National Research Vessels

Ship-Time Programme

De-risking Offshore Wind Energy Development Potential in Irish Waters (DOWindy)

Leg 1

Survey Code:	Survey Name:	Chief Scientist/ Institution
CV19023	DOWindy	Jared Peters University College Cork

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1 Executive Summary

The De-risking Offshore Wind Energy Development Potential in Irish Waters, or "DOWindy" research cruise (leg 1), was conducted aboard the *RV Celtic Voyager* offshore of Ireland from September 16 – 28, 2019. During this cruise, scientists from University College Cork (UCC) and the Centre for Marine and Renewable Energy (MaREI) collected geological data from the submerged Irish continental shelf for use in improved offshore wind farm development and site selection models. Data were collected in the Atlantic Ocean, the Celtic Sea, and the Irish Sea.

This research cruise is motivated by interest from offshore wind energy developers and the ever-increasing evidence of climate change's detrimental impacts, which may be curbed by decreasing carbon emissions. Armed with this information, global and European leaders have set goals for limiting the use of carbon emissions from fossil fuels. Renewable energy sources, like offshore wind, will play a critical role in achieving these fossil fuel reductions. Ireland has made commitments to these clean energy goals but is thus far failing to meet them. By improving the offshore data relevant to wind farm development, we hope to help achieve these goals.

The data collected during the DOWindy (leg 1) cruise consists of: multibeam echosounder measurements of the seabed bathymetry; sediment grabs of seabed surface geology; a sediment core that reveals deeper stratigraphy; and seismic sub-bottom profiles that reveal information on the entire sediment package overlying the bedrock. A total of 275 nm (509 km) of multibeam data were collected, which will extend the coverage of high-resolution bathymetric data in key areas of the seabed. In some areas, these data will also enable quantifications of sedimentary seabed form migration using comparisons with existing data. Fifteen sediment grabs were collected and subsampled, which will be used to improve surficial sediment maps and inform sediment mobility predictions. One short (42 cm) vibrocore was collected, which will inform stratigraphic models of the seabed west of Ireland. A total of 433 nm (802 km) of seismic sub-bottom data were collected. Of this, 272 nm consist of sparker data; the remainder is pinger data. These dub-bottom transects will enable assessments of large areas of stratigraphy and overall sediment depth to the underlying bedrock. Together, the stratigraphic data can be applied to seabed use and limitation models.

The DOWindy research cruise has produced data that are widely applicable to several national research programmes. These data will primarily be used by the EirWind (UCC, MaREI) research consortium to improve assessments of offshore wind development scenarios. The iCRAG-funded AggrePOP programme, which intends to map and quantify potential offshore construction aggregate sources south of Ireland, may also benefit from these data. Additionally, the information provided by the DOWindy cruise could be used to improve insights to palaeoglaciological reconstructions of the last British-Irish Ice Sheet and associated postglacial benthic adaptations. Thus, the academic research possible with data collected by the DOWindy research cruise may benefit the economies of Ireland and western Europe.

2 Cruise Details

2.1 *Award summary*

Title of research survey (survey code):	DOWindy Leg 1 (CV19023)
Co-ordinator/chief scientist:	Andrew Wheeler/Jared Peters
Vessel used for ship time:	Celtic Voyager
Total days at sea:	13
Total of grant-aided ship-time days awarded:	13
Survey dates:	16/09/2019 – 28/09/2019
Mobilisation/Demobilisation ports:	Galway/Dublin
Survey personnel:	6 scientists; 1 technician
Final Report completed by:	Jared Peters (2019)

2.2 *Science crew summary*

Table 1: Science crew summary.

	Name	Institute	Position	Number of days
Chief Scientist	Jared Peters	University College Cork/MaREI (UCC)	Postdoctoral Researcher	13
Scientist	Gerard Summers	UCC	PhD Researcher	13
Scientist	Jessica Giannoumis	UCC/MaREI	PhD Researcher	13
Scientist	Evan O'Mahony	UCC/iCRAG	MSc Researcher	13
Scientist	Júlia Terra Miranda	MaREI	Research Assistant	13
Scientist	Yeray Castillo Campo	GSI	Graduate Geologist	13
Technician	Lukasz Pawlikowski	P & O	Technician	13

2.3 *Science crew shift description*

Operations were conducted 24-hours a day using 12-hour shifts. Shift changes took place at 20:00 and 08:00 to maximise day-shift operations during sunlight hours since sediment sampling activities were deemed unsafe at night.

3 Introduction

3.1 *Rationale*

Anthropogenic climate change is a dangerous and expensive phenomenon and some predictions for its progression are dire (IPCC, 2014). New and ongoing research agrees with the long-running scientific consensus that carbon emissions need to be drastically curbed to preserve human safety and wellbeing (Pachauri et al., 2014). Thus informed, the European Union has set out ambitious renewable energy goals (EU Renewable Energy Directive (2009/28/EU)) that aim to minimise climate change impacts. These goals promote the continuing global trend of increasing renewable energy production (International Energy Agency, 2019).

Unfortunately, Ireland is not yet among the nations to join this trend. Instead of reducing carbon emissions by its goal of 1 million tonnes/yr, Ireland's emissions are currently increasing by 2.1 million tonnes/yr (Climate Change Advisory Council, 2018). Furthermore, unless serious steps toward mitigation are enacted, Ireland will "…miss its 2030 EU Effort Sharing Regulation cumulative emissions reduction target by 92 million tonnes…" (ibid). The need for additional mitigation efforts is critical. Wind power generation is one such effort and offshore wind farms are a good option because they can be built bigger, they can operate more efficiently, and they remove many issues with lack of space. Because the benefits of offshore wind energy are scientifically and economically apparent, the DOWindy cruise is endeavouring to provide new data for offshore wind development in the Irish EEZ. The Eirwind project (EirWind, 2019) will use these data by working with industry partners to help facilitate the development of Ireland's offshore wind energy resources through rigorous academic research.

3.2 *Study area*

The DOWindy research cruise focused on the Irish continental shelf offshore of western, southern, and eastern Ireland (Figure 1). Significant bathymetric and geological data gaps exist in these areas, which inhibit resource management and hampers analyses of environmental and climatic change.

Moreover, the Irish continental shelf is geologically complicated. It has been glaciated multiple times through the Quaternary (the past 2.6 million years) in response to climate oscillations, leaving the present seabed a palimpsest signature of the last glaciation and postglacial tidal and current reworking. Several studies provide evidence for extensive grounded BIIS ice on what is now the submerged continental shelf (e.g. Ó Cofaigh et al., 2012; Peters et al., 2015; Figure 2). Following deglaciation of the Irish shelf, lower relative sea levels (Brooks et al., 2008) allowed fluvial erosional and depositional processes to modify the now-submerged landscape. The ancient fluvial and glacial deposits are often reworked and/or overlain by marine sediment recording sea-level transgression (a relative rise in sea level) (Peters et al., 2015). The upward-fining, shell-rich signature of transgression is often overlain by bioturbated sand deposits that occasionally grade upwards to muddy sand or sandy mud, marking the transition to modern neritic sedimentation (cf. Chang et al., 2006).

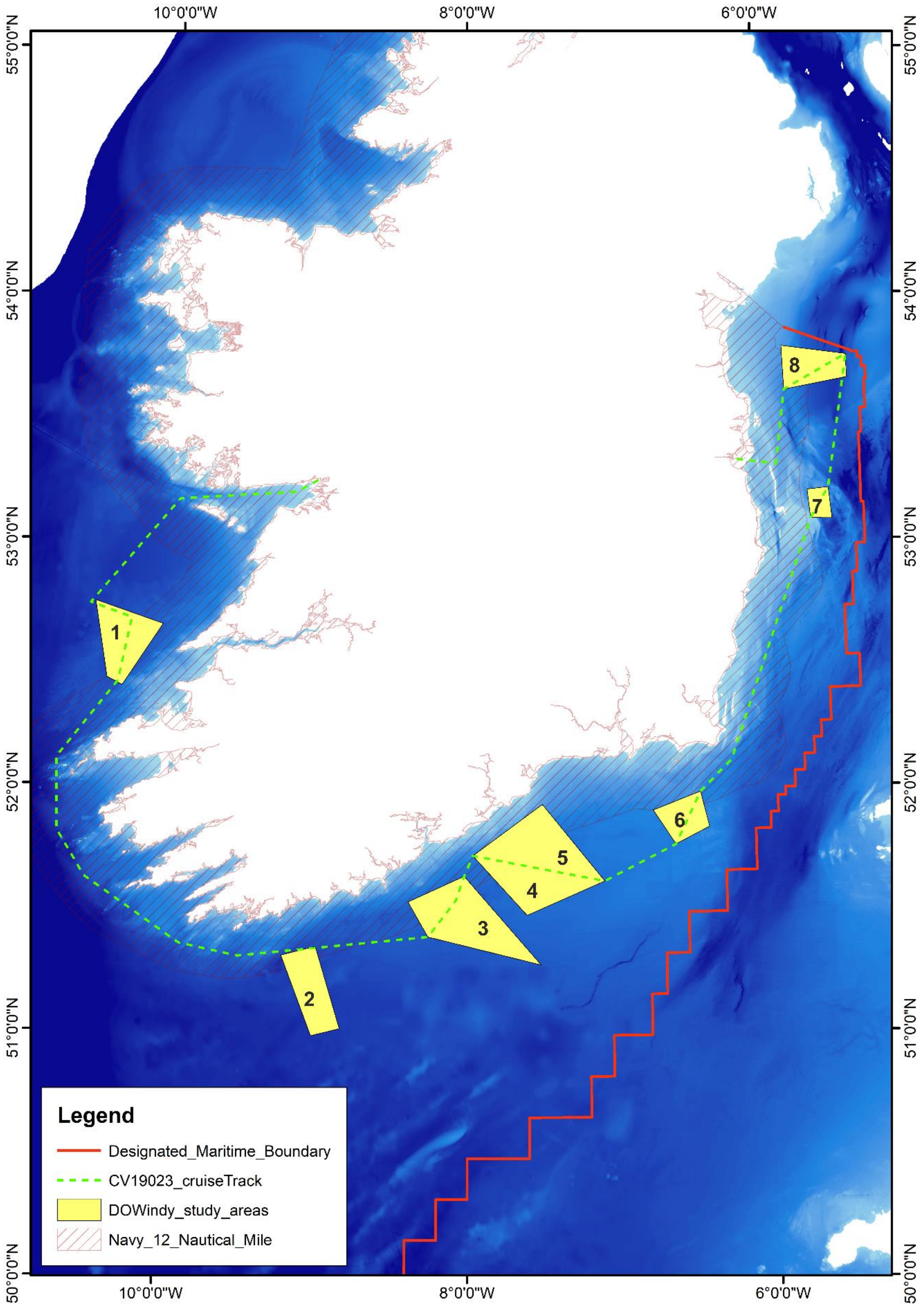

Figure 1: Map of cruise track and study areas (labelled yellow boxes). Note: area 2 will be surveyed during the second leg of DOWindy (CV19026).

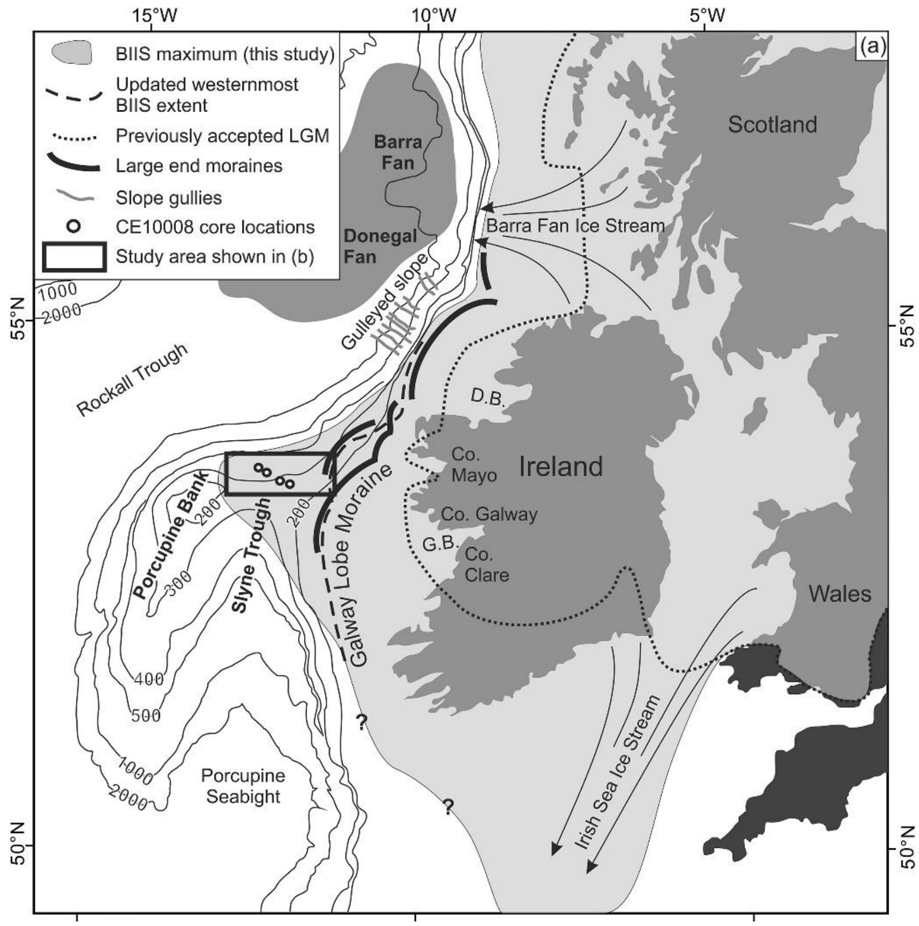

Figure 2: Schematic of the last British-Irish-Ice-Sheet, showing improved ice limits, some major landforms, and large ice streams. Reproduced from Peters et al. (2015) with permission (Elsevier reuse licence #: 4481440580651).

