Shetland Tidal Array Monitoring Report: Land-based bird and mammal surveys

Version 2.0

Document control

Title:	Shetland Tidal Array Monitoring Report: Land-based bird and mammal surveys
Document ID:	EnFAIT-0394
Version	Version 2.0
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Approved by:	Gavin McPherson
Release date:	12-Dec-22
Confidentiality:	COMMERCIAL IN CONFIDENCE

Revision history

Version	**Release date**	**Purpose/summary of amendments**
1.0	27/10/2022	Present results from analysis of land-based bird and mammal surveys from the Shetland Tidal Array area, Bluemull Sound.
2.0	12/12/2022	Incorporates feedback on Version 1.0 following consultation with Marine Scotland Licensing Operations Team, Shetland Islands Council and NatureScot.

Notice

Contents

1 Summary

Nova Innovation's ongoing programme of environmental monitoring for the Shetland Tidal Array in Bluemull Sound comprises the following two key components:

1. Land-based diving bird and marine mammal observation surveys in Bluemull Sound.
2. Subsea monitoring using turbine-mounted optical video cameras.

Combined, these methods gather data to understand the likely nature and consequences of any nearfield interactions between turbines in the array and marine wildlife, with a focus on mammals and diving birds.

This report presents the results from land-based bird and mammal surveys carried out at the project site between March 2020 and 2022. A second report presents the results from analyses of subsea video footage gathered from turbine-mounted cameras during the same period (Nova Innovation, 2022a).

Data from 144 hours of land-based surveys are presented in this report, spanning the two-year reporting period and comprising seventy-two 2-hour surveys carried out from a vantage point on the Ness of Cullivoe overlooking the project site. Each 2-hour survey gathered data on the presence, occupancy patterns and behaviour of diving birds and marine mammals in the Shetland Tidal Array area using the following methods:

1. Snapshot scans to count and identify all marine mammals and diving birds[1] in the survey area.
2. Focal watches of individual birds to observe and record their behaviour in the survey area more closely.

This report focusses on analysis of the scan data gathered during the 2020 to 2022 land-based surveys. Detailed modelling and analysis of the corresponding focal watch data was carried out by a postgraduate student working with Nova Innovation, supervised by Dr James Waggitt at Bangor University. The results are detailed in a separate report (Holmes, 2022). In addition, further analysis of data gathered during Nova's land-based surveys in Bluemull Sound between 2010 and 2019 has been carried out by a second postgraduate student also working with Nova, supervised by Dr Waggitt. These results are also presented in a separate report (Brown, 2021).

Key findings from the focal watches (Holmes, 2022), further analysis of Nova's land-based surveys conducted from 2010 to 2019 (Brown, 2021) and subsea video monitoring (Nova Innovation 2022a) are integrated into the discussion section of this report. Combined, they facilitate interpretation of the observed patterns and drivers of fine-scale movements and occupancy patterns of birds and mammals in the Shetland Tidal Array area. This enables an evidence-based approach to assessing the likelihood that diving birds and marine mammals might interact with turbines in the Shetland Tidal Array, and key influencing factors. This has enabled new insights into impact risk for the different species, further building on learning since the commencement of the monitoring programme in November 2010.

[1] Species capable of diving to turbine rotor depth of 15 m below sea level.

2 The Shetland Tidal Array

2.1 Location

The Shetland Tidal Array is situated in Bluemull Sound, between the islands of Unst and Yell, just offshore from the Ness of Cullivoe, as illustrated in Figure 2-1.

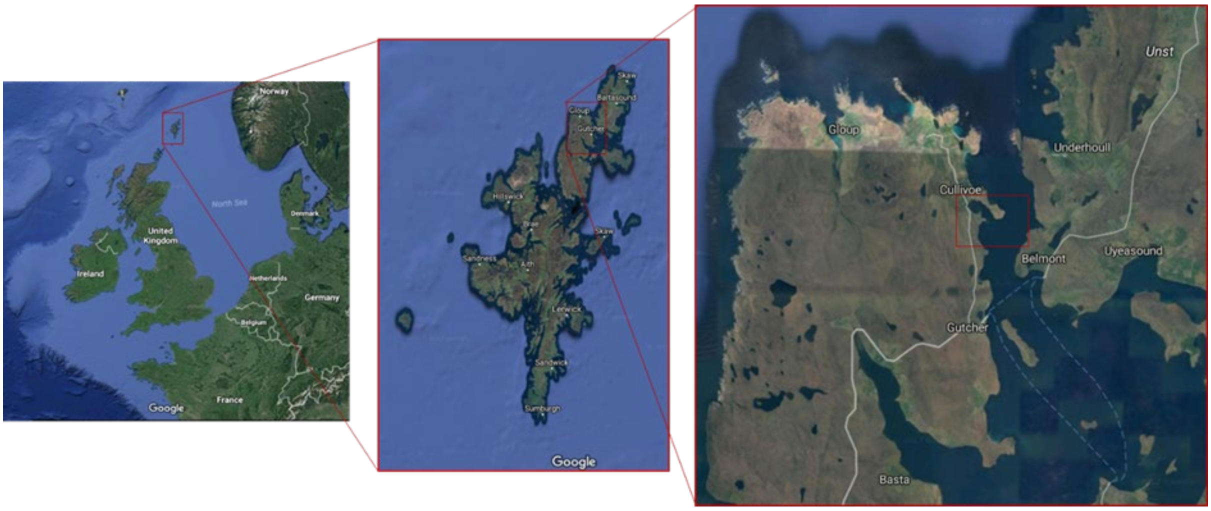

Figure 2-1 Location of the Shetland Tidal Array in Bluemull Sound, Shetland.

2.2 Project details

The Shetland Tidal Array currently consists of four Nova M100 tidal turbines, a 2-bladed, horizontal axis device, shown in Figure 2-2.

Figure 2-2 The Nova M100 turbine. *Source: Nova Innovation 2018*

The first two turbines (T1 and T2) were deployed in October 2015 and August 2016, the third (T3), in August 2017 and the fourth (T4) in October 2020.

All four turbines are installed subsea at a depth of 30-40m. The turbines use gravity base foundations that require no piling or drilling. Figure 2-3 shows the layout of the existing four turbines and infrastructure in the Shetland Tidal Array, as well as the planned location of two further turbines (T5 and T6) scheduled to be installed in late 2022/early 2023.

