bird Species Investigated in this Report, Listed in Order of Population Abundance in Welsh Waters

Species	Season	Overall Population Estimate (European Union countries)	Welsh Population Estimate[26]	Welsh % of European population
Manx shearwater *Puffinus puffinus*	Breeding	307,892 to 372,592 pairs (Mitchell *et al.*, 2004)	168,133 AOS	45 to 55%
Common scoter *Melanitta nigra*	Breeding	2,700–5,200 pairs (BirdLife International, 2004)	None	0%
	Winter	Minimum 610,000 individuals (BirdLife International, 2004)	21,779 (2006/2007 Cranswick *et al.*, 2005)	<4%
Lesser black-backed gull *Larus fuscus*	Breeding	300,000-350,000 pairs (BirdLife International, 2004)	20,722 AON	6-7%
Northern gannet *Morus bassanus*	Breeding	277,969 pairs (Mitchell *et al.*, 2004)	30,688 AOS/AON	11%
Great cormorant *Phalacrocorax carbo*	Breeding	14,210 pairs of subspecies *carbo* (Mitchell *et al.*, 2004)	1,699 AON (mostly *carbo*)	12% of *carbo*
	Winter	Minimum 260,000 individuals (BirdLife International, 2004)	Not available, likely to be ≤3,000 individuals (1%). Dee Estuary on Welsh/English border is of UK importance	Unknown
Herring gull *Larus argentatus*	Breeding	760,000-1,400,000 pairs (BirdLife International, 2004)	13,974 AON	1-2%

[25] European Union Countries Only

[26] Assessed from various sources (Austin, 2008; Mitchell, 2004 and RSPB website). AOS: Apparently occupied sites; AON: Apparently occupied nests; AOB: Apparently occupied burrows.

Species	Season	Overall Population Estimate (European Union countries)	Welsh Population Estimate[26]	Welsh % of European population
Razorbill *Alca torda*	Breeding	160,651 to 163,151 pairs (Mitchell *et al.*, 2004)	12,638 individuals	<4%
Common tern *Sterna hirundo*	Breeding	147,353 to 189,016 pairs (Mitchell *et al.*, 2004)	674 AON	<1%
Common guillemot *Uria aalge*	Breeding	1,067,785 to 1,067,835 pairs (Mitchell *et al.*, 2004)	57,961 individuals	<3%
Northern shoveler *Anas clypeata*	Winter	>200,000 individuals	>509 individuals	0.2%
European storm-Petrel *Hydrobates pelagicus*	Breeding	103,191 to 183,262 pairs (Mitchell *et al.*, 2004)	2,805 AOS	<3%
Arctic tern *Sterna paradisaea*	Breeding	149,082 to 166,511 AON (Mitchell *et al.*, 2004)	1,705 AON	1%
European shag *Phalacrocorax aristotelis*	Breeding	46,507 to 46,993 pairs (Mitchell *et al.*, 2004)	914 AON	<2%
	Winter	Minimum 3,000 individuals (BirdLife International, 2004)	Not available but likely to be ≤4,500 (%)	Unknown
	Breeding	55,343 to 57,751 pairs (Mitchell *et al.*, 2004)	450 AON	<1%
Sandwich tern *Sterna sandvicensis*	Breeding	14,479 to 17,104 AON (Mitchell *et al.*, 2004)	75 AON	<1%
Little tern *Sternula albifrons*	Breeding	621,257 AOB* (Mitchell *et al.*, 2004)	10,328 AOB	<2%
Atlantic puffin *Fratercula arctica*	Breeding	431,048 to 431,055 pairs (Mitchell *et al.*, 2004)	7,293 AON	<2%
Black-legged Kittiwake *Rissa tridactyla*	Winter	Unknown	Unknown	Unknown
	Breeding	1,500,000 – 2,200,000 pairs (BirdLife International, 2004)	850 AON	<0.1%
Black-headed gull	Winter	3,200,000 individuals (BirdLife International,	Unknown	Unknown