3.3 Objectives

The DOWindy research cruise was undertaken to supply critical data to the Eirwind project (see §2.1 for project details). The data targets are the product of one year of collaborative planning from a diverse team of researchers at the MaREI Centre and ten industry partners. Specific objectives of the survey include:

- Collect multibeam data that can be used to model sediment mobility and improve existing bathymetric coverage.
- Collect seismic sub-bottom data using a sparker acoustic system to identify stratigraphic characteristics and the thickness of the seabed sediment (i.e. depth to bedrock) in key areas.
- Collect surficial sediment samples that will help ground truth seabed/benthic terrain models and assess sediment mobility.
- Collect subsurface sediment samples using a 3-m vibrocorer to ground truth the seismic stratigraphy and improve models of seabed sediment composition.
- Ground-truth existing bathymetric data south of Ireland with improved surface-sediment sampling.

4 Equipment and Methods

4.1 RV Celtic Voyager

The *RV Celtic Voyager* is a multi-purpose research vessel measuring 31.4 m long with a 4-m draught. It has wet and dry laboratories and can remain at sea for up to 14 consecutive days. Some of the Celtic Voyager's equipment that the DOWindy cruise made use of are the large a-frame for deployment of the vibrocorrer off the aft; the port-side wench for deployment of the grab samplers, and the hull-mounted EM2040 Multi-beam echosounder.

Figure 3: The RV Celtic Voyager, a 31.4 m, multi-purpose research vessel capable of oceanographic and environmental data collection. Photograph credit: Marine Institute.

4.2 Bathymetric surveying

A Kongsberg EM2040 Multibeam echosounder (MBES; Figure 4) system was used to collect bathymetric and backscatter data. Data were collected at 300 – 400 kHz at survey speeds dictated by the seismic data acquisition system (4 knots). Sound velocity was estimated using Conductivity, Temperature and Depth (CTD) probe measurements (cf. Foote et al., 2005) from previous (recent) cruises, because we could not stop the ship during the seismic surveying long enough to take our own measurements. The calibrations using CTD measurements were updated at intervals dictated by the requirements of the EM2040 system based on user observations of the raw data.

Figure 4: Kongsberg EM2040 Multibeam echosounder hull-mounted array. (Photo credit: Marine Institute, 2014.)

4.3 Seismic data acquisition

Seismic transects were chosen based on a series of considerations deemed important by the EirWind Consortium (Peters, 2019; EirWind, 2019). Primary planning considerations included: data coverage (i.e. filling data gaps), distance from shore, water depth, restriction zones (e.g. special areas of conservation, shipwrecks), distance to potential electrical grid connections, and distance to ports with the potential to support future operation and maintenance activities (cf. Irish Maritime Development Office, 2019). Planning consideration also considered geomorphological characteristics from any existing bathymetry and an evaluation of regional geological history (§3.2).

Seismic sub-bottom data were collected using a hull-mounted pinger and a Geo-Source GeoSparker200 sparker system. The sparker system used was a Geo-Source GeoSparker200 system. This sub-bottom profiler consists of a Geo-Spark 6 kJ pulsed power supply and a Geo-Sense single channel hydrophone array. Both are towed behind the vessel during operation. The power supply emits a signal from the bang box (Figure 5) to the sound source, which consists of four evenly-spaced electrodes in a planar array suspended from a catamaran (Figure 6). After reflection/refraction from interaction with the water column and seabed, the return signal is detected by the hydrophone array while it is suspended just below the water surface (Figure 7). This system provides high-resolution (<30 cm) seismic sub-bottom profiles in water depths up to 500 m, depending on seabed characteristics (Geo-Marine Survey Systems, 2019). Data acquisition is controlled via a CODA DA2000 system.

Figure 5: Sparker system bang box in the wet lab of the *RV Celtic Voyager*.

Figure 6: Geo-Source GeoSparker200 catamaran.

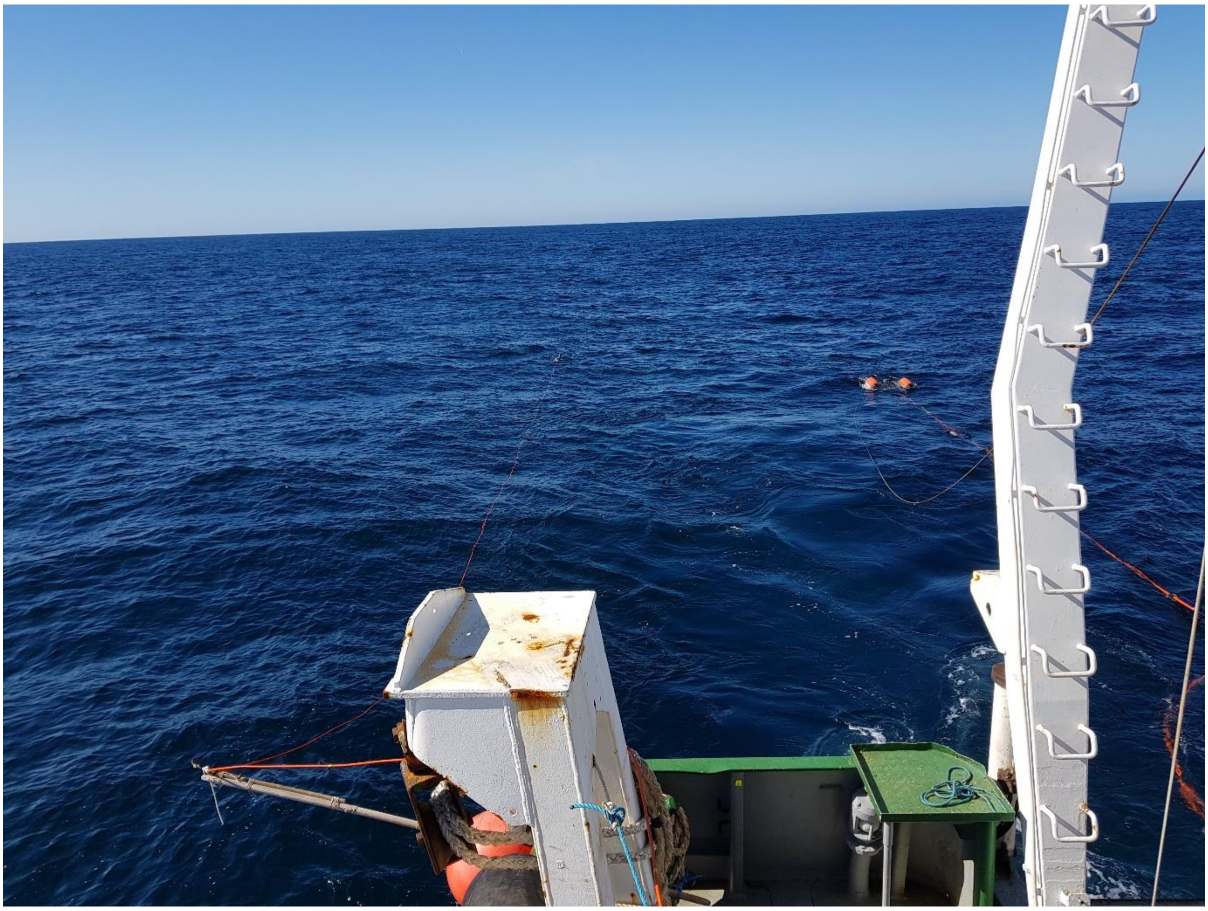

Figure 7: The Geo-Source GeoSparker200 hydrophone (thin orange stringer on left, deployed from a boom), and the sparker source catamaran on the right, deployed and ready for use.

The pinger system used was a Sonar Equipment Services Ltd Probe 5001S 3.5 kHz sub-bottom profiler. The transducers are mounted in the starboard mid sea water ballast tank and set up in a 4x4 configuration. This shallow seismic system operates at frequencies of 3.5 – 9.0 kHz.

4.4 Sediment sampling

Initial sample site locations were informed by geomorphic analyses, regional Quaternary geological history (§2.2), and analyses of existing INFOMAR multibeam bathymetry and backscatter data. These locations were further refined during the cruise using sea-floor data collected "on the fly," prior to sampling operations.

A Shipek grab sampler (Figure 8) was used to collect surface sediment samples. These samples were used to ground-truth geological analyses and inform site selections for coring operations. Ship position and water depth when the sampler reached the sea floor was recorded. Subsamples were collected and stored in sample bags for potential benthic analyses and/or quantified grain size analyses.

Figure 8: Shipek grab sampler, on its storage stand aboard the *RV Celtic Voyager*.

A 3-m vibrocorer (Figure 9) with an 11-cm barrel was used to collect subsurface sediment samples. The maximum water depth for safe operation of this corer from the *RV Celtic Voyager* was 100 m. Sediment cores were recovered in 1-m sections and labelled immediately. Recovered samples were stored upright and near the centre of the ship to minimise disturbance to unconsolidated sediments during continued operations, transit, and demobilisation activities.

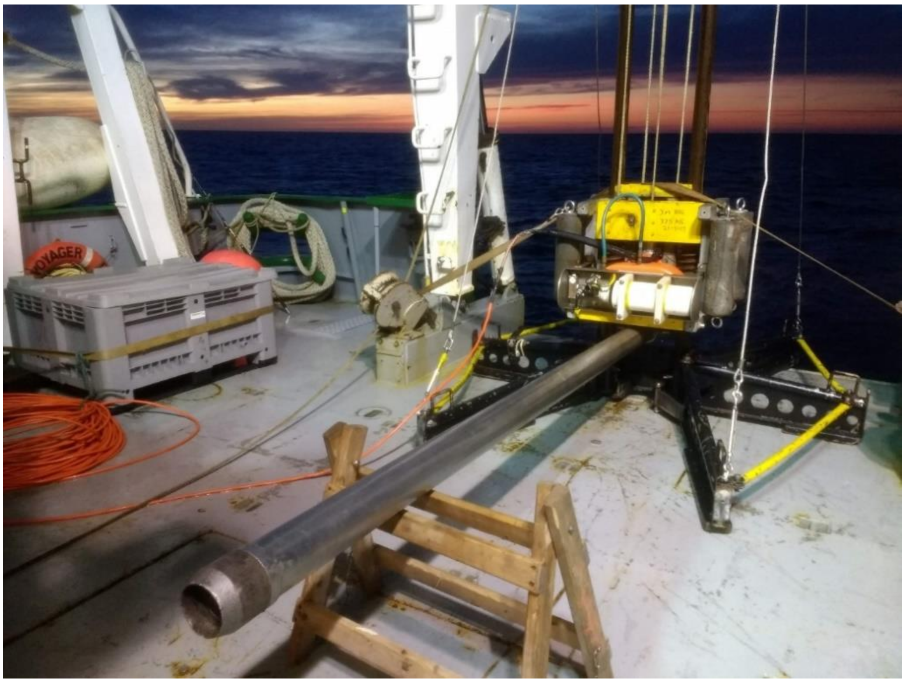

Figure 9: Vibrocorer used during the DOWindy (CV19023) research cruise on the deck of the *RV Celtic Voyager*. Barrel length is 3 m; barrel inside diameter is 11 cm.

5 Activity Overview

5.1 Overview of research survey

Times referred to in this section are GMT. A detailed log of ship activities was also kept (Appendix 9.3).

5.1.1 Day 1 (16/09/2019)

The ship was prepared for the DOWindy scientists (equipment and consumables were loaded; sparker was connected; coda was switched from pinger acquisition to sparker acquisition). Science crew arrived at the vessel (*RV Celtic Voyager*) by 14:00. Science crew boarded the ship, presented documents and identification, and took the safety tour by 16:20.

5.1.2 Day 2 (17/09/2019)

The ship left Galway Docks at 07:00 on the morning tide and began the transit to research area 1 (Figure 1). Passed Aaron Islands at 09:40. We arrived at the first survey area and started the MMO watch at 15:00 (Appendix 9.4, 9.5). The sparker soft start (following the guidelines set out by National Parks and Wildlife Service, 2014) and set up started at 15:40 and the survey started at 16:42.