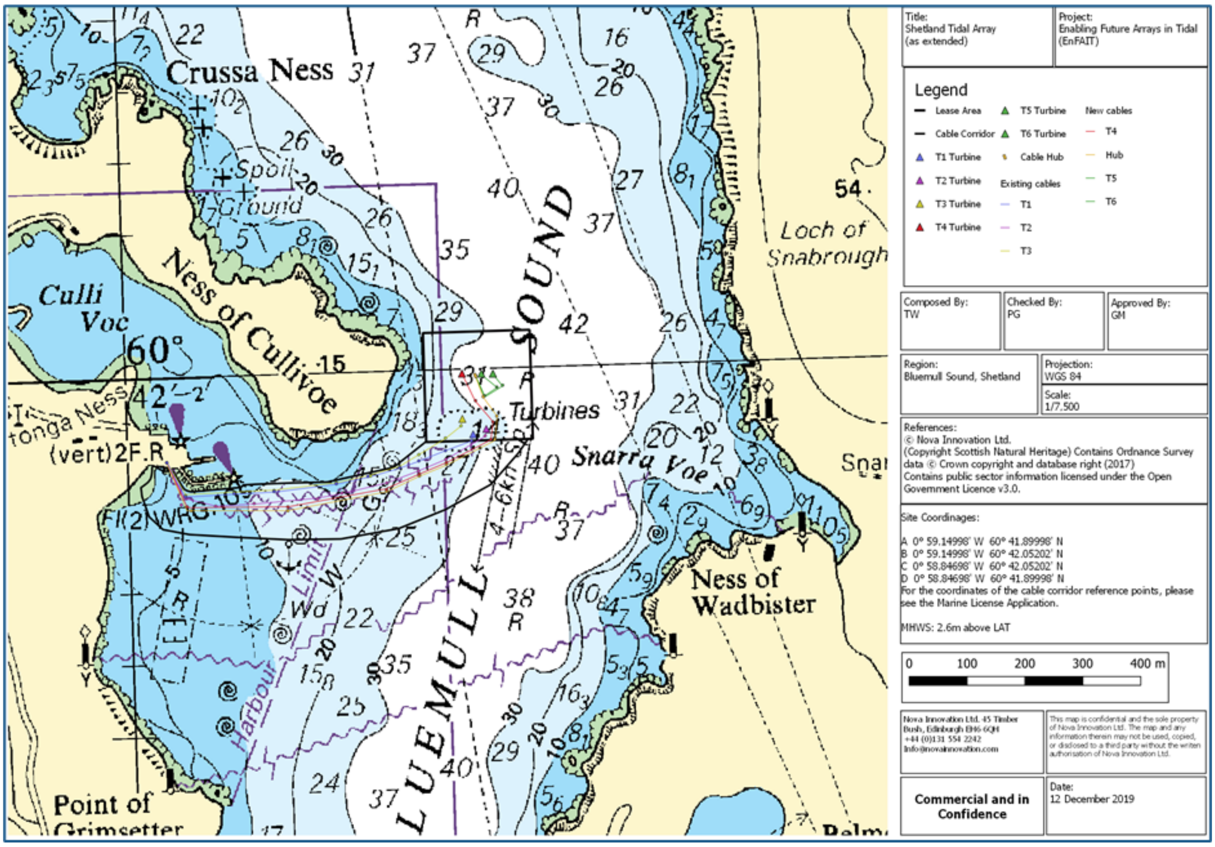

Figure 2-3 Shetland Tidal Array layout (Admiralty Chart). *Source: Nova Innovation 2020 © Crown Copyright*

2.3 Overview of environmental monitoring programme

Full details of the programme of environmental monitoring for Nova Innovation's Shetland Tidal Array in Bluemull Sound, Shetland are provided in the Project Environmental Monitoring Plan (Nova Innovation, 2022b). The monitoring comprises the following two key components, which combined gather data to understand the likely nature and consequences of any nearfield interactions between turbines in the array and marine wildlife, with a focus on mammals and diving birds:

1. Land-based diving bird and marine mammal observation surveys in Bluemull Sound.

2. Subsea monitoring using turbine-mounted optical video cameras.

This report presents the results from analysis of land-based bird and mammal surveys carried out at the project site between March 2020 and March 2022. Restrictions during the Covid-19 pandemic meant that surveys were not carried out from March to June 2020, inclusive. However, for consistency with the project monitoring reporting schedule set out in the PEMP, this report refers to the March 2020 to March 2022 reporting period.

The focus of this analysis in this report is on refining understanding about whether species of diving birds and marine mammals are likely to interaction with operational turbines in the Shetland Tidal Array.

The land-based surveys have also been used to inform a structured approach to selecting a subset of data gathered from turbine-mounted cameras for manual review and analysis, as detailed in a separate report (Nova Innovation, 2022a). Both reports are provided in support of discharge of conditions attached to the following licences for the Shetland Tidal Array:

1. Marine Licence MS-00009110, issued by Marine Scotland Licensing Operations Team on behalf of the Scottish Ministers, under the Marine (Scotland) Act 2020.
2. Shetland Islands Council (SIC) Works Licence 2022/015/WL, issued by Shetland Islands Council under the Zetland County Council Act 1974.

3 Land-based surveys

3.1 Objectives

The objectives of the land-based marine bird and mammal surveys conducted in Bluemull Sound are set out in the Project Environmental Monitoring Plan (PEMP), and as follows:

1. To gather information on the presence and abundance of diving birds and marine mammals in the immediate array area, as a key factor influencing collision risk for the Project.
2. To gather information on the fine-scale movements and behaviour of diving birds and marine mammals within the immediate array area, as a key factor influencing collision risk for the Project.
3. To gather information to better understand the relationship between surface and subsea wildlife observations and to inform a sampling protocol for analysis of simultaneous video footage gathered from turbine-mounted subsea cameras.
4. To meet the requirements of condition 3.2.1.1 of Marine Licence MS-00009110 issued by Marine Scotland.
5. To meet the requirements of conditions 3 and 11 of Works Licence 2022/015/WL issued by Shetland Islands Council.

3.2 Methods

3.2.1 Survey area and design

The land-based surveys were conducted from a vantage point approximately 10m above sea level on the Ness of Cullivoe at the following position:

60.69949°N	-0.97091°W

This vantage point provides good coverage and uninterrupted views of the survey area, while avoiding disturbance to otters on the shoreline of the Ness of Cullivoe. The survey area encompasses the following:

1. The sea area in which the existing four turbines (T1 to T4) are located.
2. The area in which the remaining two turbines (T5 and T6) will be installed.
3. A buffer around the entire area in which turbines are or will be located.

