Beatrice Offshore Windfarm

Post-construction Cod Spawning Survey – Technical Report

Beatrice
Offshore Windfarm Ltd

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Cod Spawning Survey Results – Technical Report

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List of Abbreviations

BMM	Brown and May Marine Ltd.
BOWL	Beatrice Offshore Windfarm Ltd
CPUE	Catch Per Unit Effort
EGNOS	European Geostationary Navigation Overlay Service
EU	European Union
ICES	International Council for the Exploration of the Sea
MS-LOT	Marine Scotland Licensing and Operations Team
MSS	Marine Scotland Science
OT	Otter Trawl
OWF	Offshore Wind Farm
PEMP	Project Environmental Monitoring Programme
TAC	Total Allowable Catch

Executive Summary

This Technical Report has been prepared for Beatrice Offshore Windfarm Ltd (BOWL) as part of the Project Environmental Monitoring Programme (PEMP) required as part of the Section 36 Consent. This report describes the post-construction element of condition 27 of the PEMP in relation to cod spawning and satisfies condition 35 of BOWL's Section 36 consent.

The report details the findings of the post-construction cod spawning survey undertaken between 1st March and 29th March 2021.

The objective of this survey was to characterise cod spawning within the BOWL site and adjacent areas in the Moray Firth. The overall survey methodology and survey equipment used replicated that previously agreed with Marine Scotland Science (MSS) and Marine Scotland Licensing and Operations Team (MS-LOT) for the undertaking of the pre-construction survey.

A total of 42 tows of 30 minutes duration were completed at 21 stations in two sampling trips between 1st March and 29th March 2021. Sampling was undertaken using a commercial rock-hopper otter trawl with a 120 mm mesh cod-end, fitted with a 40 mm blinder. The length, sex and spawning condition of each cod was identified and recorded.

Cod were caught in 13 out of 42 tows undertaken, with a maximum of five individuals recorded at a single station (0T05, Trip 1). A total of 19 spawning cod were caught during the survey, 17 in Trip 1 and 2 in Trip 2. In line with the previous survey conducted in 2014, the number of cod by swept area (catch rate) were calculated using the net sensor data outputs.

During Trip 1 two stations had spawning cod catch rates considered to be indicative of the presence of a "spawning area". During Trip 2, no stations recorded spawning cod catch rates indicative of the presence of a "spawning area".

In addition, to cod, a total of 142,043 individuals of 30 commercial fish and shellfish species were caught in the survey. Haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) accounted for the majority of the total by-catch (82.2 % and 13.4 % respectively).

Comparison of the results of the pre- and post-construction surveys suggests that cod spawning occurred in the survey area pre-construction and that this continues to be the case post-construction. Both surveys found cod in relatively low numbers.

1 Introduction

This Technical Report has been prepared for Beatrice Offshore Windfarm Ltd (BOWL) by Brown and May Marine Ltd (BMM) to inform the Project Environmental Monitoring Programme (PEMP) required as part of the Section 36 Consent. This report describes the post-construction element of condition 27 of the PEMP in relation to cod spawning and satisfies condition 35 of BOWL's section 36 consent.

The report details the findings of the post-construction cod spawning survey undertaken between 1st March and 29th March 2021 within the BOWL site and adjacent areas in the Moray Firth.

BOWL committed in 2014 to undertake pre- and post-construction cod surveys, based on recommendations by Marine Scotland Science (MSS) and in consultation with Marine Scotland Licensing and Operations Team (MS-LOT). The objective of the surveys was to characterise the baseline presence of spawning cod and allow comparison post-construction.

The overall survey methodology and survey equipment used during the post-construction survey replicated that previously agreed with Marine Scotland Science (MSS) and Marine Scotland Licensing and Operations Team (MS-LOT) for the undertaking of the pre-construction survey. For further background information, please see the BOWL Pre-Construction Cod Survey (BOWL, 2014).

Following discussions with the MS Access to Fisheries teams, the EU landing obligation was not derogated against through allocation of scientific Total Allowable Catch (TAC). Instead, the species caught were either landed against the vessel's quota, or discarded at sea, as required by the landing obligation.

A summary of the Health and Safety performance of the survey is provided in Appendix 1 – Health and Safety.