The sparker system was used at full power and the system was towed at 4 knots during acquisition. Data were collected at 1,500 J to maximise penetration. The gain was adjusted throughout the survey to optimise the raw signal. The sound travel time was left at the original setting of 1,600 m/s. Time varying gain (TVG) was adjusted as needed based on signal appearance. Apparent penetration in the raw data was about 50 m. The input voltage range was pre-selected at + - 2.5 V. Filter and gain settings were also adjusted on the GEO Sense filter/gain interface box (Figure 10).

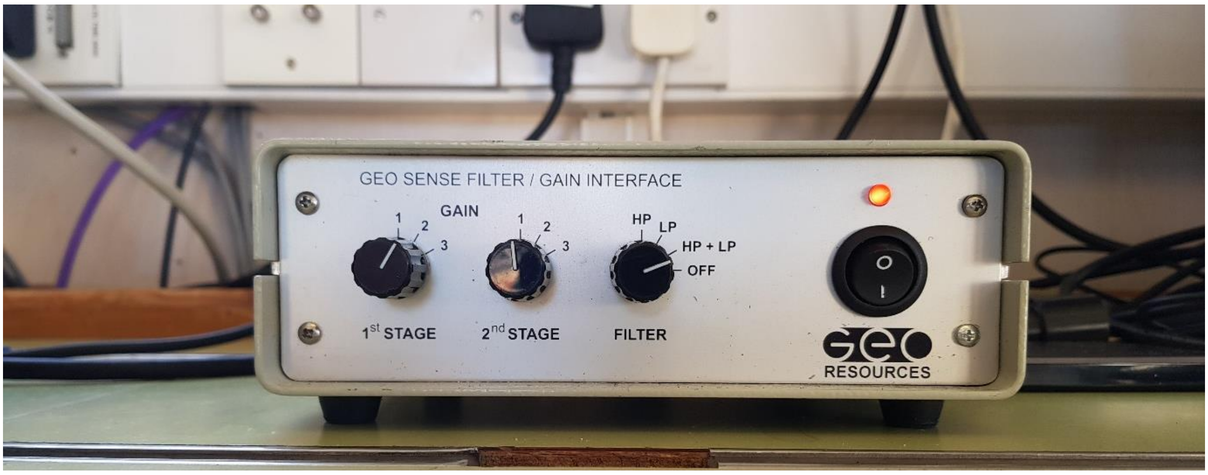

Figure 10: Geo Resources, filter/gain interface box with settings used during seismic data acquisition in area 1. Knobs from left: 1st stage gain (set to 2); 2nd stage gain (set to 1); and filter (set to HP + LP). For the final line of the Area 1 sparker, the 2nd stage gain was also set to 2.

Multibeam data were also collected during the sparker survey. No sound velocity data (e.g. CTD) could be collected during the seismic survey because the ship could not be stopped while trailing the sparker catamaran. So, sound velocity adjustments/corrections were made using recent CTD measurements from previous research cruises. The sparker and MBES data collection was ended at 14:33 to prepare for sediment activities. The planned sparker survey was not entirely finished but was ended because most of the seismic was collected and we needed to catch the slack tide at ~15:00 to use the vibrocorer and stay on schedule.

Sediment sampling activities started at 15:10. Grab sampling was carried out first to gauge the tide and ground truth prior to vibrocore operations. Grabs in three vibrocore stations were attempted; two were successful and these samples were bagged. One vibrocore station was successfully cored, which yielded a 42-cm core (19023VC_01).

Transit to the next study area "area 3" (the second to be surveyed) began at 18:05. This transit is expected to take >20 hours.

5.1.3 Day 3 (18/09/2019)

Transit continued to research area 3 until 14:55. Conditions were assessed for sediment sampling at the upcoming slack water tide, however, the drift was deemed too strong for coring by the captain. So, we prepared the sparker seismic survey. The MMO watch lasted until 15:38 because dolphins were seen near the ship and the seismic was collecting data at 16:21 (Appendix 9.4, 9.5).

The sparker system was used at 1,400 J (1,500 J is maximum power output, however 1,400 J looked slightly cleaner and still returned similar penetration). The sound travel time was left at the original setting of 1,600 m/s. Time varying gain (TVG) was selected with "auto," and this was calculated as needed based on signal appearance. Apparent penetration in the raw data was about 50 m. The input voltage range was pre-selected at + - 2.5 V. Filter and gain settings were also adjusted on the GEO Sense filter/gain interface box (Figure 11).

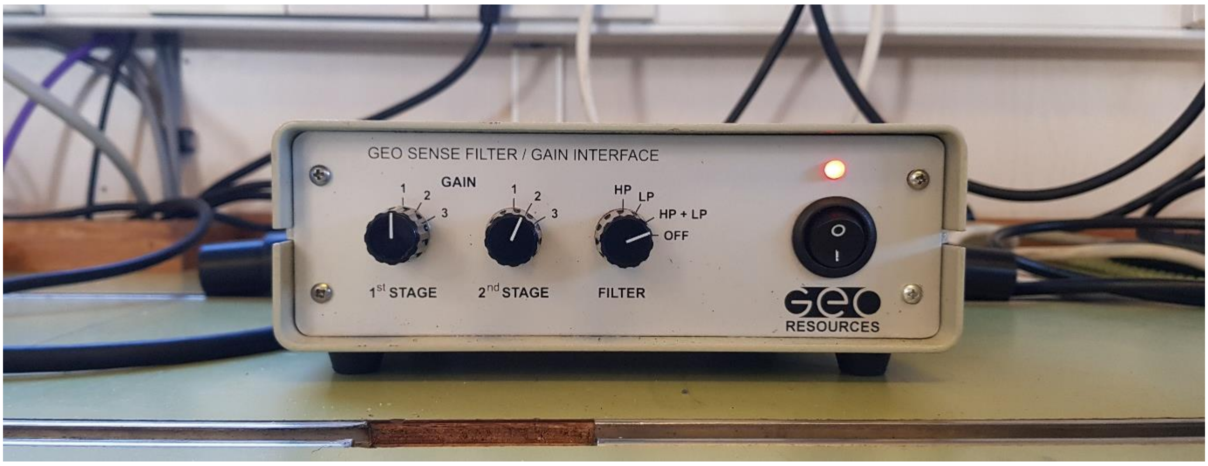

Figure 11: Geo Resources, filter/gain interface box with settings used during seismic data acquisition in area 3. Knobs from left: 1st stage gain (set to 1); 2nd stage gain (set to 2); and filter (set to HP + LP).

Multibeam data were also collected during the sparker survey. See §5.1.2 for acquisition notes.

5.1.4 Day 4 (19/09/2019)

Sparker and MBES data were collected all day and night. See above for acquisition notes.

5.1.5 Day 5 (20/09/2019)

Sparker and multibeam data were collected until 09:30 when the captain deemed the weather unfit for the survey (Appendix 9.2). The sparker system was retrieved and all scientific equipment was stowed for transit into Cork Harbour to shelter.

5.1.6 Day 6 (21/09/2019)

Weather standby in Cork (Appendix 9.3).

5.1.7 Day 7 (22/09/2019)

Untied from Port of Cork at 08:30 (Appendix 9.3). After arrival at Area 4 the 30-minute MMO watch was immediately started, followed by the 40-minute soft start (Appendix 9.4, 9.5).

The sparker system was used at 1,400 J (the bang box stopped firing several times at 1,500 J but ran fine at 1,400 J). The sound travel time was left at the original setting of 1,600 m/s. See §5.1.3 for more acquisition notes.

Multibeam data were also collected during the sparker survey. See §5.1.2 for acquisition notes.

Pinger seismic data were also collected. These data were aquired using a voltage range of +/- 5 V, a digitised sweep time of 64 ms, and a start delay of 0 ms. Gain and visual filters were applied and adjusted as needed during the survey to optimise monitoring of the incoming signal.

5.1.8 Day 8 (23/09/2019)

Seismic data acquisition continued through the night until the planned survey at area 4 was finished at 02:45. Pinger seismic data was collected while transiting westward towards the incomplete sparker line in area 3. Upon arrival at area 3, the Capitan deemed the weather unsafe (Appendix 9.2) and we returned to Cork Harbour. Pinger data was collected for most of the transit. See above for seismic data acquisition settings.

We tied up alongside Horgan's Quay at 10:50. Weather standby continued all day (Appendix 9.3).

5.1.9 Day 9 (24/09/2019)

Weather standby (Appendix 9.3).

5.1.10 Day 10 (25/09/2019)

Weather standby and transit to Irish Sea stations.

5.1.11 Day 11 (26/09/2019)

Transit to study area 8. On station at 10:30. Weather conditions didn't allow an MMO watch or coring (Appendix 9.2). So, extra grab samples were taken. We collected 12 sediment grabs in total. Most took several tries and yielded small returns, likely due to the poor weather (Appendix 9.2) interfering with the grab sampler's contact with the seabed.

Weather was too poor for sparker or coring (Appendix 9.2) and was forecast to get worse overnight. So, the captain chose to move us to shelter until we could reassess what was possible in the morning.

5.1.12 Day 12 (27/09/2019)

Weather is poor again with >16 knots of southerly wind creating >1-m wind waves with a very short period (Appendix 9.2). There is also rain and fog creating poor visibility for the MMO. Thus, we stayed on weather standby until 07:30, when we transited back to Study Area 8 to assess the possibility of sparker. A successful MMO watch was completed (Appendix 9.4, 9.5) and the sparker was started. It returned fairly good, though noisy, data. The sparker data were collected at frequencies from 400 J, by far the lowest of the cruise (selected because the rough weather was creating too much noise in the raw data at higher frequencies) to 800 J. The sound travel time was left at the original setting of 1,600 m/s. See §5.1.3 for more acquisition notes.

At about 18:50 the captain noticed that the supply cable feeding the sparker catamaran needed adjusted for device safety. The system was shut down and the cable was adjusted. This seems to have also resulted in a subtle change in the catamaran's position relative to the hydrophone, which has proven detrimental to the quality of the incoming data.

Multibeam data were also collected during the sparker survey. See §5.1.2 for acquisition notes.

Pinger seismic data were also collected until 19:27. See §5.1.7 for acquisition notes.

5.1.13 Day 13 (28/09/2019)

The seismic survey initiated on 27/09/2019 was continued until 02:00. At this point the captain deemed the weather unsafe for sparker operations (Appendix 9.2) and the catamaran and hydrophone were recovered and stowed. Pinger and MBES data acquisition continued during much of the transit to Dublin Port.

We entered Dublin Port around 08:00 and tied up at 09:00. The science crew demobilised and had disembarked by 09:30.

5.2 *Activity summary*

Table 2: CV19023 hourly activity summary (see also Figure 12).

Activity	Time (hours:minutes)	Hourly %
MMO watches	5:37	2
Sediment collection	10:37	4
Transit	65:02	25
Seismic and MBES data acquisition	75:41	29
Weather standby	105:27	40

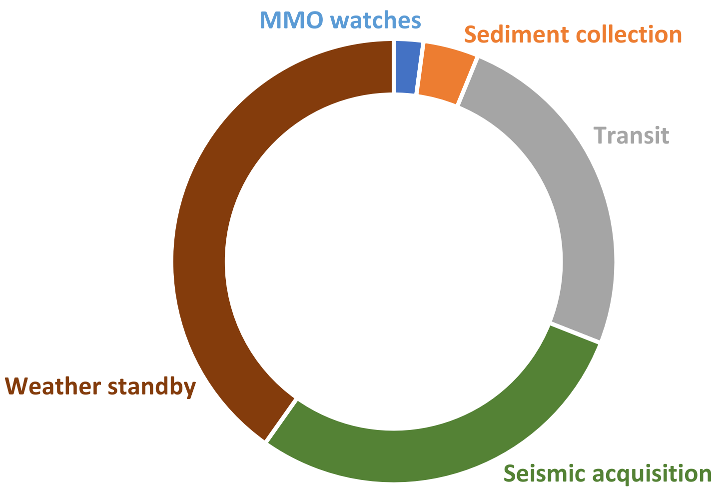

Figure 12: Doughnut graph of major cruise activities as percentages of total operational time (see also Table 2).

6 Results and data summary

6.1 *Study Area 1 results*

88 nm of sparker seismic sub-bottom data were gathered in study area 1 (Figure 13). These data targeted the 12-nm limit offshore of the Shannon Estuary, because Money Point Port has been identified as potentially suitable for OWE O&M activities (Irish Maritime Development Office, 2018). After the seismic acquisition, and when slack water conditions permitted, sediment sampling activities were also carried out. Three grab samples and one vibrocore were collected (Figure 13, Table 6, Table 5.)