Figure 3-1 shows the survey area, which covers a total area of approximately 0.19 km^2. The figure shows the sightlines to landmarks on Unst used by the surveyor to demarcate the northern and southern limits of the survey area. The curved boundary reduces problems of survey area delineation, as it follows a constant distance from the surveyor. The near boundary of the survey area is the shoreline. The maximum distance from the surveyor to the edge of the survey area is 500 m, while the turbines are all located within 300 m of the surveyor. Figure 3-1 also shows the locations of the existing four turbines (T1 to T4), the locations of the two additional turbines that will be added to the array in 2022/23 and the seabed area leased to Nova by Crown Estate Scotland.

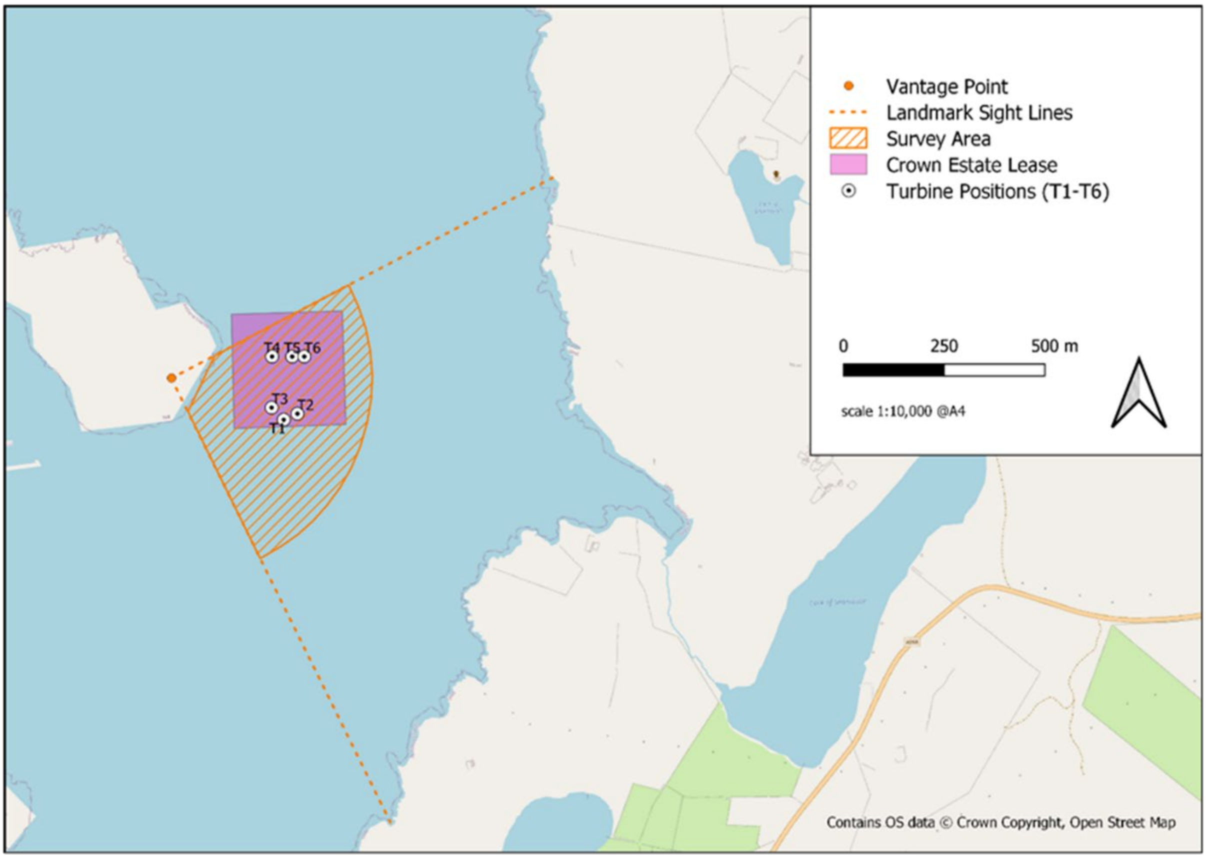

Figure 3-1 Land-based survey area in Bluemull Sound, showing locations of the four installed turbines (T1 to T4) and locations of turbines in the expanded array (T5 to T6).

All land-based surveys were carried out in sea state 2 or less and during periods of good visibility, to ensure confidence in the data. Over the period between March 2020 and March 2022, surveys were carried out across the full tidal cycle, which was divided into six 2-hour periods, as follows:

1. Increasing flood: 2-4 hours after low water (LW), starts immediately after LW slack in Bluemull Sound.
2. Maximum flood: 4-6 hours after LW.
3. Decreasing flood: 0-2 hours after high water (HW), starts 1.5 hours before and straddles HW slack in Bluemull Sound.
4. Increasing ebb: 2-4 hours after HW, starts around 30 minutes after HW slack in Bluemull Sound.
5. Maximum ebb: 4-6 hours after HW.
6. Decreasing ebb: 0-2 hours after LW, starts 2 hours before LW slack in Bluemull Sound.

These tidal periods are defined according to local conditions in Bluemull Sound derived from Nova's tidal model and are set out in Figure 3-2.

	HIGH WATER						LOW WATER						HIGH WATER	
Time after HW/LW	6th hr	1st hr	2nd hr	3rd hr	4th hr	5th hr	6th hr	1st hr	2nd hr	3rd hr	4th hr	5th hr	6th hr	1st hr
Bluemull slacks			HW SLACK						LW SLACK					
Simplified slacks			HW SLACK						LW SLACK					
Relative speed (R.O. Twelfths)	3	2	1	1	2	3	3	2	1	1	2	3	3	2
Direction	FLOODING			EBBING						FLOODING				
Tidal Periods	MF	**Decreasing Flood**		**Increasing Ebb**		**Maximum Ebb**		**Decreasing Ebb**		**Increasing Flood**		**Maximum Flood**		DF

Figure 3-2 The six tidal periods within the tidal cycle during which land-based surveys are conducted.

The survey was designed to spread effort for each 2-hour tidal period over time. Details of survey effort for each tidal period between March 2020 and March 2022 are provided in Section 5).

The survey design also took account of key annual stages for diving birds, cetaceans[2] and grey and common seals by dividing the year into four annual periods, detailed in Table 3-1. Over the year, sampling frequency is asymmetric across the four annual periods, as limited daylight hours during winter in Shetland (approximately 09:00 to 15:00) prevent the completion of surveys over two full tidal cycles. The frequency of sampling across the four annual periods is detailed in Table 3-1.

Table 3-1 The four annual periods during which land-based surveys were undertaken.