Species	Season	Overall Population Estimate (European Union countries)	Welsh Population Estimate[26]	Welsh % of European population
Larus ridibinus		2004)		
	Breeding	540,208 to 540,213 pairs (Mitchell *et al.*, 2004)	3,474 AOS	<1%
Northern fulmar *Fulmarus glacialis*	Winter	Unknown	Unknown	Unknown
	Breeding	1,870 to 2,394 pairs (Mitchell *et al.,* 2004)	2 AON	<1%
Roseate tern *Sterna dougallii*	Breeding	130,000-300,000 pairs (BirdLife International, 2004)	28 individuals	<0.1%
Black guillemot *Cepphus grille*	Passage	1,700–2,000 pairs (BirdLife International, 2004	Regular passage recorded through Welsh waters, minimal data	Unknown
Balearic shearwater *Puffinus mauretanicus*	Winter	Minimum 100,000 individuals (BirdLife International, 2004)	Concentrated on Dee Estuary on Welsh/English border	Unknown
Greater scaup *Aythya marila*	Breeding	490,000–610,000 pairs (BirdLife International, 2004)	None	None
Common eider *Somateria mollissima*	Winter	Minimum 880,000 individuals (BirdLife International, 2004)	Occurs along south Wales coast	Unknown
	Breeding	280,000–360,000 Pairs (BirdLife International, 2004)	None	None
Common goldeneye *Bucephala clangula*	Winter	Minimum 270,000 Individuals (BirdLife International, 2004)	Not available but widely distributed	Unknown
	Winter	Minimum 1,500 individuals (BirdLife International, 2004)	Very low numbers	Unknown
Red-necked grebe *Podiceps grisegena*	Breeding	3,300–5,700 pairs (BirdLife International, 2004)	None	None
Slavonian grebe *Podiceps auritus*	Winter	Minimum 1,800 individuals (BirdLife International, 2004)	Not available but occurs widely in low numbers. Lavan Sands in Wales is of UK importance	Unknown
	Breeding	9,100–13,000 pairs	None	None

Species	Season	Overall Population Estimate (European Union countries)	Welsh Population Estimate[26]	Welsh % of European population
		(BirdLife International, 2004)		
Black-necked grebe *Podiceps nigricollis*	Winter	Minimum 43,000 individuals (BirdLife International, 2004)	Not available but occurs in South Wales	Unknown
	Breeding	50,000–67,000 pairs (BirdLife International, 2004)	Not available but widely distributed along coast	Unknown
Little grebe *Tachybaptus ruficollis*	Winter	Minimum 45,000 individuals (BirdLife International, 2004)	Not available but widely distributed including sheltered coastal sites	Unknown
	Breeding	53,000 – 93,000 pairs (BirdLife International, 2004)	Not available but widely distributed	Unknown
Red-breasted merganser *Mergus serrator*	Winter	Minimum 52,000 individuals (BirdLife International, 2004)	Not available but widely distributed along coast. Lavan Sands in Wales is of UK importance	Unknown
	Winter	Minimum 4,200 individuals (BirdLife International, 2004)	Not available but widespread along coast in low numbers	Unknown
Great northern diver *Gavia immer*	Breeding	14,000–17,000 pairs(BirdLife International, 2004)	None	None
Black-throated diver *Gavia arctica*	Winter	Minimum 8,300 individuals (BirdLife International, 2004)	Occurs rarely in Welsh waters	Unknown
	Breeding	3,000–4,000 pairs (BirdLife International, 2004)	None	None
Red-throated diver *Gavia stellata*	Winter	Minimum 51,000 individuals (BirdLife International, 2004)	Not available but occurs widely around coast	Unknown
	Breeding	140,000–210,000 pairs (BirdLife International, 2004)	*Not on coastal waters in breeding season*	None
Great crested grebe *Podiceps cristatus*	Winter	Minimum 140,000 individuals (BirdLife International, 2004)	Widely distributed. Lavan Sands in Wales is of UK importance	Unknown
	Passage only –	Unknown		

Species	Season	Overall Population Estimate (European Union countries)	Welsh Population Estimate[26]	Welsh % of European population
	minimal data available			
Sooty shearwater *Puffinus griseus*				