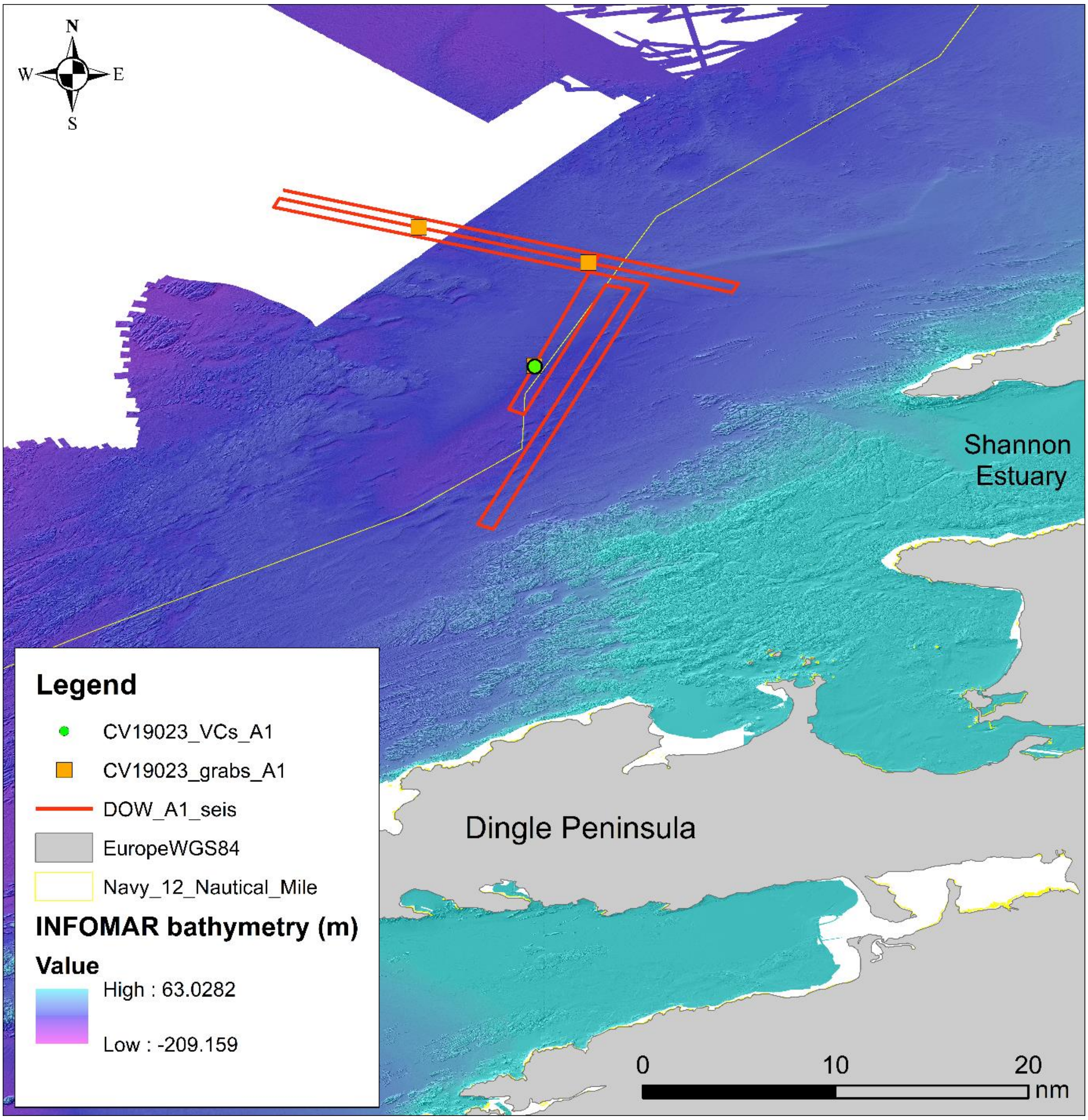

Figure 13: Map of study area 1 showing the 88 nm of sparker seismic data, three sediment grabs, and one vibrocore collected. Hillshaded bathymetric DEM is made from INFOMAR data and has a 10-m resolution; white map areas have no INFOMAR data coverage.

6.2 Study Area 3 results

73 nm of sparker seismic sub-bottom data and MBES data were gathered offshore of Cork Harbour in study area 3 (Figure 14). These data targeted the 12-nm limit offshore of Cork Harbour, because the Port of Cork has been identified as potentially suitable for OWE O&M activities (Irish Maritime Development Office, 2018). Palaeovalley systems identified using the INFOMAR bathymetric data (Figure 14) were also targeted during this survey because they probably incise Quaternary glacial sediments (cf. Gallagher et al., 2004), and therefore potentially allow for improved seismic penetration into a diverse set of strata. This information will likely also be beneficial to palaeoclimate and palaeoglacial research as well as investigations of marine construction aggregate resources.

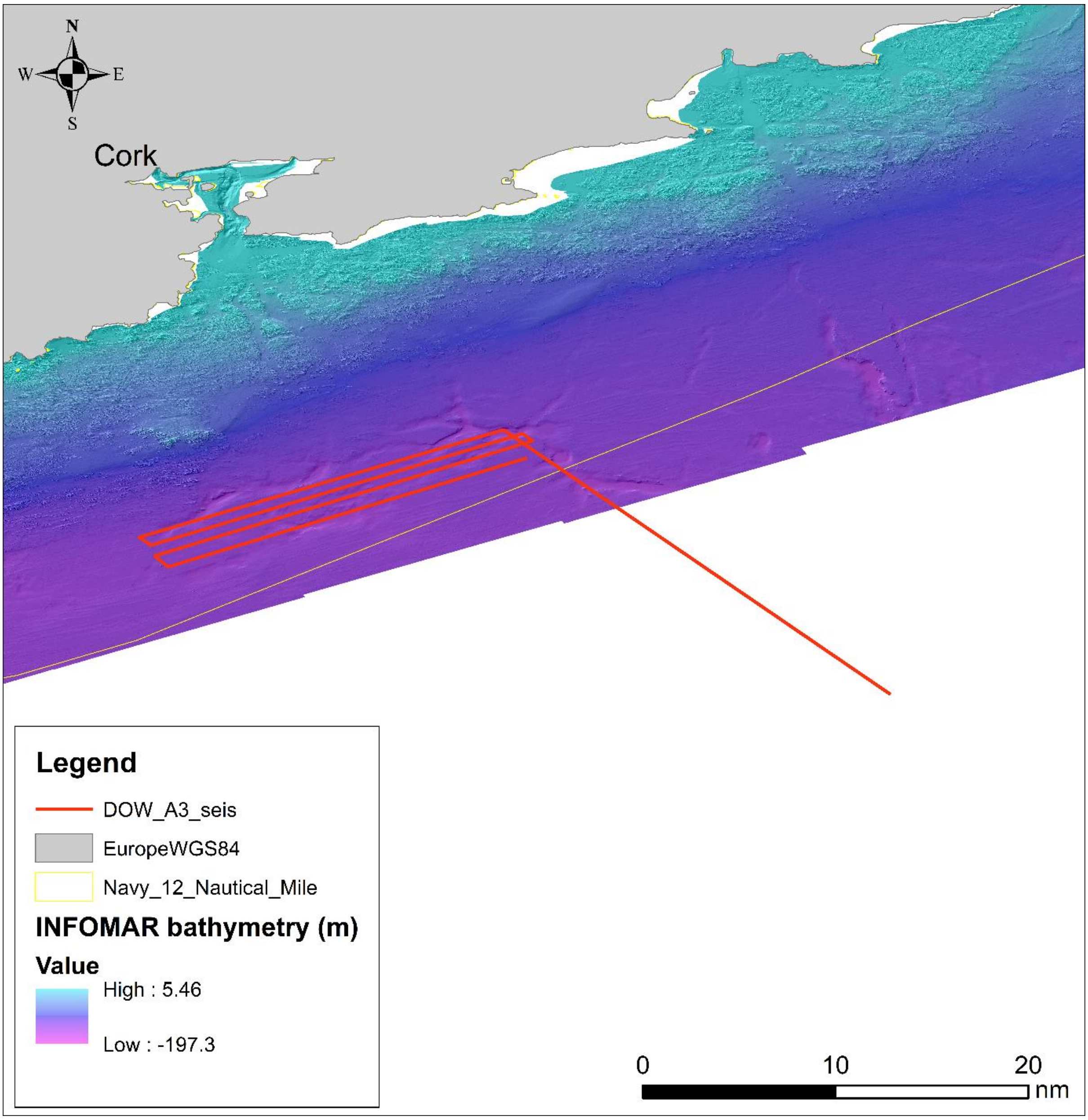

Figure 14: Map of study area 3 showing the 73 nm of sparker seismic data collected. Hillshaded bathymetric DEM is made from INFOMAR data and has a 10-m resolution; white map areas have no INFOMAR data coverage.

6.3 Study Area 4 results

57 nm (106 km) of sparker seismic, pinger seismic, and MBES data were gathered in study area 4, offshore of Ballycotton (Figure 15). Following the seismic survey, the cruise was put on weather standby for safety reasons. An "extra" (i.e. unplanned) 30 nm of pinger data was collected during the transit into Cork Harbour (Figure 15). These data targeted the 12-nm limit proximal to Cork Harbour, because this distance from shore has been deemed important for promoting responsible offshore wind energy development (EirWind, 2019), and the Port of Cork has been identified as potentially suitable for OWE O&M activities (Irish Maritime Development Office, 2018). Palaeovalley systems identified using the INFOMAR bathymetric data (Figure 15) were also targeted during this

survey because they probably incise Quaternary glacial sediments (cf. Gallagher et al., 2004), and therefore potentially allow for improved seismic penetration into a diverse set of strata.

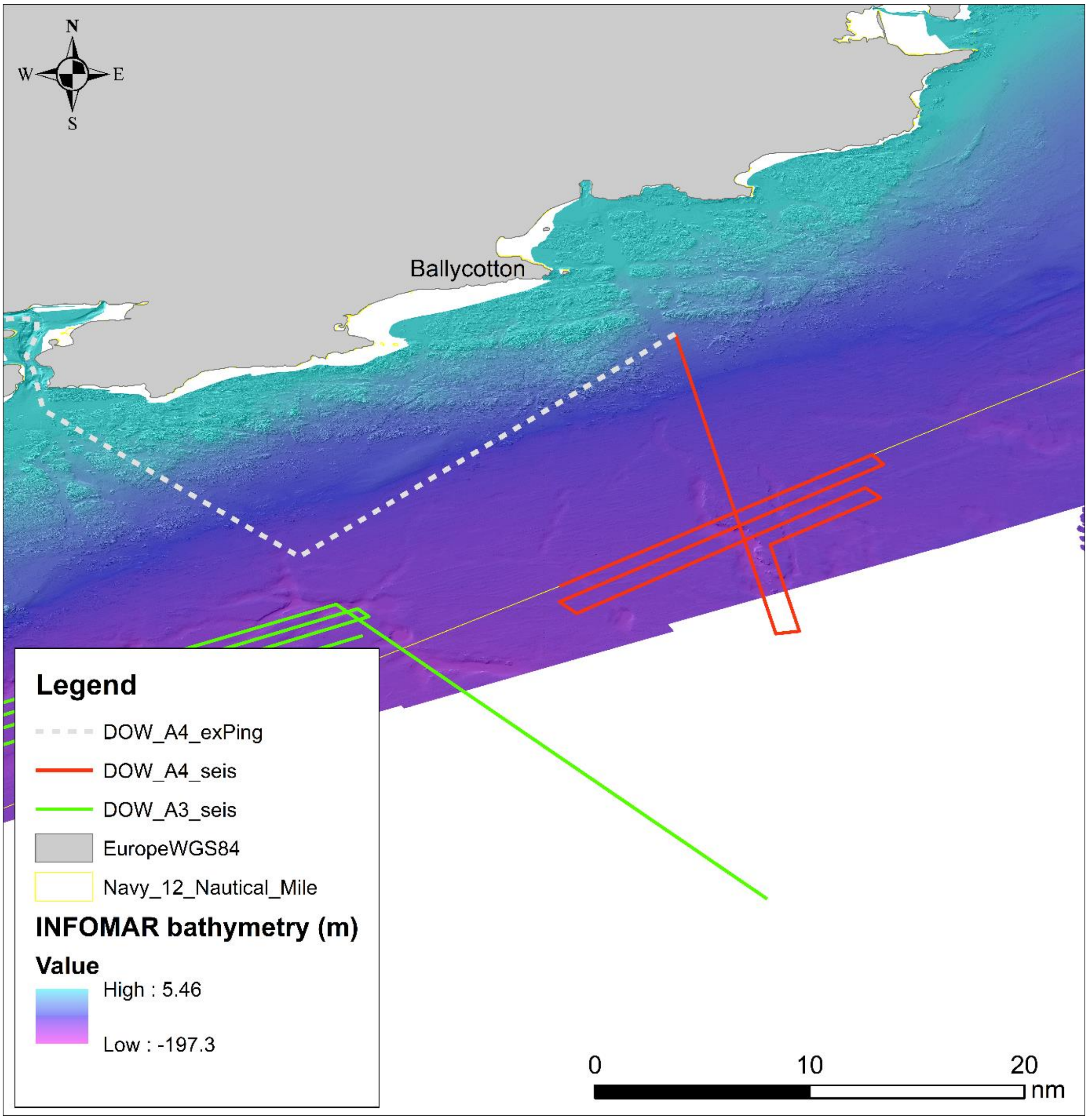

Figure 15: Map of study area 4 showing the 57 nm of sparker seismic data collected (red line), the sparker collected in area 3, and the "extra" 30 nm of pinger seismic data (light-grey dashed line) collected while steaming back to Cork Harbour for weather standby. Hillshaded bathymetric DEM is made from INFOMAR data and has a 10-m resolution; white map areas have no INFOMAR data coverage.