Annual period and key stage for birds & mammals	Details	Survey frequency within period
1: Breeding season (birds), common seal pupping, grey seal moulting, harbour porpoise birth period.	April to July	Two complete tidal cycle (12 x 2 hr surveys)
2: Post-breeding/moult (birds, common seal), harbour porpoise breeding season, gannet fledging.	August to mid-September	Two complete tidal cycle (12 x 2 hr surveys)
3: Autumn (start of grey seal pupping).	Mid-September to October	Two complete tidal cycles (12 x 2 hr surveys)
4: Winter (grey seal pupping).	November to March	One complete tidal cycle (6 x 2 hr surveys)

[2] Key stages for harbour porpoise included, as the most common cetacean recorded in surveys to date.

3.2.2 Survey protocol

Equipment

All land-based surveys between March 2020 and March 2022 were carried out by the same surveyor using Swarovski EL 8.5 x 42 binoculars, with a Swarovski ATS 65 HD 25-50 zoom spotting scope for confirming species identification, where necessary. A stopwatch and Dictaphone were used to enable the surveyor to maintain visual contact with the survey area during counts and focal watches. Data were transcribed into excel following surveys.

Snapshot scans

Each 2-hour survey was divided into two 60-minute survey periods, with a 10-minute break midway to ensure surveyor welfare and maintenance of concentration and data quality. In each 60-minute survey period, up to ten snapshot counts of all diving birds and mammals were carried out. Where possible, the ten counts were spread evenly throughout the 60-minute survey period, at 0 mins, 5 mins, 10 mins, 15 mins, 20 mins, 35 mins, 40 mins, 45 mins, 50 mins, 55 mins (with 10-minute break at 25 mins). The varying length of focal watches meant scans could not always be conducted at these precise intervals, but this does not affect the relevance of the data since it is not used to calculate density estimates.

During snapshot counts diving birds and mammals were identified to species level and counted. If the tide was running scans were carried out against the tide to minimise double counting. Birds were only recorded as sightings if on the surface, diving or hovering above the survey area. Birds flying through the survey area were not counted. All mammals in the survey area during snapshot scans were counted.

Focal watches

Focal watches were interspersed with the snapshot counts in each 60-minute survey period, as an additional technique for gathering data on how animals interact with the project site, for example for foraging or transiting. The design of and rationale for focal watches was based on information in Waggitt & Scott (2014) and Waggitt et al (2014) and on advice provided to Nova by Dr James Waggitt.

An individual bird (either a European shag or black guillemot) in the survey area was selected[3] and followed with binoculars. Every 5 seconds a record was made of whether the bird was on the surface (S) or below the surface/diving (D). Focal watch observations were recorded in the field as tallies, using a stopwatch with audible alarm and Dictaphone enabling totals to be calculated afterwards. Individual birds were watched until they left the survey area from the surface or resurfaced outside the survey area. If an individual was not observed re-surfacing after 60 seconds it was assumed to have moved on unobserved. Focal watches varied in length from only a few seconds up to several minutes, resulting in a different number of focal watches within each 60-minute survey period.

To ensure that focal watches provide a robust record of behaviour within the survey area, the following ‘rules’ were followed:

[3] Initially it was proposed to target all species of diving birds and marine mammals in focal watches. However, black guillemot and European shag were the only species consistently present in numbers to obtain data sufficient for detailed analysis. These species are also thought to be particularly at risk of nearfield interactions with turbines, since they frequently dive to the seafloor to depths within range of turbine installations such as the Shetland Tidal Array (Furness et al., 2012). These two species were therefore targeted for focal watches.

1. Individual birds were selected for focal watches rather than those within large groups, since these individuals were easier to follow. Data gathered to date in Bluemull Sound suggest that large groups of birds are rare at the site (Nova Innovation, 2021a).

2. The individual bird nearest the surveyor but within the survey area was selected to watch.

3. If European shag and black guillemot were present within the 60-minute survey an attempt was made to carry out focal watches for at least one individual of each species.

4. On the flood tide (north to south), if possible, individuals at the north end of the survey were selected for focal watches. On the ebb tide (south to north), individuals at the south end were selected. This increases the chance that the watch will take the individual past the turbine area, rather than out of the survey area.

3.2.3 Clarification on potential issues with methods

Detection bias

Surface count data gathered from a land-based vantage point can be subject to bias caused by reduced detectability with increasing distance from the observer. Scottish Natural Heritage (now NatureScot) guidance on survey and monitoring for marine renewables deployments in Scotland indicates that detections using binoculars of marine birds will fall off markedly beyond about 700m (Jackson and Whitfield, 2011). All of the survey area is within 500m of the vantage point, so detection decay is unlikely to be a significant issue.

Availability bias

There is no published literature on dive times in tidal energy habitats, which is likely to be quite different to that in other habitats. Provisional data (Waggitt, unpublished, pers. comm.) suggests that dive times are shorter and shallower dives in areas of faster currents, so availability bias is less likely to be an issue in habitats like Bluemull Sound. The focal watches will provide data to help understand the degree of possible availability bias.

Replication of animals in focal follows

Whilst a potential weakness in the focal watch methodology may be that the same birds or mammals might be unknowingly followed multiple times, the replication of watches over time will increase the sample size and confidence that data are representative of the occupancy patterns and behaviour of each of the species observed.

4 Data analysis

4.1 Scan data March 2020 to March 2022

The snapshot scans gather data on the presence and abundance of all diving birds and marine mammals in the array area at different times of the year, across the tidal cycle. The dataset gathered between March 2020 and March 2022 is relatively small and for most species, zero-dominated. Descriptive statistics have therefore been used to explore the likelihood of near-field encounters between turbines and diving birds and marine mammals and how this varies with different times of the year and tidal state.

4.2 Focal watch data

The focal watches gather detailed data on fine-scale movements and behaviour of the two species that are consistently present in the array area, namely European shag (*Gulosus aristotelis*) and black guillemot, (*Cepphus grylle*). Detailed modelling and analysis for these data was carried out by a postgraduate student working in collaboration with Nova Innovation and supervised by Dr James Waggitt at Bangor University. The results from this analysis are presented in a separate report (Holmes, 2022) with key findings provided in the discussion section of this report (Section 7).

4.3 Further analysis of historic land-based survey data

In 2021 Nova produced a report presenting the results from analyses of the nine-year programme of land-based marine wildlife observation surveys conducted between 2010 and 2019 in Bluemull Sound (Nova Innovation, 2021a). This dataset was further analysed in this current reporting period by a postgraduate student working in collaboration with Nova and supervised by Dr James Waggitt at Bangor University. This work combined data on the presence and numbers of seabirds and marine mammals gathered during Nova's land-based surveys in Bluemull Sound between 2010 and 2019 with information on environmental conditions (including sea surface temperature, salinity and wind). This enabled an assessment of the influence of environmental conditions on the likelihood that species might interact in the nearfield with operational turbines in the Shetland Tidal Array. The results from this work are presented in a separate report (Brown, 2021) with key findings provided in the discussion section of this report (Section 7).