2 Scope of Works

The scope of works for the cod spawning survey is detailed below. The sampling stations are illustrated in Figure 2.1. These replicated the stations sampled during the 2014 pre-construction cod survey where possible. The pre-construction sampling locations were plotted against the wind farm infrastructure and each location was reviewed with the skipper of the survey vessel. If a trawl station was considered to be too close to a turbine or subsea cable (within 250 m and 100 m, respectively), the station was moved to the nearest feasible location.

- Otter Trawl – 21 stations
  - Trip 1: 21 tows of 30 minutes duration
  - Trip 2: 21 replicate tows of 30 minutes duration
- Sample Analysis – Cod
  - Number of individuals
  - Catch Per Unit Effort (CPUE) expressed as number of cod/km^2
  - Length distribution (nearest 0.5 cm below)
  - Maturity analysis – Bucholtz *et al.* (Draft manual) maturity key
- Sample Analysis – By-catch species
  - Number of individuals and catch rate by species
- Cod Spawning Analysis by CPUE
  - MSS guidance (derived from Wright *et al.,* 2006) defining spawning areas based on CPUE (Pers.com A. Kafas 7th April 2014) was used to determine if significant cod spawning occurred at any sampling stations during the survey. Three categories were assigned based on the values provided in the MSS guidance: (i) Not important for spawning cod (≤15 spawning cod/km^2), (ii) May be important for spawning cod (>15 to ≤ 75 spawning cod/km^2) and (iii) Spawning area (>75 spawning cod/km^2).

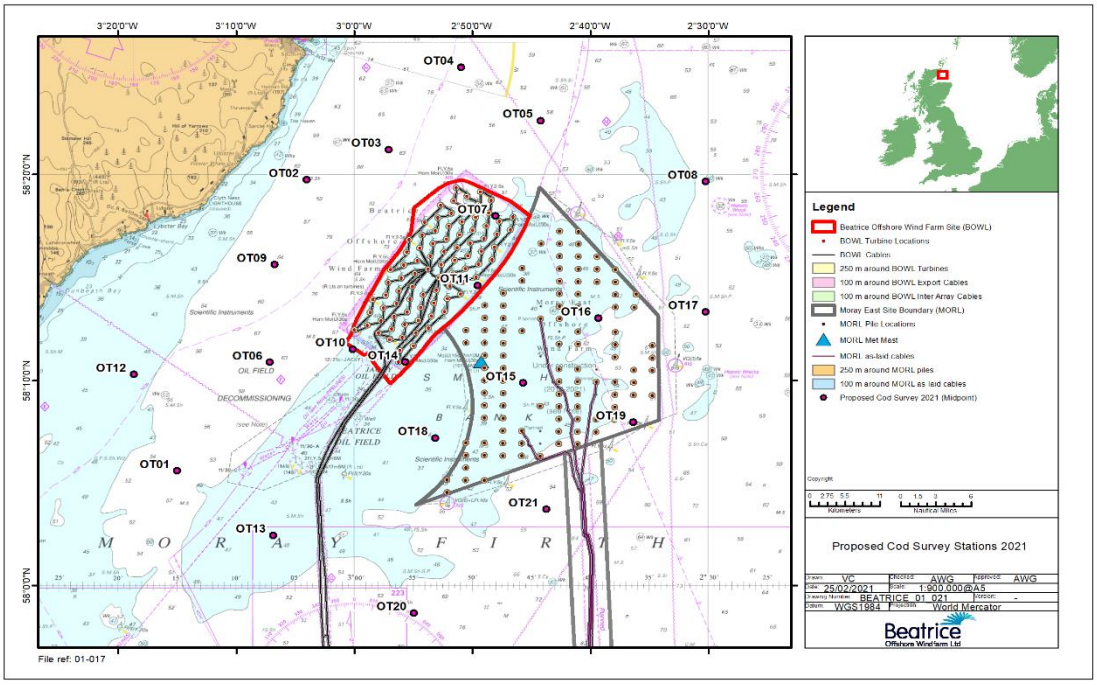

Figure 2.1 Planned Cod Survey Trawl Stations Trip 1 and Trip 2

3 Survey Methodology

The survey was undertaken during daylight hours between 1st March and 29th March 2021 in order to target the peak cod spawning period in the area.