6.4 Study Area 8 results

54 nm of sparker seismic pinger seismic, and MBES data were gathered in study area 4, offshore of Lambay Island (northeast of Dublin) (Figure 16). At 02:00 (28/09/2019) the weather was deemed

too poor for safe operation of the sparker system. After the sparker catamaran and hydrophone were recovered, an additional ~20 nm of pinger seismic and MBES data were collected (Figure 16).

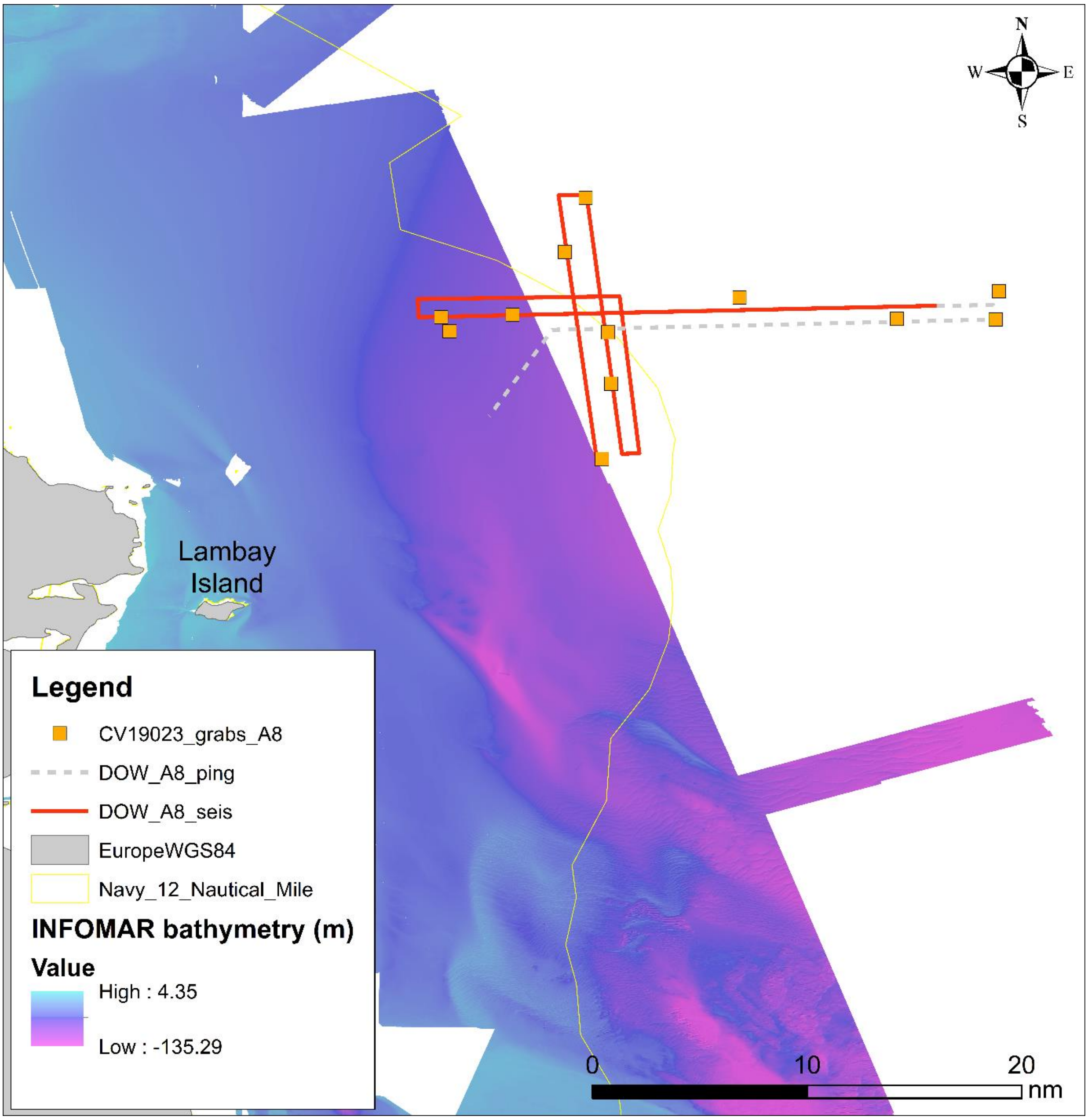

Figure 16: Map of Study Area 8 showing the 54 nm (~99 km) of sparker and pinger sub-bottom seismic data (red line) and the additional 20 nm (37 km) of pinger acquired after the weather made sparker operations unsafe. Locations of the 12 sediment grabs collected in Study Area 8 are also shown (orange boxes). Hillshaded bathymetric DEM is made from INFOMAR data and has a 10-m resolution; white map areas have no INFOMAR data coverage.

6.5 Data summary

6.5.1 Seismic data

A total of 433 nm (802 km) of seismic data were collected (Table 3). Of this, 272 nm consist of sparker data.

Table 3: Seismic (sparker and pinger) data.

Study Area	Seismic type	Length acquired	Apparent penetration (from unprocessed two-way travel time)
1	Sparker	88 nm (~163 km)	Unclear, possibly to bedrock
3	Sparker	73 nm (~135 km)	Unclear, likely 50 m
4	Sparker	57 nm (106 km)	Unclear
4	Pinger	87 nm (162 km)	~5 m
8	Sparker	54 nm (~99 km)	Up to 50 m
8	Pinger	74 nm (136 km)	~5 m

6.5.2 Multibeam Echosounder data

A total of 275 nm (509 km) of MBES data were collected (Table 4). These data were typically collected simultaneously with the sparker and/or pinger data.

Table 4: MBES data.

Study Area	Length acquired
1	71 nm (132 km)
3	73 nm (~135 km)
4	57 nm (106 km)
8	74 nm (136 km)

6.5.3 Sediment data

One sediment core (vibrocore, Table 5) and 15 sediment grabs (Table 6) were collected. These samples were typically taken from on or near the seismic and MBES transects (Figure 13, Figure 16) to maximise continuity and data relatability.

Table 5: Vibrocore information.

Study Area	Sample number	Latitude	Longitude	Length (cm bsf)
1	01VC	52°34.911’	10°15.445’	42

Table 6: Sediment grabs.

Study Area	Sample number	Latitude	Longitude
1	01G	52°40.300’	10°12.692’
1	02G	52°42.112’	10°21.466’
1	03G	52°34.946’	10°15.455’
1	03aG	52°34.977’	10°15.442’
8	04G	53°36.465’	5°43.247’
8	05G	53°39.937’	5°42.780’
8	06G	53°42.321’	5°42.920’
8	07G	53°42.945’	5°29.465’
8	08G	53°42.920’	5°24.868’
8	09G	53°44.239’	5°24.719’
8	10G	53°43.947’	5°36.793’
8	11G	53°48.585’	5°43.964’
8	12G	53°46.068’	5°44.932’
8	13G	53°43.143’	5°47.365’
8	14G	53°43.027’	5°50.689’
8	15G	53°42.368’	5°50.303’

7 Benefits, impacts and contributions

7.1 Benefits and potential impacts to the Marine Sector

The DOWindy research cruise has produced data that are widely applicable to several national research programmes. The research was designed for, and by, the industry-led Eirwind project. These data help to improve bathymetric and geologic information within several large data gaps that occupy areas of interest for the development of Ireland’s offshore wind energy industry. The new bathymetric data reveal seabed characteristics like bedrock outcrops and mobile-sediment landforms that are important for de-risking aspects of offshore wind farm development (Kallehave et al., 2015).

Ireland is rich in untapped offshore wind energy (Gallagher et al., 2016) and many European nations are already benefiting from offshore wind energy production. In 2017, offshore wind farms in the UK experienced an 8% increase in financial investors (The Crown Estate, 2018). These investments seem to be paying off, since the debt-to-equity ratio for financing these projects has risen from 70:30 to 75:25 (ibid). Considering these facts, the relatively small investment for this research cruise from a variety of academic and industry partners (Table 7) has the potential to result in a high cost/benefit ratio through projects like Eirwind and any subsequent offshore wind farm developments.

Another potential benefit of the sediment data collected by the DOWindy cruise is insights into marine aggregate potentials. Building materials are essential to continued socioeconomic development in Ireland (Paul et al., 2006), a nation with an appetite for construction aggregate that is approximately four times higher than the mean European Union per capita demand (~30 tonnes per person/yr in 2005; Sutton et al., 2008). Approximately 33 million tonnes of aggregate were mined for use as construction material in Ireland during 2017 (Irish Concrete Federation, 2018). These materials help drive Ireland’s construction industry, which represents a large portion of the GNP (Paul et al.,

2006) and offshore aggregate resources are particularly economically viable (Sutton et al., 2008). Despite these facts, the stratigraphy of palaeovalley infill sequences offshore of Ireland, which could consist of sand and gravel, have not been thoroughly investigated. The iCRAG Centre, a Science Foundation Ireland programme, is currently working with UCC to investigate the viability of offshore marine aggregate sources. Thus, the sedimentological data provided by the DOWindy research cruise could add information that benefits other research programmes and helps de-risk future mining activities.

Climate change is already affecting our environment and economy (Pachauri et al., 2014), and projections for Ireland predict a temperature increase of 2° by 2100 (Christensen et al., 2007). These changes are exacerbating the vulnerability of coastal areas (Flannery et al., 2015) and some analyses predict irregular and serious issues from even small changes in Ireland's climate (e.g. Lennon, 2015). The data collected by the DOWindy research cruise, especially the sedimentary data, may prove insightful to palaeoglaciological reconstructions of the last BIIS (Clark et al., 2012) and postglacial benthic adaptations. These reconstructions are valuable to predictive models for modern climatic and cryospheric changes because they enable comparative assessments of model validity. The sediment data from the vibrocore and seismic data could also be used to assess palaeoenvironmental changes since the last glaciation, thereby providing insightful context for any research on modern benthic habitats on the Irish continental shelf. Thus, the academic research possible with data collected by the DOWindy research cruise may benefit the economies of Ireland and western Europe if properly considered by policy makers.

7.2 Benefits and contributions to specific research programmes

Table 7: CV19023 contributions to specific research programmes.

Programme	Programme duration	Programme partners	Contributions from DOWindy (CV19023)	CV19023 cost to programme	Potential programme benefits to Ireland
Eirwind	2 years	UCC; MaREI; various national and international industry partners	Bathymetric and backscatter data; sediment data; ground truthing	Minimal (<€1,000)	Improved site selection for offshore wind farm development
AggrePOP	2 years	UCC; iCRAG	Sediment data; ground truthing	Minimal (<<€500)	Construction aggregate sources; improved seabed mapping resolution

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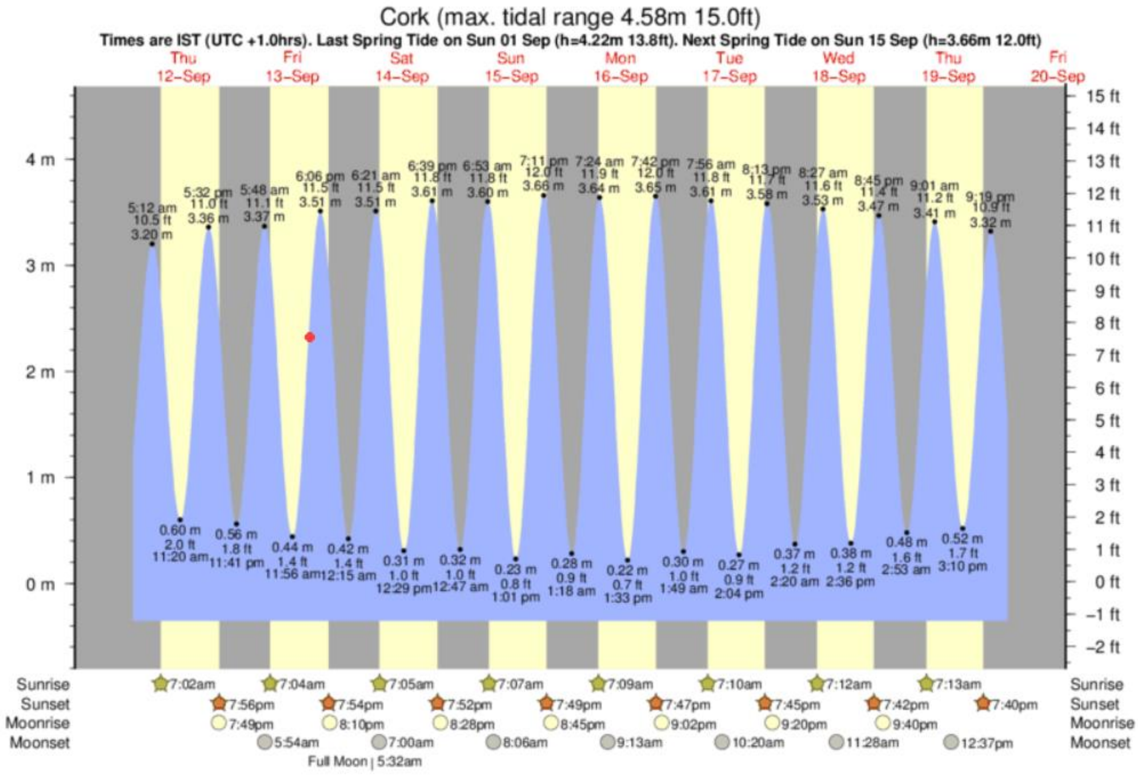
9 Appendix

9.1 Tidal charts



Tidal chart for Cork downloaded from www.tide-forecast.com.