5 Survey effort

Seventy-two 2-hour surveys were carried out in the current reporting period, from March 2020 to March 2022[4]. These surveys represent a total survey effort of 144 hours. Table 5-1 details survey effort for the four annual period and six tidal periods.

Table 5-1 Total surveys across a) annual period and b) tidal period for the reporting period.

a) Annual period

	No surveys
Annual period 1 (April to July)	17
Annual period 2 (August to mid-September)	25
Annual period 3 (Mid-September to October)	18
Annual period 4 (November to March)*	12

* Surveys did not start until July 2020.

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b) Tidal period

	No surveys
Tidal period 1 (Increasing flood)	12
Tidal period 2 (Maximum flood)	11
Tidal period 3 (Decreasing flood)	12
Tidal period 4 (Increasing ebb)	12
Tidal period 5 (Maximum ebb)	13
Tidal period 6 (Decreasing flood)	12

[4] Covid restrictions means that surveys were not carried out from March to June 2020. For consistency with the project monitoring reporting schedule set out in the PEMP, this report refers to the March 2020 to March 2022 reporting period.

6 Results

6.1 Species recorded

All species recorded in land-based surveys in Bluemull Sound between March 2020 and March 2022 were identified with very high confidence to species level. Ten species of diving birds and five species of marine mammals were recorded. Details of the fifteen species and the numbers of separate 2-hour surveys (from the total of 72) in which each was recorded are provided in Tables 6-1 and 6-2. The total numbers of individuals of each species recorded across all surveys between March 2020 and March 2022 are also provided.

Table 6-1 Diving bird and marine mammal species recorded in Bluemull Sound land-based surveys between March 2020 and March 2022.

Common name	Scientific name	Number of surveys in which recorded (N=72)	Total individuals recorded in all surveys
Anatidae (ducks, geese and swans)			
Long-tailed duck	*Clangula hyemalis*	3	16
Alcidae (auks)			
Common guillemot	*Uria aalge*	13	81
Razorbill	*Alca torda*	7	17
Black guillemot	*Cepphus grylle*	72	1582
Atlantic puffin	*Fratercula articulata*	18	310
Gaviidae (divers)			
Red-throated diver	*Gavia stellata*	9	21
Great northern diver	*Gavia immer*	1	1
Sulidae (gannets)			
Northern gannet	*Morus bassanus*	32	175
Phalacrocoracidae (cormorants and shags)			
Great cormorant	*Phalacrocorax carbo*	3	17
European shag	*Gulosus aristotelis*	68	1075

Table 6-2 Marine mammals bird species recorded in Bluemull Sound vantage point surveys.

Common name	Scientific name	Number of surveys in which recorded (N=72)	Total individuals recorded in all surveys
Phocidae (seals)			
Grey seal	*Halichoerus grypus*	3	7
Common seal	*Phoca vitulina*	8	18
Phocoenidae (toothed whales)			
Harbour porpoise	*Phocoena phocoena*	9	13
Delphinidae (oceanic dolphins)			
Killer whale	*Orca orcinus*	1	8
Balaenopteridae (rorquals)			
Minke whale	*Balaenoptera acutorostrata*	2	2

All fifteen of these species had been recorded in previous land-based surveys at the project site (Nova Innovation, 2021a). As has been observed previously, only European shag (*Gulosus aristotelis*) and black guillemot (*Cepphus grylle*) were recorded either consistently or in high numbers at the project site. This is also consistent with previous surveys and other similar tidal sites in the north of Scotland (James Waggitt, pers. comm.).

Variations in the presence and abundance of the fifteen species recorded in land-based surveys throughout the year and with tidal state are explored in the following sections.

6.2 Species recorded by annual period

The land-based surveys conducted in Bluemull Sound between March 2020 and March 2022 were designed to distribute effort over four annual periods. These annual periods were defined by key annual stages in breeding cycles of diving birds and cetaceans and moulting and breeding periods of common and grey seals, detailed in Table 3-1 (Section 3).

Tables 6-3 and 6-4 provide descriptive statistics for diving bird and mammal species in the 2-hour surveys between March 2020 and March 2022 for each of the four annual periods.

Table 6-3 Mean abundance (± standard deviation) of diving bird species by annual period in land-based surveys between March 2020 and March 2022. Figures in brackets are the number of surveys from the total for each period (N) in which the species was present; figure in bold is the most individuals recorded in any single 2-hr survey.

Species	April to July (N=17)	August to mid-September (N=25)	Mid-September to October (N=18)	November to March (N=12)
Long-tailed duck			0.11 ± 0.47 (1/18) **2**	1.17 ± 2.76 (2/12) **8**
Common guillemot	3.18 ± 6.49 (7/17) **26**	0.12 ± 0.44 (2/25) **2**	1.33 ± 3.55 (4/18) **12**	
Razorbill	0.24 ± 0.97 (1/17) **4**	0.24 ± 1.01 (2/25) **5**	0.39 ± 0.98 (4/18) **4**	
Black guillemot	18.82 ± 15.03 (17/17) **57**	19.56 ± 13.55 (25/25) **48**	32.39 ± 27.30 (18/18) **91**	15.83 ± 12.20 (12/12) **46**
Atlantic puffin	17.71 ± 36.18 (16/17) **154**	0.36 ± 1.60 (2/25) **8**		
Red-throated diver	0.35 ± 0.79 (3/17) **2**	0.56 ± 1.39 (5/25) **6**	0.06 ± 0.24 (1/18) **1**	
Great northern diver				0.08 ± 0.29 (1/12) **1**
Northern gannet	1.29 ± 3.87 (5/17) **16**	5.64 ± 6.80 (21/25) **30**	0.33 ± 0.77 (4/18) **3**	0.50 ± 1.24 (2/12) **4**
Great cormorant	0.12 ± 0.49 (1/17) **2**			1.25 ± 3.49 (2/12) **12**
European shag	5.47 ± 6.52 (14/17) **22**	21.84 ± 57.14 (24/25) **293**	13.56 ± 17.30 (18/18) **67**	16.00 ± 13.33 (12/12) **45**

Table 6-4 Mean abundance (± standard deviation) of marine mammal species by annual period in land-based surveys between March 2020 and March 2022. Figures in brackets are the number of surveys from the total for each period (N) in which the species was present; figure in bold is the most individuals recorded in any single 2-hr survey.