Two sampling trips were undertaken: Trip 1 from 1st March to 7th March, and Trip 2 from 22nd March to 29th March. Sampling was undertaken using a commercial rock-hopper otter trawl with a 120 mm mesh cod end, fitted with a 40 mm blinder. The 40 mm net blinder was utilised to try to reduce the overall by-catch of juvenile fish in light of the implementation of the EU landing obligation, without reducing potential catches of spawning cod.

A summarised log of events is given in Appendix 2 - Log of Events.

3.1 Survey Vessel

The vessel chartered for the survey, the “Reaper” (Figure 3.1), is a Wick-based commercial whitefish trawler. The specifications of the vessel are given in Table 3.1.

Figure 3.1 Survey vessel "Reaper"

Table 3.1 Survey vessel specifications

Survey Vessel Specifications	
Length	16.75 m
Beam	7.00 m
Draft	4.15 m
Main Engine	Caterpillar 3412C kW – 403
GPS	2 x Furuno GP-39
Plotters	2 x Sodena, 1 x Furuno MaxSEA TIMEZERO (with wassp/3D mapping)
Sounder	Furuno Wassp and JRC twin screen sounder
Net sensor	Simrad TV80 Data Logging
Berths	8

3.2 Survey Gear

A commercial rock-hopper otter trawl (Figure 3.2) was used for cod sampling. The specifications of the gear used are detailed in Table 3.2.

In order to calculate the area sampled by the trawl (trawl swept area) during each tow, a receiver and data processing unit (SIMRAD TV80 Data Logging) was used to receive data from five net sensors; two were fitted onto the trawl doors, two attached to the net wings, and one attached to the headline.

Figure 3.2 Rock-hopper otter trawl used

Table 3.2 Commercial rock-hopper otter trawl specifications

Trawl Specifications	
Towing Warp	180 m, 20 mm diameter, dyform
Depth: Payout Ratio	3:1
Trawl Doors	850 kg, 2 backstrops into one attachment
Net	80 -120 mm mesh cod-end whitefish trawl with a 40 mm cod end blinder
Groundline	Rock-hopper 14” centre bobbins and 12” wing bobbins
Estimated Headline Height	2.5 m
Distance between Trawl Doors	45– 60 m

3.3 Sampling Procedures

A total of 21 tows of 30 minutes duration were undertaken during Trip 1. These were replicated during Trip 2. No stations were omitted from either of the survey trips.

The otter trawl tow tracks for Trip 1 and Trip 2 are illustrated in Figure 3.3. The start and end times, co-ordinates, depths and durations of each otter trawl tow are given in Appendix 3 – Times and Coordinates.