9.2 Weather report

9.2.1 Day 2 (17/09/2019):

04.00 Everything calm (tied up in Galway Docks).

06.00 Everything calm (tied up in Galway Docks).

08.00 Easterly wind at 2 – 3 knots (variable). Force 1 – 2. Approximately 0.5 m swell (singlebeam). No waves, clear skies.

14.00. N/A

12.00 South easterly wind at 3 –4 knots (variable). Force 2. Approximately 1.5 m swell (Observation). V. Small waves, clear skies.

16.00 South easterly wind at 2 – 3 knots (variable). Force 1 –2. Approximately 1.2-1.8 m swell (forecast and observation). V. Small waves, clear skies.

18.00 North easterly wind at 3 –4 knots (Variable). Force 2. Approximately 1 m swell (forecast and observation). V. Small waves, clear skies.

20.00 North easterly wind 2-3 knots (variable) Force 1 Approximately 1m swell (forecast and observation) Small waves, clear skies.

24.00 North easterly wind3-4 knots (Variable). Force 2 Approximately 2 m swell (forecast and observation). V. Small waves, clear skies.

9.2.2 Day 3 (18/09/2019):

02.00 North easterly wind at 2-3 knots (Variable). Force 2. Approximately 2 m swell (forecast and observation). V. Small waves, clear skies.

04.00 North easterly wind at 2-3 knots (Variable). Force 2. Approximately 2 m swell (forecast and observation). V. Small waves, clear skies.

06.00 North easterly wind at 2 knots. Force 1. Approximately 2 m swell (forecast and observation). V. Small waves, clear skies.

08.00 South easterly wind at 1 –2 knots. Force 1. Approximately 1.5 m swell (forecast and observation). No waves, clear skies.

12.00 South easterly wind at 2 –3 knots. Force 1. Approximately 1.5-2.0 m swell (forecast and observation). No waves, clear skies.

14.00 South easterly wind at 2 knots. Force 1. Approximately 1.5-2.0 m swell (forecast and observation). No waves, almost no ripples, clear skies.

16.00 South easterly wind at 2 knots. Force 1. Approximately 1.5-2.0 m swell (forecast and observation). No waves, almost no ripples, clear skies.

18.00 South easterly wind at 2 –3 knots. Force 1 –2 (Variable). Approximately 1—1.5 m swell (Forecast and observation). No waves, almost no ripples, clear skies.

20.00 South Easterly Winds at 2-3 knots Force3-4, approximately 2-4 m swell (forecast and observation) No waves, almost no ripples, clear skies

24.00 South Easterly Winds 2knots.Force 1, approximately 2m swell (forecast and observation) No waves, almost no ripples, clear skies

9.2.3 Day 4 (19/09/2019):
04.00 South Easterly Winds 2-3 knots. Force 1, approximately 2m swell (forecast and observation) Small waves, clear skies

06.00 South Easterly Winds 2-3 knots. Force 2, approximately 1-2m swell (forecast and observation) Small waves (wavelets), clear skies

08.00 South Easterly winds at 4 –5 knots. Force 2, approximately 1 –2 m swell (forecast and observation). Small waves, clear skies.

12.00 South Easterly winds at 3 –4 knots. Force 2, approximately 1 –2 swell (forecast and observation). Small waves, clear skies.

14.00 South Easterly winds at 3 –4 knots. Force 2, approximately 1 –2 m swell (forecast and observation). V. Small waves, clear skies.

16.00 South Easterly winds at3 –4 knots. Force 2, approximately 1 –2 m swell (Forecast and observation). V. Small waves, clear skies.

18.00 South Easterly winds at 3-4 knots. Force 2, approximately 1 –2 m swell (Forecast and observation). V. Small waves, clear skies.

20.00 South Easterly winds 3-4- knots. Force 2, approximately 1-2m swell (forecast and observation) no waves, clear skies.

24.00 South Easterly winds 3-4 knots. Force 2, approximately 0-2m swell (forecast and observation) small waves, clear skies.

9.2.4 Day 5 (20/09/2019):
04.00 00 South Easterly winds 4 knots. Force 2, approximately 0-2m swell (forecast and observation) small waves (ripples), clear skies.

06.00 South Easterly winds 4-5 knots. Force 2, approximately 2-4m swell (forecast and observation) medium waves, clear skies.

08.00 South Easterly winds 8 –10 knots. Force 3, approximately 2 –4 m swell (forecast and observation) medium waves, partial cloud cover.

12.00 South Westerly winds at 6 –8 knots, Force 3, approximately 2 m swell (forecast and observation) medium waves, partial cloud cover.

14.00 – 24.00. Everything calm (Tied up at Cork Dock).

9.2.5 Day 6 (21/09/2019):
04.00 – 24.00 Everything calm (Tied up at Cork Dock).

9.2.6 Day 7 (22/09/2019):
04.00 – 08.00 Everything calm (Tied up at Cork Dock).

10.00 Westerly wind at 6 knots. Force 2-3. ~2 m swell, 8 s period (Satellite (Windy.com) and observed). Small waves. Clear skies.

12.00 Westerly wind at 14 knots. Force 4. ~2—3 m swell (Satellite (Windy.com) and observation). Medium waves, clear skies.

14.00. Westerly wind at 14 knots. Force 4. ~2 m swell (Satellite (Windy.com) and observation). Medium waves, clear skies.

16.00 Westerly wind at 14 knots. Force 4. ~2 m swell (Satellite (Windy.com) and observation). Medium waves, white caps increasing, moderate cloud cover.

18.00 Westerly wind at 14 knots. Force 4. ~2 m swell (Satellite (Windy.com) and observation). Medium waves, white caps increasing, moderate cloud cover.

20.00 Westerly wind at 15 knots. Force 4. ~2 m swell (Satellite (Windy.com) and observation). Medium waves, white caps increasing, clear sky.

24.00 Westerly wind at 11 knots. Force 4. ~2 m swell (Satellite (Windy.com) and observation). Medium waves, clear sky.

9.2.7 Day 8 (23/09/2019):

04.00 Westerly wind at 17 knots. Force 5. ~2-4 m swell (Satellite (Windy.com) and observation). Medium waves, clean sky.

06.00 Southerly wind at 17 knots. Force 5. ~2 m swell. 1 m wind waves (Windy.com and observed). Cloudy; rainy.

08.00 Southerly wind at 21 knots. Force 6. ~2 m swell. 1-2 m wind waves (Windy.com and observed). Cloudy; raining.

10.00 – 24:00 Everything calm (Tied up at Cork Dock).

9.2.8 Day 9 (24/09/2019):

04.00 – 24.00 Everything calm (Tied up at Cork Dock).

9.2.9 Day 10 (25/09/2019):

04.00 – 10.00 Everything calm (Tied up at Cork Dock).

12.00 South Westerly winds at11 knots. Force 4. ~3 m swell. ~1m wind waves (Windy.com and observed).Cloudy, raining.

14.00 South Westerly winds at 16 knots. Force 5. ~3 m swell. ! –2 m wind waves (Windy.com and observed). Cloudy, raining.

16.00 South Westerly winds at 18 knots. Force 5. ~3 m swell. 1 –2 m wind waves (Windy.com and observed). Partially cloudy, dry.

18.00 Stormy. In Cork.

20.00 Raining. In Cork.

24.00 Raining.

9.2.10 Day 11 (26/09/2019):

04.00 Raining.

06.00 Cloudy. Force 2-3. In transit.

08.00 South Westerly winds at 18 knots. Force 4-5. ~1 m swell. 1-2 m wind waves. High cloud cover. No precipitation.

10.00 South Westerly winds at 20 knots. Force 5. ~1 m swell. 1-2 m wind waves. High cloud cover. No precipitation.

12.00 South Westerly winds at 20 knots. Force 5-6. ~1 m swell. 1-2 m wind waves. High cloud cover. No precipitation.

14.00. South Westerly winds at 19 knots. Force 5. ~0.5 -1 m swell. 1-2 m wind waves. High cloud cover. No precipitation.

16.00 South westerly wind at 21 knots. Force 6. ~0.5-6 m swell. ~1-2 m wind waves. High cloud cover. Some squalls in the distance.

18.00 South westerly wind at 21 knots. Force 6. ~0.6 m swell. ~1-2 m wind waves. Medium cloud cover. Some squalls in the distance.

20.00 South westerly wind at 19 knots. Force 5. ~0.7 m swell. ~1-2 m wind waves. Medium cloud cover. Some squalls in the distance.

24.00 South westerly wind at 17 knots. Force 5. ~0.8 m swell. ~1-2 m wind waves. Medium cloud cover. Some squalls in the distance.

9.2.11 Day 12 (27/09/2019):

04.00 South westerly wind at 16 knots. Force 5. ~0.7 m swell. ~1.1 m wind waves. Medium cloud cover. Some squalls in the distance.

06.00 Southerly wind at 16 knots. Force 4-5. ~0.5 m swell. 1 m wind waves. Heavy cloud cover and fog with some rain.

08.00 SW wind at 16 knots. Force 4-5. 0.5-1m swell. Very short period. 1 m wind waves. Heavy cloud cover, areas of fog, some rain.

10.00 SW wind at 15 knots. Force 4. ~1 m swell. Very short period. 1 m wind waves. Moderate cloud cover, some rain.

12.00 SW wind at 18 knots. Force 5. 1—2 m swell. Short period. 1 m wind waves. Moderate cloud cover.

14.00 Westerly wind at 15 knots. Force 4. 1 m swell. Average period. 1—1.5 m wind waves. Patchy cloud cover.

16.00 Westerly wind at 17 knots. Force 4. 1 m swell. 1 m wind waves. High clouds.

18.00 Westerly wind at 16 knots. Force 4. ~1 m swell. 0.5 – 1 m wind waves. Moderate cloud cover.

20.00 Westerly wind at 18 knots. Force 4. ~1 m swell. 0.9 m wind waves. Moderate cloud cover.

24.00 South westerly winds at 15 knots force 4. ~1 m swell, 0.7 m wind waves. Low cloud cover

9.2.12 Day 13 (28/09/2019):

04.00 South westerly winds at 17 knots force 4. 0.6 m swell, 0.8 m wind waves. Moderate cloud cover

9.3 Activity log

Day	Date	Activity	Start time	End time	Duration (hrs)
2	17/09/2019	Sail	07:00:00	07:00:00	00:00:00
2	17/09/2019	Transit	07:00:00	14:30:00	07:30:00
2	17/09/2019	MMO watch, soft start, sparker set up, sparker soft start	15:00:00	16:42:00	01:42:00
2	17/09/2019	Sparker seismic data acquisition and MBES	16:42:00	00:00:00	07:18:00
3	18/09/2019	Sparker seismic data acquisition and MBES	00:00:00	14:33:00	14:33:00
3	18/09/2019	Prep for sed collection	14:33:00	15:10:00	00:37:00
3	18/09/2019	Sed grabbing and coring	15:10:00	18:05:00	02:55:00
3	18/09/2019	Transit to "area 3" (the second survey area)	18:05:00	00:00:00	05:55:00
4	19/09/2019	Transit to "area 3" (the second survey area)	00:00:00	14:55:00	14:55:00
4	19/09/2019	MMO watch	14:55:00	15:38:00	00:43:00
4	19/09/2019	Soft start, sparker set up, sparker soft start	15:38:00	16:21:00	00:43:00
4	19/09/2019	Sparker seismic data acquisition	16:21:00	16:46:00	00:25:00
4	19/09/2019	Sparker seismic data acquisition and MBES	16:46:00	00:00:00	07:14:00
5	20/09/2019	Sparker sesimic data acquisition and MBES	00:00:00	09:34:00	09:34:00
5	20/09/2019	Transit to Cork harbour for shelter from rough weather	09:34:00	14:20:00	04:46:00
5	20/09/2019	Tied up in Port of Cork (weather standby)	14:20:00	00:00:00	09:40:00
6	21/09/2019	Weather standby	00:00:00	23:59:00	23:59:00
7	22/09/2019	Weather standby	00:00:00	08:30:00	08:30:00
7	22/09/2019	Transit	08:30:00	12:19:00	03:49:00
7	22/09/2019	Arrive at station. MMO watch, sparker soft start	12:19:00	13:30:00	01:11:00
7	22/09/2019	Sparker and pinger seismic data acquisition and MBES	13:30:00	15:40:00	02:10:00
7	22/09/2019	Sparker and pinger seismic data acquisition and MBES	15:43:00	00:00:00	08:17:00