Species	April to July (N=17)	August to mid-September (N=25)	Mid-September to October (N=18)	November to March (N=12)
Grey seal		0.12 ± 0.6 (1/25) **3**	0.17 ± 0.71 (1/18) **3**	0.08 ± 0.29 (1/12) **1**
Common seal		0.24 ± 0.83 (2/25) **3**	0.56 ± 1.34 (4/18) **5**	0.17 ± 0.39 (2/12) **1**
Harbour porpoise		0.68 ± 1.13 (6/25) **4**	0.33 ± 0.84 (3/18) **3**	
Killer whale			0.44 ± 1.86 (1/18) **8**	
Minke whale	0.06 ± 0.24 (1/17) **1**	0.04 ± 0.20 (1/25) **1**		

The figures in Tables 6-2 and 6-3 give an indication of the persistency of presence and abundance of each species at the project site throughout the year. However, care should be taken in drawing anything other than high-level conclusions from the data, given the low frequency and abundance of most species recorded. The fact that for all species except black guillemot (and European shag in winter), standard deviation is greater than the mean indicates that presence and abundance at the site is highly variable in all seasons.

6.3 Species recorded by tidal period

The land-based surveys conducted in Bluemull Sound between March 2020 and March 2022 were designed to distribute effort over the full tidal cycle, divided into six 2-hour tidal periods. These six periods were defined according to local conditions in Bluemull Sound derived from Nova's tidal model and are set out in Section 3.2.1.

Tables 6-5 and 6-6 provide descriptive statistics for diving bird and mammal species in the 2-hour surveys between March 2020 and March 2022 for each of the six tidal periods.

Table 6-5 Mean abundance (± standard deviation) of marine mammal species by tidal period in land-based surveys between March 2020 and March 2022. Figures in brackets are the number of surveys from the total for each period (N) in which the species was present; figure in bold is the most individuals recorded in any single 2-hr survey.

Species	Increasing flood (N=12)	Maximum flood(N=11)	Decreasing flood (N=12)	Increasing ebb (N=12)	Maximum ebb (N=13)	Decreasing ebb (N=12)
Long-tailed duck	0.17 ± 0.58 (1/12) **2**		1.17 ± 0.58 (2/12) **2**			
Common guillemot	1 ± 2.89 (2/12) **10**		0.25 ± 0.62 (2/12) **2**	1 ± 2.22 (3/12) **7**	3.15 ± 7.35 (4/13) **26**	1.08 ± 3.45 (2/12) **12**
Razorbill		0.18 ± 0.40 (2/11) **1**		0.08 ± 0.29 (1/12) **1**	0.77 ± 1.69 (3/13) **5**	0.33 ± 1.15 (1/12) **4**

Species	Increasing flood (N=12)	Maximum flood(N=11)	Decreasing flood (N=12)	Increasing ebb (N=12)	Maximum ebb (N=13)	Decreasing ebb (N=12)
Black guillemot	28.08 ± 20.63 (12/12) **70**	16 ± 12.63 (11/11) **42**	20.83 ± 15.02 (12/12) **47**	33.46 ± 23.28 (12/12) **91**	19.62 ± 20.99 (13/13) **85**	10.75 ± 8.54 (12/12) **23**
Atlantic puffin	2.17 ± 4.24 (3/12) **13**	0.27 ± 0.65 (2/11) **2**	1.17 ± 2.44 (4/12) **8**	2.67 ± 5.40 (3/12) **17**	5.69 ± 10.85 (3/13) **27**	13.42 ± 44.31 (3/12) **154**
Red-throated diver	0.58 ± 1.73 (2/12) **6**	0.09 ± 0.30 (1/11) **1**		0.50 ± 0.90 (3/12) **2**	0.15 ± 0.55 (1/13) **2**	0.42 ± 1.00 (2/12) **3**
Great northern diver				0.08 ± 0.29 (1/12) **1**		
Northern gannet	1 ± 1.35 (5/12) **3**	1.73 ± 2.87 (5/11) **9**	5.17 ± 8.91 (5/12) **30**	5.85 ± 6.58 (8/12) **18**	1.38 ± 2.63 (5/13) **9**	0.75 ± 1.36 (4/12) **4**
Great cormorant			1.00 ± 3.46 (1/12) **12**	0.17 ± 0.58 (1/12) **2**	0.23 ± 0.83 (1/13) **3**	
European shag	8.50 ± 6.84 (10/12) **23**	15.18 ± 21.09 (11/11) **67**	42.25 ± 80.45 (11/12) **293**	7.08 ± 6.69 (12/12) **24**	7.08 ± 5.72 (12/13) **22**	10.17 ± 6.89 (12/12) **21**

Table 6-6 Mean abundance (± standard deviation) of marine mammal species by tidal period in land-based surveys between March 2020 and March 2022. Figures in brackets are the number of surveys from the total for each period (N) in which the species was present; figure in bold is the most individuals recorded in any single 2-hr survey.

Species	Increasing flood (N=12)	Maximum flood (N=11)	Decreasing flood (N=12)	Increasing ebb (N=12)	Maximum ebb (N=13)	Decreasing ebb (N=12)
Grey seal		0.55 ± 1.21 (2/11) **3**				0.08 ± 0.29 (1/12) **1**
Common seal	0.08 ± 0.29 (1/12) **1**	1.09 ± 1.76 (4/11) **5**	0.33 ± 0.89 (2/12) **3**			0.08 ± 0.29 (1/12) **1**
Harbour porpoise	0.42 ± 1.00 (2/12) **3**	1.00 ± 1.48 (4/11) **4**	0.08 ± 0.29 (1/12) **1**	0.17 ± 0.58 (1/12) **2**	0.31 ± 0.11 (1/13) **4**	
Killer whale		0.72 ± 2.42 (1/11) **8**				
Minke whale					0.08 ± 0.29 (1/13) **1**	0.08 ± 0.27 (1/12) **1**

The figures in the tables provide an indication of the persistency of presence and abundance of each species at the project site across the tidal cycle. However, as with the results for annual period, care should be taken in drawing anything other than high-level conclusions from the data, particularly where numbers are low, or standard deviation is greater than the mean.

European shag numbers were generally greater on the flood tide than the ebb. Black guillemot numbers, and Atlantic puffin, were relatively greater on ebb tides. European shag numbers were greatest around high water slack on the decreasing flood tide, through this was subject to high variability. Black guillemot numbers were relatively greater immediately following high and low water slack on the increasing flood and ebb tides.

Possible variations in use of the site between flood and ebb tides for European shag, black guillemot and Atlantic puffin were further explored by amalgamating all survey data for these three species across the flood and ebb tide[5]. Gannet was included in this examination, as the only other species persistently present at the project site The results are presented in Table 6-7.