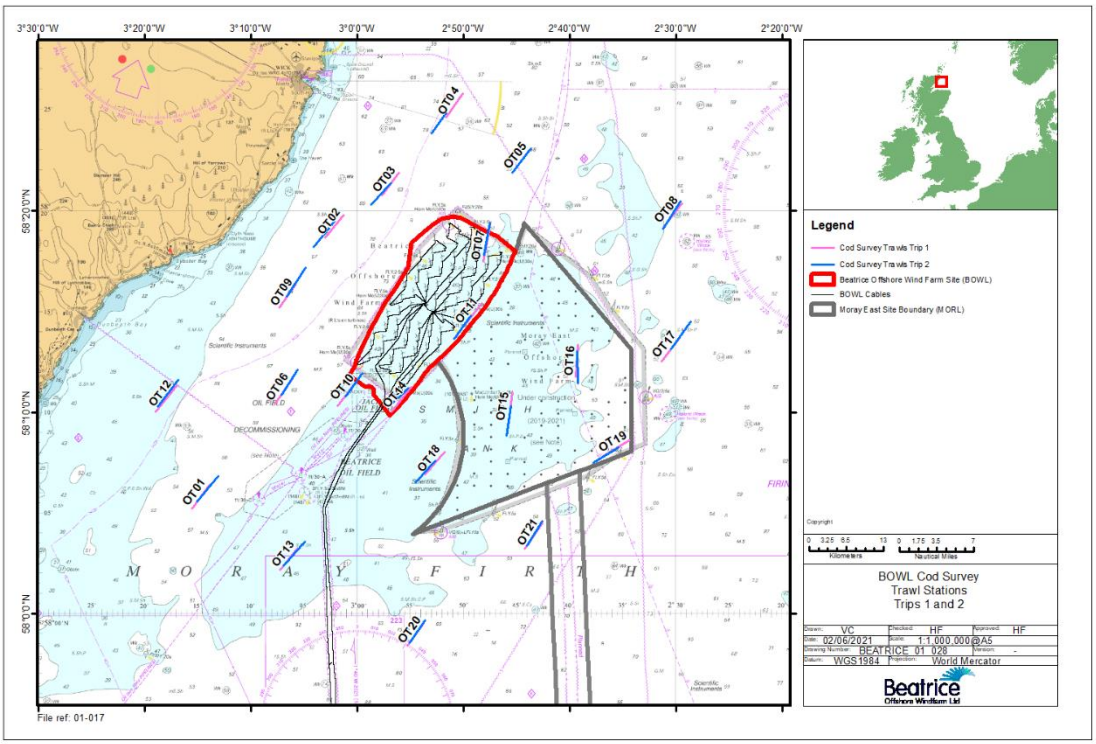

Figure 3.3 Cod Survey Trawl Tracks - Trip 1 and Trip 2

3.3.1 Positioning and Navigation

The position of the vessel was tracked at all times using a Garmin GPSMap 278 with a European Geostationary Navigation Overlay Service (EGNOS) differential connected to an external Garmin GA30 antenna. Net sensors monitored and recorded the trawl door and wing spread and provided information for positioning and management of the trawl.

Otter trawl start times, positions and water depths were taken when the skipper advised that the gear was settled on the seabed and had reached the appropriate spread based on the net's sensor readings. Otter trawl end times and positions were taken when hauling of the gear commenced. The start and end times, co-ordinates, depths and durations of each otter trawl tow are given in Appendix 3 – Times and Coordinates.

3.3.2 Otter Trawl Sampling

At each sampling station, the otter trawl was deployed and once the skipper advised that the gear was settled, the otter trawl was towed for 30 minutes at a speed of approximately 2.5-3.0 knots.

The catch from each otter trawl was emptied into the hopper, photographed, and sorted into baskets by species. The length, sex and spawning condition of each cod was identified and recorded. The gonads of each individual were photographed.

By-catch species were identified, counted, measured and either landed against the vessel's quota or returned to sea, as required by the EU landing obligation. Sub-sampling by species was carried out at sea where necessary.

3.3.3 Cod Maturity Analysis

The gonadal maturity key used to determine the spawning condition of the cod sampled is presented in Table 3.3. This was as provided by MSS (Bucholtz *et al*., Draft manual). As shown, stage III cod is considered to be in spawning condition. Individuals that have recently spawned (spent) are included under stage IV.

For the purposes of this report, and in line with Wright *et al*. (2006), the presence of stage III cod is considered indicative of spawning activity. Examples of spawning individuals are provided in Appendix 4 - Examples of Cod Maturity Stages.

Table 3.3 Cod maturity key (adapted from Bucholtz *et al*., Draft manual)

Stage		Description of Appearance	
		Female	Male
I	**Juvenile/Immature**	Ovaries small but easily distinguishable posterior in body cavity, soft with smooth surface, blurred translucent, reddish-orange	Testes small, but distinguishable along air bladder. Lobules small, blurred translucent reddish-white
II	**Maturing**	Ovaries occupy between half and 2/3 of the body cavity, plump and firm with prominent blood vessels, opaque, orange to creamy yellow. Oocytes clearly visible and densely packed	Testes enlarged and prominent dorsal in body cavity; lobules plump and brittle; reddish-white. Empty transparent spermatoducts with prominent blood vessels; no sperm release