8	23/09 /2019	Sparker seismic data acquisition dropped to 1400 J, MBES continued.	00:0 0:00	02:4 5:00	02:4 5:00
8	23/09 /2019	Sparker line completed; pinger and MBES acquisition continued.	02:4 5:00	07:3 0:00	04:4 5:00
8	23/09 /2019	Captain decided to take us in for safety (start a new weather standby). Pinger continued during transit to Cork.	07:3 0:00	10:0 0:00	02:3 0:00
8	23/09 /2019	Transit and docking for weather standby in Cork.	10:0 0:00	23:5 9:00	13:5 9:00
9	24/09 /2019	Docking for weather standby in Cork.	00:0 0:00	23:5 9:00	23:5 9:00
10	25/09 /2019	Docking for weather standby in Cork.	0:00 :00	12:0 0:00	12:0 0:00
10	25/09 /2019	Transit to next location from Cork.	12:0 0:00	00:0 0:00	12:0 0:00
11	26/09 /2019	Transit to next location from Cork.	00:0 0:00	09:2 5:00	09:2 5:00
11	26/09 /2019	On station. Assessing conditions for attempting an MMO watch.	09:2 5:00	09:4 1:00	00:1 6:00
11	26/09 /2019	Weather deemed too poor for MMO, or sparker, or corer. Transiting to grab stations.	09:4 1:00	11:0 5:00	01:2 4:00
11	26/09 /2019	Sediment grabs in Area 8.	11:0 5:00	18:1 0:00	07:0 5:00
11	26/09 /2019	Transit to shelter for the night.	18:1 0:00	20:4 0:00	02:3 0:00
11	26/09 /2019	Shelter for the night (weather standby).	20:4 0:00	00:0 0:00	03:2 0:00
12	27/09 /2019	Shelter for the night (weather standby).	00:0 0:00	07:3 0:00	07:3 0:00
12	27/09 /2019	Transit to study area 8 to assess conditions for MMO and sparker.	07:3 0:00	10:1 8:00	02:4 8:00
12	27/09 /2019	MMO watch and soft start for sparker in area 8.	10:1 8:00	11:2 0:00	01:0 2:00
12	27/09 /2019	Sparker, pinger, MBES data acquisition.	11:2 0:00	00:0 0:00	12:4 0:00
13	28/09 /2019	Sparker, pinger, MBES data acquisition.	00:0 0:00	02:0 0:00	02:0 0:00
13	28/09 /2019	Recovered Sparker to deck survey finished backup commenced	02:0 0:00	02:0 0:00	00:0 0:00
13	28/09 /2019	Continued MBES and pinger acquisition while transiting to Dublin	02:0 0:00	06:0 0:00	04:0 0:00

9.4 MMO weekly logs

The following reports were provided by Jessica Giannoumis (the DOWindy MMO).

DOWindy SPARKER SURVEY
MARINE MAMMAL OBSERVATION
WEEKLY REPORT

Report Reference Week Number: 1 Date: September 17-22, 2019

Project Details:

Client	Marine Institute
Contractor and Vessel	Marine Institute, R.V. Celtic Voyager
Survey Type	2D Sparker
Project Reference	CV19023
Marine Mammal Observers	Jessica Giannoumis
PAM Operators	-

Summary of Weekly Activity:
There were no shutdowns for weather or other operations during the week.

Activity	Number
Prewatches	3
Soft starts	3
Line Acquisition	
Turn Acquisition	
Delays	1

Weekly Total

Total hours of observation	5:14
Hours of observation while operations ongoing	3:21
Number of daylight starts/tests	1
Number of night time starts	0
Number of visual pre-watches	1
Number of sightings	0
Number of delays to starts/tests	0

Project Total

Total hours of observation	5:14
Hours of observation while operations ongoing	3:21
Total number of daylight starts/tests	1
Total number of night time starts	0
Total number of visual pre-watches	1
Total sightings during the project	0
Number of delays to starts/tests	0

Sighting Conditions:

Conditions for visual monitoring were moderate. WMO/Beaufort sea states varied from 2 to 4 and visibility was mostly good with occasional fog. Swell remained moderate to low, from less than 2 m to below 2 m.

Details of Sightings:
There were eleven sightings.

No.	Species	Total Number	Lat	Long	Closest distance
1	Harbour seal	1	52° 33.10'	10° 16.48'	350m
2	Common dolphin	2	52° 35.95'	10° 14.99'	800m
3	Common dolphin	10	52° 38.45'	10° 18.23'	5m
4	Common dolphin	4	52° 42.76'	10° 41.02'	200m
5	Fin whale	2	51° 24.02'	9° 01.38'	800m
6	Common dolphin	4	51° 39.40'	8° 06.71'	5m
7	Bottlenose dolphin	1	51° 23.63'	7° 41.89'	40m
8	Bottlenose dolphin	1	51° 46.80'	7° 48.03'	10m
9	Bottlenose dolphin	2	51° 26.36'	7° 45.54'	5m
10	Common dolphin	4	51° 37.44'	7° 51.50'	15m
11	Common dolphin	5	51° 39.07'	8° 07.16'	10m

Details of Mitigation/Non-Compliance:
At the start of the first seismic survey, technical issues between the Quincy and CODA programs caused the soft start period to be extended to just over 2 hours. MMO protocols were adhered to throughout this period.

DOWindy SPARKER SURVEY
MARINE MAMMAL OBSERVATION
WEEKLY REPORT

Report Reference Week Number: 2 Date: September 23-28, 2019

Project Details:

Client	Marine Institute
Contractor and Vessel	Marine Institute, R. V. Celtic Voyager
Survey Type	2D Sparker
Project Reference	CV19023
Marine Mammal Observers	Jessica Giannoumis
PAM Operators	-

Summary of Weekly Activity:
There were no shutdowns for weather or other operations during the week.

Activity	Number
Prewatches	1
Soft starts	1

Line Acquisition	
Turn Acquisition	
Delays	0

Weekly Total

Total hours of observation	1:10
Hours of observation while operations ongoing	0:40
Number of daylight starts/tests	1
Number of night time starts	0
Number of visual pre-watches	1
Number of sightings	3
Number of delays to starts/tests	0

Project Total

Total hours of observation	6:24
Hours of observation while operations ongoing	4:01
Total number of daylight starts/tests	4
Total number of night time starts	0
Total number of visual pre-watches	4
Total sightings during the project	0
Number of delays to starts/tests	1

Sighting Conditions:
Conditions for visual monitoring were moderate. WMO/Beaufort sea states varied from 2 to 4 and visibility was mostly good with occasional fog. Swell remained moderate to low, from less than 2m to below 2m.

Details of Sightings:
There were three sightings.

No.	Species	Total Number	Lat	Long	Closest distance
12	Common Dolphin	4	51° 44.73’	7° 14.97’	20m
13	Common Dolphin	5	53° 46.26’	5° 40.50’	2m
14	Harbour porpoise	3	53° 34.41’	6° 18.34’	20m

Details of Mitigation/Non-Compliance:
None

9.5 MMO Report

The following report was provided by Jessica Giannoumis (the DOWindy MMO) and it’s formatting and figure references were modified for inclusion into this document.

Marine Mammal Observer Report

R.V. Celtic Voyager

Marine Institute

CV19023

Derisking Offshore Wind Energy Development Potential in Irish Waters (DOWindy)

Atlantic, Celtic Sea, Irish Sea

17th - 28th of September, 2019

Contents

1. Executive Summary

Between September 17th – 28th a total of 6 hours and 24 minutes of visual monitoring were carried out by a dedicated Marine Mammal Observer (MMO) during geophysical seismic survey operations in the Atlantic, Celtic Sea, and Irish Sea. Sparker survey operations took place over the course of four days, amounting to a total of 72 hours and 22 minutes surveying.

(i) Marine Mammal Detection

During the survey there were a total of 14 sightings of marine mammals. Of the 14 sightings, one occurred during a pre-shoot watch, 5 sightings occurred while the source was active, and 9 sightings occurred while the source was inactive.

(ii) Detections During Pre-shoot Watch

During the second pre-shoot watch on September 19th one marine mammal was detected.

(iii) Mitigation Actions Required

The soft start was delayed until 30 minutes after the last sighting of the marine mammal.

(iv) Night-time and Bad Weather Operations

No soft starts occurred during night-time. Where pre-shoot watches and soft start procedures have commenced during daylight hours, ongoing sparker surveys continued into the night-time.

Operations were stopped due to bad weather beyond sea state 4 the night of September 27th.

Due to bad weather the vessel was sheltered in Cork harbour September 20th – 22nd, and September 23rd – 25th.

(v) Problems in Implementing Mitigation Guidelines

At the start of the first seismic survey, technical issues between the Quincy and CODA programs caused the soft start period to be extended to just over 2 hours. MMO protocols were adhered to throughout this period.

2. Introduction

Irish waters are among the most important in Europe for a wide range of marine mammals, including cetaceans (whales, dolphins, and porpoises) and pinnipeds (seals) which are present regularly or seasonally. The 1976 Wildlife Act (NPWS, 1976) and the subsequent Amendments (2000, 2005, 2010, and 2012) provide a legal framework extending to Ireland's Territorial Sea (i.e. the 12 nautical mile limit from the baseline) for the protection of marine mammal species and their habitats in Irish waters. Under the Wildlife Act, it is an offence to hunt and injure (unless licences or Ministerial permits have previously been obtained), disturb, or destroy breeding places of protected species. The Habitats Directive further states that all marine mammals normally occurring within Ireland's 200 nautical mile limit must be given protection (DAHG, 2014). In Ireland, 24 cetaceans and 2 pinnipeds can be found, some of these marine mammals are abundantly spread throughout Irish waters, while others are rarely encountered (Berrow, 2001).

Man-made sound, such as sound generated by seismic surveys, can have life-threatening effects on marine mammals, hence, any acoustic introduction into the marine space needs to be carefully considered and monitored (Weilgart, 2007). Any geophysical acoustic surveys should use the minimum acoustic source level to achieve the desired result. The undertaking of geophysical acoustic surveys carried out by vessels within Irish waters require Marine Mammal Observers (MMO) to be present. Prior to any seismic operations, MMOs will carry out 30 minute pre-shoot watches in waters up to 200 meter deep, followed by a 40 minute soft start. If any marine mammals during the pre-shoot watches within the mitigation zone (1000 metre of the acoustic source) have been detected, seismic operations are to be halted until the marine mammal has moved away. Seismic operations may only start once the marine mammals had sufficient time to leave the area (30 minutes from when the marine mammal was last seen). Soft starts will slowly introduce acoustic emissions to the environment, achieving maximum or desired sound output after 40 minutes.

This document serves to meet the reporting requirements as outlined in the Department of Arts, Heritage and the Gaeltacht's Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters, January 2014 (DAHG, 2014) for geophysical surveys.

3. Date and Location of Survey

The CV19023 survey was planned for September 17th – 28th, 2019 in the Atlantic, Celtic Sea, and Irish Sea.

4. Survey Vessel

R.V. Celtic Voyager (call sign: EIQN), 31.4 m in length and 4 m draught, is a multi-purpose vessel (Figure 3) and is equipped with wet, dry, and chemical laboratories which are permanently fitted with standard scientific equipment. The vessel accommodates 15, depending on the survey between 6-8 scientists and 7-9 crew members, highly skilled in handling and deploying the scientific equipment. The Celtic Voyager has a maximum endurance of 14 days.

Key features of the R.V. Celtic Voyager include EM2040 Multi-beam echosounder, Ixsea Gaps USBL System, ideally suited to towed Underwater TV operations, Capable of beam and pelagic and demersal otter trawling, CTD work to 1000 m, and full oceanographic services.

5. Survey Equipment

The Geo-Source 200 sparker seismic system of the Marine Institute was used during the survey. This sparker seismic system uses a 6kJ (max 5,600 V) pulsed power supply which emits a pulse to the sparker source which is towed behind the vessel. The return signal is picked up in Geo-Sense single channel hydrophone array at frequencies ranging from 200 – 1,500 kHz. The Geo-Spark 200 provides high resolution seismic profiles of up to 300 m depth, depending on the composition of the water column, sea conditions, and the underlying seabed. A multi-tip array of sparker nodes are evenly spaced in planar array which enhances the downward projection of the acoustic energy. The Geo-Source 200 is designed to float on or just below the water-surface.