Table 6-7 Mean abundance (± standard deviation) of European shag, black guillemot and Atlantic puffin on the flood and ebb tide in land-based surveys between March 2020 and March 2022.

Species	Flood tide (N=35)	Ebb tide (N=37)
European shag	22.17 ± 49.64	8.08 ± 6.42
Black guillemot	21.80 ± 16.82	21.55 ± 20.72
Atlantic puffin*	4.78 ± 4.12	29.67 ± 47.53
Northern gannet	2.66 ± 5.67	2.22 ± 4.35

* Data for Atlantic puffin excluded those surveys where no birds were recorded, since presence of this species is highly seasonal.

The data in the table above confirm the apparent preference for European shag for foraging flood tides and the preference of Atlantic puffin for ebb tides. Black guillemot and gannet showed no preference.

[5] Flood tide is tidal periods 1, 2 and 3; ebb tide is tidal periods 4, 5 and 6.

7 Discussion

This report presents results from Nova Innovation's ongoing programme of land-based diving bird and marine mammal surveys of the Shetland Tidal Array site, carried out as part of the project environmental monitoring programme. Data from seventy-two 2-hour surveys conducted between March 2020 and March 2022 are presented in this report. A separate report presents results from review and analysis of subsea video footage gathered from turbine-mounted cameras during the same period (Nova Innovation, 2022a).

Each 2-hour land-based survey comprised a series of up to twenty scans to count and identify all marine mammals and diving birds in close proximity to the Shetland Tidal Array. During each survey, focal watches of individual European shag and black guillemot were also carried out to record the fine-scale movements and behaviour of these two species in the array area.

The analyses in this report focus on the scan data gathered during the 2020 to 2022 land-based surveys. Key findings from the focal watches (presented in Holmes, 2022) and subsea video monitoring during this period are also referred to in this discussion, as are those from further analysis of Nova's land-based surveys conducted from 2010 to 2019 (presented in Brown, 2021). Combined, these studies facilitate interpretation of the observed patterns and drivers of fine-scale movements and occupancy patterns of birds and mammals in the Shetland Tidal Array area. This enables an evidence-based approach to assessing the likelihood that species will interact with turbines in the Shetland Tidal Array, and key influencing factors.

A total of ten diving bird species and five marine mammal species were recorded in the 2020-2022 scans of the Shetland Tidal Array area. Of these, only European shag (*Gulosus aristotelis*) and black guillemot (*Cepphus grylle*) occurred either persistently year-round, or in high numbers. These two species can be considered local ranging with the other species recorded being wide-ranging (Brown, 2021). This is consistent with Nova's previous land-based surveys in Bluemull Sound, and other studies which found that these two species use tidal stream environments to forage all year round (Waggitt et al, 2016). On this basis, and as previously reported (Nova Innovation, 2021a) European shag and black guillemot are the two species most likely to interact in the nearfield with turbines in the Shetland Tidal Array. These species are also thought to be more at risk of nearfield interactions with turbines than many other species, since they frequently dive to the seafloor to depths within range of turbine installations such as the Shetland Tidal Array (Furness et al., 2012).

The remaining eight diving bird and five mammal species recorded in the land-based surveys between March 2020 and 2022 occurred infrequently and/or in low numbers. Descriptive statistics were therefore used to analyse the data and assess the likelihood of nearfield interactions with turbines in the Shetland Tidal Array, and factors which may affect this risk. The further analysis of the long-term dataset gathered during Nova's land-based surveys from 2010 to 2019 considered environmental drivers of the presence and occupancy patterns of species in the project site, so have been incorporated to the interpretation of the 2020-2022 scan data, as have results from the subsea video monitoring and focal watches.

The 2020-2022 scans showed that European shag abundance was notably greatest around high water slack on the decreasing flood tide and generally greater on the flood tide than the ebb. The only sighting of European shag in the subsea video monitoring carried out between March 2020 and March 2022 was on a decreasing ebb tide (detailed in Nova Innovation, 2022a). Black guillemot numbers were relatively greater during slower flow speeds immediately following high and low water slack on the increasing flood and ebb tides. Waggitt et al (2016) similarly observed these two species favouring low-velocity currents around times of low and high water slack when foraging in tidal sites, thought to reflect the high energetic costs of diving under high velocity conditions (Butler and Jones, 1997; Heath and Gilchrist, 2010).

Nova's subsea video monitoring has demonstrated that fish (*Pollachius sp.*) aggregate around the turbines, moving vertically up and down in the water column according to tidal flow (Nova Innovation, 2021b; 2022a). Fish are rarely observed under higher velocity conditions and when they have they can be seen sheltering behind the nacelle, in the lee of the flow. Combined, the results from the land-based surveys and subsea video monitoring indicate overlap in habitat utilisation of the area around the turbines by predators at times of slow tidal velocity, when fish are present. This suggests that in addition to a high energetic cost of diving under high velocity conditions, the foraging behaviour of predators may be driven by the influence of tidal velocity on the distribution of their prey.

Black guillemot counts in scans were also greater on the maximum ebb tide, though numbers were highly variable. A diagonal rip forms off the Ness of Cullivoe, to the north of the Shetland Tidal Array when the currents are running north during the ebb tide (surveyor observations and detailed in Robbins, 2017). Black guillemots have previously been recorded drifting downstream on this rip, undertaking short flights upstream against the current, before landing and diving, apparently using the flow to maximise foraging in this restricted area (Robbins, 2017). Foraging seabirds often associate with specific hydrodynamic features (Benjamins et al., 2015; Hunt et al., 1999), as prey items often aggregate around these features (Zamon, 2003; Wade et al., 2012). Diving seabirds have been known to use these 'tidal conveyor belts' to reduce energy expenditure while foraging, by allowing the current to 'carry' the individual to foraging sites, diving and then flying back upstream (Holm and Burger, 2002; Robbins, 2017). Installing turbines in areas of sheer or turbulence such as those associated with tidal rips would yield less energy and potentially damage turbines, so there is no spatial overlap. The use of this rip micro-habitat for feeding during higher tidal velocities by black guillemot or other species therefore does not place them at greater risk of nearfield encounters with operational turbines. This demonstrates the critical importance of understanding fine-scale habitat use by predators in tidal sites to accurately understand risk of nearfield encounters with turbines.