Appendix 3

Existing Sites of Marine Protected Areas in Wales

Special Protection Areas

Carmarthen Bay

Burry Inlet

Castlemartin Coast

Dyfi Estuary

Aberdaron Coast and Bardsey Island

Holy Island Coast

Grassholm

Liverpool Bay

Mynydd Cilan, Trwyn y Wylfa ac Ynysoedd Sant Tudwal

Ramsey and St David’s Peninsula Coast

Severn Estuary

Skokholm and Skomer

The Dee Estuary

Lavan Sands, Conwy Bay

Ynys Feurig, Cemlyn Bay and The Skerries

Puffin Island

Ramsar Sites

Burry Inlet

Severn Estuary

Dee Estuary

Cors Fochno and Dyfi

Sites of Special Scientific Interest with Intertidal Features and Saltmarsh

Allt Wen A Traeth Tanybwlch

Arfordir Abereiddi

Arfordir Gogleddol Penmon

Marros-Pendine Coast

Newgale To Little Haven Coast

Pembrey Coast

Angle Peninsula Coast

Saundersfoot -Telpyn Coast

Barry Island

Beddmanarch-Cymyran

Benarth Wood

Blackcliff-Wyndcliff

Blackpill, Swansea

Borth -Clarach

Bracelet Bay

Broadwater

Broomhill Burrows

Burry Inlet And Loughor Estuary

Cadnant Dingle

Carmel Head

Carreg Y Llam

Castlemartin Cliffs and Dunes

Caswell Bay

Cemlyn Bay

Clegir Mawr

Cliff Wood -Golden Stairs

Coed Y Gell and Morfa Dulas

Coedydd Afon Menai

Cors Llyferin

Craig Ddu -Wharley Point Cliffs

Craig gr Alderyn

Craigyfulfran & Clarach

Creigiau Aberarth-Morfa

Creigiau Abergwaun (Fishguard Cliffs)

Creigiau Cwm-Ceriw A Ffos-Las (Morfa Bychan)

Creigiau Llansteffan (Llanstephan Cliffs)

Creigiau Pen Y Graig Little Ormes Head

Crymlyn Burrows

Kenfig Dale and South Marloes Coast

St Bride's Bay South

Dee Estuary

Dinas Dinlle

Dyfi

East Aberthaw Coast

Flat Holm

Freshwater East Cliffs to Skrinkle Haven

Gallt Y Bwlch

Glanllynnau A Glannau Pen-Ychain I Gricieth

Glannau Aberdaron

Glannau Penmon -Biwmares

Glannau Porthaethwy

Glannau Rhoscolyn

Glannau Tonfanau I Friog

Holy Island Coast

Glaslyn Gower Coast: Rhossili To Porteynon

Grassholm

Great Ornes Head

Gronant Dunes and Talacre Warren

Gwent Levels -Magor and Undy

Gwent Levels -Nash and Goldcliff

Gwent Levels -Redwick and Llandevenny

Gwent Levels -Rumney and Peterstone

Gwent Levels -St. Brides

Gwent Levels -Whitson

Gwydir Bay

Gwylan Island

Hayes Point to Bendrick Rock

Henborth

Hook Wood

Horton, Eastern And Western Slade

Langland Bay (Rotherslade)

Lavan Sands and Conwy Bay

Llanbadrig -Dinas Gynfor

Llyn Alaw

Llyn Trafwll

Lydstep Head to Tenby Burrows

Malltraeth Marsh

Merthyr Mawr

Milford Haven Waterway

Minchin Hole

Minwear Wood

Monknash Coast

Cwm Ivy Marsh and Tor

Morfa Abererch

Morfa Dinlle

Morfa Dyffryn

Morfa Harlech

Morfa Uchaf, Dyffryn Conwy

Mynydd Penarfynnydd

Mynydd Tir Y Cwmwd A'r Glannau at Garreg Yr Imbill

Newborough Warren -Ynys Llanddwyn

Newport Cliffs

Oxwich Bay

Pen Benar

Great Ormes Head

Penard Valley

Penarth Coast

Penrhynoedd Llangadwaladr

Pierce, Alcove and Piercefield Woods

Porth Ceiriad, Porth Neigwl Ac Ynysoedd Sant Tudwal

Porth Dinllaen I Borth Pistyll

Porth Towyn I Borth Wen

Puffin Island -Ynys Seiriol

Pwll-Du Head and Bishopston Valley

Ramsey

Rhoscolyn Reedbed

Rhosneigr

Rhosneigr Reefs

Rhossili Down River Usk (Lower Usk)

River Wye (Lower Wye)

Severn Estuary

Shotton Lagoon and Reedbanks

Skokholm

Skomer Island and Middleholm

Slebech Stable Yard Loft, Cellars & Tunnels

Southerndown Coast

St. David's Peninsula Coast

St. Margaret's Island

Stackpole

Stackpole Quay -Trewent Point

Strumble Head -Llechdafad Cliffs

Sully Island

Tenby Cliffs and St. Catherine's Island

The Offshore Islets of Pembrokeshire

The Skerries

Tiroedd A Glannau Rhwng Cricieth Ac Afon Glaslyn

Traeth Lafan

Traeth Llanon

Traeth Lligwy

Traeth Pensarn

Trwyn Dwlban

Twyni Chwitffordd, Morfa Landimor A Bae Brychdwn/Whiteford Burrows Etc

Laugharne -Pendine Burrows

Ty Croes Tywyn Aberffraw

Valley Lakes

Waterwynch Bay to Saundersfoot Harbour

Whitehill Down

Wig Bach A'r Glannau I Borth Alwm

Y Foryd

Ynys Enlli

Ynys Feurig

Ynysoedd Y Gwylanod, Gwylan Islands

Yr Eifl

Marine Nature Reserve

Skomer