6. Marine Mammal Observers/Qualifications

MMO: Jessica Giannoumis

Address: Douglas, Co. Cork, T12 Y7FV, Ireland

Email: Jessica.Giannoumis@ucc.ie

Academic Qualifications:

- M.Sc. in International Environmental Studies, Norwegian University of Life Sciences, 2017

Specialised in the regulation of mitigation procedures of anthropogenic sound in marine environments in the United States

- BA in Media Studies and Human Geography, University of Oslo, 2015

- Diploma in Environmental Impact Assessment and Natural Disasters, University of Hong Kong, 2014

Training and Certifications:

- IWDG Marine Mammal Observer course (2019)

- JNCC Marine Mammal Observer Training (2019)

- 5yr+ of marine mammal observation and detection of marine wildlife in European waters and Puget Sound

Recent Marine Mammal Survey Experience (accounting for at least 6 weeks):

- Marine Mammal Observer

Charter boats varied in West Cork, Ireland – using marine mammal observation techniques to detect marine wildlife (May – September 2019 3 weeks)

- Marine Mammal Observer

Celtic Mist, SW Ireland, IWDG – using marine mammal observation techniques to survey humpback whales along 100 m contour line (August 2019 1 week)

- Marine Mammal Observer

Vessels varied and were provided by local dive centres and fisher people on Faial island, Azores, Portugal – research project in collaboration with the University of the Azores, documenting the effects of man-made sound introduction and marine megafauna (July – August 2016 6 weeks)

Casual observations: bridge and deck crew - there were sightings of marine mammals by other crew on board which always were verified by the MMO.

7. Survey Areas

The survey was undertaken to increase the understanding of seabed and sub-seabed conditions in areas of good grid connectivity (west, south, and east coasts) at the 12 mile limit where offshore windfarms are most likely to be developed.

- To repeat multibeam bathymetric and backscatter mapping to assess seabed dynamics
- To collect spark seismic data to assess sub-seabed conditions e.g. depth to the rock
- To collect seabed sampling to collect sediment grab samples

The key target areas for seismic data and sediment grab sampling were undertaken to achieve the above objective. The table below documents the planned locations for sediment grab sampling as detailed in Marine Notice No. 30 of 2019 (Irish Maritime Administration, 2019). All other data acquisition activities are planned within ~3 nm of these coordinates. All positions based on WGS 84 datum.

Figure 1 shows the areas planned for the CV19023 survey data acquisition activities (yellow). The green line outlines the travel path of the survey.

Table 1: CV19023 planned locations for sediment grab sampling

ID	Latitude	Longitude
1	52° 38.34' N	010° 05.23' W
2	52° 38.91' N	010° 05.11' W
3	52° 40.30' N	010° 12.66' W
4	52° 42.12' N	010° 21.43' W
5	52° 41.22' N	010° 19.45' W
6	52° 35.14' N	010° 15.37' W
7	51° 18.35' N	009° 10.36' W
8	51° 13.56' N	009° 05.63' W

ID	Latitude	Longitude
24	51° 43.26' N	007° 20.65' W
25	51° 38.18' N	007° 15.24' W
26	51° 38.58' N	007° 14.46' W
27	51° 37.48' N	007° 13.16' W
28	51° 36.98' N	007° 13.23' W
29	51° 54.15' N	006° 35.52' W
30	51° 50.38' N	006° 42.34' W
31	51° 57.28' N	006° 27.49' W

9	51° 11.30' N	009° 04.63' W
10	51° 11 07' N	009° 03.92' W
11	51° 34.35' N	007° 58.28' W
12	51° 33.97' N	007° 57.73' W
13	51° 31.26' N	007° 53.82' W
14	51° 23.01' N	007° 43.19' W
15	51° 23.91' N	007° 43.22' W
16	51° 44.44' N	007° 44.20' W
17	51° 41.11' N	007° 43.60' W
18	51° 39.96’ N	007° 42.70' W
19	51° 38.66' N	007° 42.27' W
20	51° 36.12' N	007° 40.92' W
21	51° 36.49' N	007° 41.54' W
22	51° 47.79' N	007° 27.53' W
23	51° 45.14' N	007° 23.65' W

32	51° 48.95' N	006° 30.46' W
33	53° 10.27' N	005° 36.20' W
34	53° 07.36' N	005° 34.34' W
35	53° 12.19' N	005° 34.42' W
36	53° 10.22' N	005° 38.16' W
37	53° 43.04' N	005° 50.65' W
38	53° 42.60' N	005° 43.14' W
39	53° 48.72' N	005° 43.92' W
40	53° 44.31' N	005° 24.67' W
41	51° 34.73' N	007° 57.90' W
42	53° 10.30' N	005° 35.08' W
43	53° 08.31' N	005° 35.98' W
44	53° 06.60' N	005° 34.23' W
45	53° 10.37' N	005° 33.02' W

8. Marine Mammal Observations

Observations for marine mammals, and turtles were conducted by a specialized MMO with previous mitigation experience (see Section 3) and were made from the bridge deck (height: 5.5 m) at a height of 7.2 m above sea level. Observations were conducted around the vessel from the bridge which offered a near 360° view with only minor visual obstruction to the stern where a life-raft was stored. The MMO searched for blows, splashes, or disturbances to the sea surface. Data were recorded on JIP22 forms.

In addition to naked eye observations, reticular binoculars (7 x 50 mm) were used and pre-calibrated with the specific conditions of work (height from sea level and eye height of the observer). To determine the range between the Sparker and marine mammals, one of the divisions present in the binoculars is placed on the horizon. The following formular was used to determine the distance between the vessel and the marine mammal.

Formular: Distance (m) = (height of eye above sea level (m) x 1000/ no. of mils down from horizon)

As detailed in the “Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters” (DAHG, 2014), prior to commencement of the acoustic surveys, 30 minute watches in unprotected areas and in waters up to 200 m depth within 1000 m range of the sparker equipment were carried out. Pre-shoot watches were only carried out when weather conditions were below sea state 4 or Beaufort Scale force 4 and during day light hours. If marine mammals were spotted in the area, the soft start procedure was halted for 30 minutes from the time the marine mammal has left the 1000 m mitigation zone or was last seen. If no marine mammals were detected during the pre-watch, a sparker soft start was carried out.

A normal soft start comprises of a ramp up of source power of acoustic emission over at least 40 minutes until the sparker reached full power. During transit between the different study areas the sparker was stopped.

Once the sparker reached full operating power, there is no need for further MMO watches.

9. Pre-Shoot Watches

Visual monitoring was conducted on September 17th, 19th, 22nd, and 27th when the R.V. Celtic Voyager reached the survey area, during daylight, and when weather conditions were favourable to safely carry out pre-shoot watches.

Visual monitoring while acoustic source was inactive amounting to 2 hours and 23 minutes (36 %), visual monitoring while acoustic source was active amounting to 4 hours and 01 minutes (64 %) (Table 2).

Table 2: Visual monitoring effort over the course of the survey

Visual Monitoring Effort	Duration (hh:mm)	% of Overall Visual Monitoring Effort
Total monitoring while acoustic source silent	2:23	36%
Total monitoring while acoustic source active	4:01	64%
Total monitoring effort	6:24	100%

10. Results of Operations

The acoustic source was soft started 4 times over the course of the survey in order to commence full volume survey operations. The soft starts were conducted starting with the sparker emitting sound at low frequency of 100 Hz where gradually more energy was added until the sparker reached full power.

With the exception of the first soft start, the soft starts were exactly 40 minutes. At the start of the first seismic survey, technical issues between the Quincy and CODA programs caused the soft start period to be extended to just over 2 hours. MMO protocols were adhered to throughout this period.

The acoustic source was active for a total of 72 hours 22 minutes throughout the project. This includes testing and soft start of the sparker and full power (Table 3). A detailed description of the operations can be found in Appendix I.

Table 8: Duration of seismic operations throughout the survey

	Number	Duration (hh:mm)
Soft starts	4	2:22
Reduced Output	1	1:20
Full volume on survey line		68:40

Total time acoustic source was active		72:22

11. Marine Mammals Effort Sightings

Visual monitoring conducted during the sparker survey resulted in a total of 14 sightings of marine mammals.

These sightings comprised one sighting of two fin whales (Balaenoptera physalus), one sighting of a harbour seal (Phoca vitulina), one sighting of three harbour porpoises (Phocoena phocoena), three sightings of bottlenose dolphins (Tursiops truncates), and seven sightings of short-beaked common dolphins (Delphinus delphis). There were no sightings of sea turtles though mitigation was extended to turtles.

Of the 14 sightings of marine mammals that occurred during the survey, one sighting occurred during a pre-shoot watch, and 5 sightings occurred while the source was active. The majority of sightings occurred while the source was inactive (Appendix II).

12. References

Berrow, S. (2001). Biological diversity of cetaceans (whales, dolphins and porpoises) in Irish waters. Paper presented at the Marine biodiversity in Ireland and adjacent waters. Proceedings of a conference.

DAHG, D. o. A., Heritage and the Gaeltacht). (2014). Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters.

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NPWS, N. P. W. S. (1976). Wildlife Act. Retrieved from https://www.npws.ie/legislation/irish-law/wildlife-act-1976

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Appendix I: Record of Operations Form

Date	Reason for firing	Time soft start/ ramp-up began (UTC)	Time of full power (UTC)	Time of start of line (UTC)	Time of end of line (UTC)	Time of reduced output (UTC) (if relevant)	Time airguns/ source stopped (UTC)	Time pre-shooting search began (UTC)	Time search ended (UTC)	Time PAM began (UTC)	Time PAM ended (UTC)	Was it day or night in the period prior to firing?	Was any mitigating action required?	Comments
17/09/2019	x	13:41	15:42	15:42		13:41		13:11	13:41			d	n	technical complications, continous MMO watch
18/09/2019	l				13:45		13:45							
19/09/2019	x	14:40	15:20					13:47	14:39			d	y	
20/09/2019	l				8:33		8:33							line finished next day
22/09/2019	x	11:50	12:30	12:30			11:20	11:30				d	n	
23/09/2019	l				1:45				1:45					line finished next day
27/09/2019	x	9:40	10:20	10:20	23:30		23:30	9:10	9:40			d	n	

Appendix II: Record of Sightings Form (limited information)

Sighting number	Date	Time at start of encounter (UTC)	Time at end of encounter (UTC)	Position - degrees latitude	Position - minutes latitude	Position - north/ south	Position - degrees longitude	Position - minutes longitude	Position - east/ west	Water depth (metres)	Species or species group	Bearing to animal	Range of animal (metres)	Total number	Number of adults (visual sightings only)	Number of calves (visual sightings only)	Airgun/ source activity when animals first detected	Airgun/ source activity when animals last detected	Closest distance of animals from airguns/ source (metres)	Time of closest approach (UTC)	What action was taken?	Length of power-down and/ or shut-down (if relevant)	Estimated loss of production (if relevant) due to mitigating actions (km)
1	18/09/2019	11:45	11:48	52	33.10	n	10	16.48	w	99.8	harbour seal	35	300	1	1		f	f	350	11:45	n		
2	18/09/2019	12:30	12:31	52	35.95	n	10	14.99	w	100.0	common dolphin	150	800	2	2		f	f	800	12:30	n		
3	18/09/2019	13:45	14:05	52	38.45	n	10	18.23	w	52.0	common dolphin	90	1	10	9	1	n	n	5	13:53	n		
4	18/09/2019	18:50	18:59	52	42.76	n	10	41.02	w	93.4	common dolphin	90	200	4	4		n	n	200	18:59	n		
5	19/09/2019	7:50	8:42	51	24.02	n	9	1.38	w	109.0	fin whale	40	750	2	2		n	n	800	8:40	n		
6	19/09/2019	9:28	9:31	51	39.40	n	8	6.71	w	78.0	common dolphin	0	1	4	4		n	n	5	9:28	n		
7	19/09/2019	14:09	14:09	51	23.63	n	7	41.89	w	83.0	bottlenose dolphin	340	5	1	1		n	n	40	14:09	d	30	0.00
8	19/09/2019	15:33	15:38	51	46.80	n	7	48.03	w	86.0	bottlenose dolphin	330	5	1	1		f	f	10	15:35	n		
9	19/09/2019	15:54	16:30	51	26.36	n	7	45.54	w	86.0	bottlenose dolphin	330	3	2	2		f	f	5	16:20	n		
10	22/09/2019	17:52	18:47	51	37.44	n	7	51.50	w	82.0	common dolphin	270	5	4	4		f	f	15	17:52	n		
11	23/09/2019	6:10	6:42	51	39.07	n	8	7.16	w	75.0	common dolphin	50	10	5	5		n	n	10	7:15	n		
12	25/09/2019	17:12	17:14	51	54.73	n	7	14.97	w	65.4	common dolphin	270	15	4	4		n	n	20	17:14	n		
13	26/09/2019	14:55	15:20	53	46.26	n	5	40.50	w	87.0	common dolphin	90	40	5	4	1	n	n		14:55	n		
14	28/09/2019	8:20	8:25	53	34.41	n	6	18.34	w	8.0	harbour porpoises	190	20	3	2	1	n	n	20	8:20	n		