The focal watch data gathered during land-based surveys enabled detailed examination of foraging behaviour in black guillemot as well as European shag in the Shetland Tidal Array area. Analysis of the data (Holmes, 2022) found that black guillemots appear to forage during the ebb tide, while the European shags favour the flood tide, corroborating the scan data. This suggests the European shags and black guillemots are exhibiting spatial and temporal variation in foraging. Sympatric species that share resources (e.g., prey items) are presumed to show variation in feeding approaches to reduce interspecific competition (Chase, 2011). It appears that the European shags and black guillemots are utilising the variation of the hydrodynamic features throughout the tidal cycle to reduce spatial overlap while foraging.

The focal watches also found that black guillemots generally perform deeper/longer dives in the Shetland Tidal Array area compared to European shags, probably due to a combination of dive behaviour and physiology favouring short, quick dives in shags. In addition, both species spent more time on the surface and carried out fewer, shorter dives during high flow, turbulent conditions. Both factors further reduce the likelihood the two species encountering operational turbines during foraging.

Of the other bird species recorded in the 2020-2022 land-based surveys, northern gannet was also present throughout the year, but in much lower numbers than European shag or black guillemot and counts showed a high degree of variability. Other diving bird species were present in low or very low numbers and displayed a high degree of stochasticity. Numbers of all marine mammal species in the vicinity of the Shetland Tidal Array were very low. Possible causes of this variation in counts are further considered below.

Atlantic puffin was notably present in relatively high numbers at the site between April and July (the breeding season). Bird breeding seasons have been found to impact the importance of tidal stream environments to seabirds such as auks including the Atlantic puffin (Waggitt et al, 2014). The further analysis of Nova's land-based surveys in Bluemull Sound between 2010 and 2020 detailed in Brown (2021) identified no such clear relationships for other species during breeding or non-breeding seasons, with fluctuations in occurrence for many in both the breeding and non-breeding season. This indicates that other environmental conditions may influence the likelihood of species occurring in the vicinity of the Shetland Tidal Array. The further analysis of the 2020-2019 data identified a number of possible species-specific responses to the environment in Bluemull Sound, explaining the shifts in community composition, since the presence and number of each species depends on underlying environmental conditions. For example, northern gannet, Atlantic puffin, grey seal, and harbour porpoise tend to occur in Bluemull Sound during summer, when the environmental conditions such as productivity are ideal. Northern gannet is also more likely to occur in Bluemull Sound in warmer winters when productivity is greater. Periods of strong wind affect the occurrence of species such as common seal and puffin. While it is difficult to draw firm conclusions from these results, they indicate that environmental variables such as wind strength, sea surface temperature and productivity all play a role in influencing the presence and abundance of diving bird and marine mammal species in the vicinity of the Shetland Tidal Array. Nevertheless, the presence and abundance of diving birds and marine mammals is very low, with the exception of European shag and black guillemot.

The results from Nova's ongoing programme of environmental monitoring for the Shetland Tidal Array indicate that nearfield encounters between most diving bird species and operational turbines are very unlikely. The likelihood is greater for European shag and black guillemot, which continue to be the only species that occur either consistently or in high numbers at the project site and the only bird species that have been observed in footage from subsea video monitoring. Data for these two species indicate some preference for foraging within or near to the array area at times of slower flow speeds, at or below the turbine cut-in speed (0.8 m/s). Numbers of all marine mammal species in the vicinity of the Shetland Tidal Array continue to be very low. Common seal (*Phoca vitulina*) is the only marine mammal species observed in subsea video, with no marine mammals observed in footage collected between March 2020 and 2022 (Nova Innovation, 2022a).

8 Next steps

8.1 Ongoing monitoring

The monitoring programme for the Shetland Tidal Array is ongoing. Over coming months there will be a period of further array expansion, as two more 100 kW Nova M100 turbines are installed in Bluemull Sound (T5 and T6).

Ongoing monitoring will add to the contribution the project has already made to improving knowledge on the environmental effects of tidal turbines and arrays and on the development of efficient, reliable and cost-effective monitoring solutions for tidal energy projects. In line with the approach set out in the Project Environmental Monitoring Plan (Nova Innovation, 2022b), the monitoring will be kept under review to ensure it remains necessary, proportionate and fit for purpose. This includes further refining methods to continue to focus on key outstanding uncertainties and knowledge gaps as the array is expanded and reconfigured. It also includes considering phasing out of monitoring that is no longer proportionate to the growing knowledge of project impact risk.

8.2 Dissemination of learning and evidence transfer

Sharing learning and experience from environmental monitoring of the Shetland Tidal Array is important to Nova. It is critical in facilitating the development of best practice for cost-effective environmental monitoring of tidal energy projects and the sustainable development of the sector and for improving access to information on tidal energy to the general public. In addition to the formal monitoring reports provided to MS-LOT and Shetland Islands Council, information from the environmental monitoring programme for the Shetland Tidal Array has been shared via the following mechanisms:

1. Key results and lessons learnt have been published the US 2020 “State of the Science” report dedicated to examining the environmental effects of marine renewable energy technologies (Copping & Hemery, 2020). This 300-page report remains the most comprehensive international analysis to date on the issue.
2. Monitoring results and key learning have been shared and presented at UK and international workshops, conferences and seminars, including most recently at the Environmental Interactions of Marine Energy (EIMR) 2022 and the International Conference on Ocean Energy (ICOE) 2022.
3. The environmental monitoring programme, including footage from subsea video cameras, have featured on UK national television, including BBC One Countryfile in June 2021.
4. Results have been shared in an accessible format for the general public in reports produced as part of the multi-partner £20million project Enabling Future Arrays in Tidal (EnFAIT) led by Nova (e.g., EnFAIT, 2022).
5. The environmental monitoring programme and its key findings are regularly promoted using social media channels, including to coincide with global initiatives such as COP26, World Oceans Day and World Earth Day.
6. Key findings and lessons learnt have been incorporated into key consenting and regulatory guidance documents, including a series of technical, topic specific Information Notes

produced by the Welsh Government to provide a shared understanding of how the best available science and evidence is currently applied to key consenting issues[6].

7. Results from the environmental monitoring of the Shetland Tidal Array was used as part of the evidence base in applications for permits and the design of the environmental monitoring programme for Nova's 1.5 MW project in the Bay of Fundy, Canada.

Opportunities to further develop and expand the dissemination and transfer of knowledge and learning from the Shetland Tidal Array will continue to be explored and developed. This includes opportunities to combine evidence and knowledge from the Shetland Tidal Array with that gained from environmental monitoring of Nova's other tidal energy projects, such as the Nova Tidal Array in Petit Passage, Canada. This is anticipated to deliver further benefits by improving the evidence base on the environmental effects of tidal stream energy, de-risking and accelerating consenting, and reducing the cost of monitoring for the tidal sector.

[6] See https://gov.wales/marine-renewable-energy-environmental-information-notes

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