Stage		Description of Appearance	
		Female	Male
III	Spawning	Ovaries fill most of body cavity; very distended and soft; appear granulated orange- to reddish-grey from mixture of opaque and glassy oocytes. Lumen containing viscous fluid in excess or hydrated eggs	Testes large and prominent in body cavity. Lobules still plump, but soft; completely opaque, whitish. Spermatoducts filled with fluid, milky semen that easily flows from vent
IV	Spent	Ovaries contracted; slack with greyish cast; rich in blood vessels; dim translucent reddish-grey. Vitollogenic oocytes absent but single hydrated eggs or atretic oocytes (opaque irregular granules) may occur	Testes contracted, close to air bladder; rich in blood vessels. Lobules empty, flabby, reddish potentially with a greyish cast. Spermatoducts with signs of previous distension, often with visible remains of semen
V	Resting/Skip of spawning	Ovaries small as in stage I but with signs of previous spawning; e.g. greyish cast and somewhat uneven walls; blurred translucent, reddish-grey, but more granulated and opaque than in stage I	Testes small but with signs of previous spawning; e.g. lobules slightly larger than in stage I; spermatoducts often with a greyish cast
VI	Abnormal	Stone roe. Ovary has a thick wall, grey-whitish cast and hard parts	Testes with adipose tissue formation; affected parts undeveloped, hard and yellowish

3.3.4 Cod Analysis by CPUE

Cod CPUEs were calculated for each station using the number of cod caught at each station and the swept area of each tow, as derived from the net's sensor data, following the methodology provided in Wright *et al.* (2006). This produced a CPUE value of number of cod per km^2 for each station.

In order to identify whether or not the CPUE of spawning cod (stage III) recorded was indicative of significant spawning activity, the following guidance produced by MSS (and based on Wright *et al*. (2006) findings) was applied):

- "Not important" for spawning cod (≤15 spawning cod/km^2);
- "May be important" to spawning cod (>15 to ≤ 75 spawning cod/km^2); and
- "Spawning area" (>75 spawning cod/km^2).

The full dataset used to calculate catch rates from the net sensor outputs is given in Appendix 8 - Calculations Using Simrad TV80 Logging Tow Data.

4 Cod Results

4.1 Trip 1

4.1.1 Cod Abundance

The number of cod caught by station during Trip 1 together with the length, sex and maturity stage of each individual is shown in Table 4.1. The percentage contribution of cod of maturity stage III (spawning) to the total catch in each sampling station is also provided.

A total of 25 cod were recorded during Trip I. Of these 17 were spawning cod (Stage III), two were spent fish (Stage IV) and six were immature/juveniles (Stage I).

The spatial distribution of cod caught during Trip 1 by maturity stage (stages I to IV) and spawning state (spawning/not spawning) are shown in Figure 4.2 and Figure 4.1 respectively. Cod were recorded in nine of the 21 stations sampled. In general terms, cod abundance was higher in the northern and eastern section of the survey area and spawning cod accounted for a significant proportion of the cod catch at most stations.

Table 4.1 Number of cod, sex and maturity stage by sampling station – Trip 1

Station	Length (cm)	Sex	Spawning Condition	Total No. Individuals	Total No. Spawning Cod	Percentage of Spawning Cod
OT01	37.0	F	Spawning (Stage III)	1	1	100.0%
OT02	17.5	F	Immature/Juvenile (Stage I)	4	2	50.0%
	18.5	F	Immature/Juvenile (Stage I)			
	36.0	M	Spawning (Stage III)			
	38.0	M	Spawning (Stage III)			
OT04	28.0	F	Immature/Juvenile (Stage I)	3	2	66.7%
	28.0	M	Spawning (Stage III)			
	32.0	M	Spawning (Stage III)			
OT05	29.0	M	Spawning (Stage III)	5	4	80.0%
	33.5	M	Spawning (Stage III)			
	34.0	F	Spawning (Stage III)			
	37.5	M	Spent (Stage IV)			
	45.0	M	Spawning (Stage III)			
OT07	36.0	M	Spawning (Stage III)	3	3	100.0%
	37.0	F	Spawning (Stage III)			
	40.5	M	Spawning (Stage III)			
OT11	19.0	U	Immature/Juvenile (Stage I)	3	0	0.0%
	33.5	M	Spent (Stage IV)			
	34.0	F	Immature/Juvenile (Stage I)			
OT17	30.0	M	Spawning (Stage III)	4	4	100.0%
	34.0	M	Spawning (Stage III)			
	41.0	M	Spawning (Stage III)			

Station	Length (cm)	Sex	Spawning Condition	Total No. Individuals	Total No. Spawning Cod	Percentage of Spawning Cod
	51.0	M	Spawning (Stage III)			
OT19	31.0	F	Spawning (Stage III)	1	1	100.0%
OT20	16.5	F	Immature/Juvenile (Stage I)	1	0	0.0%
Total				25	17	68.0%

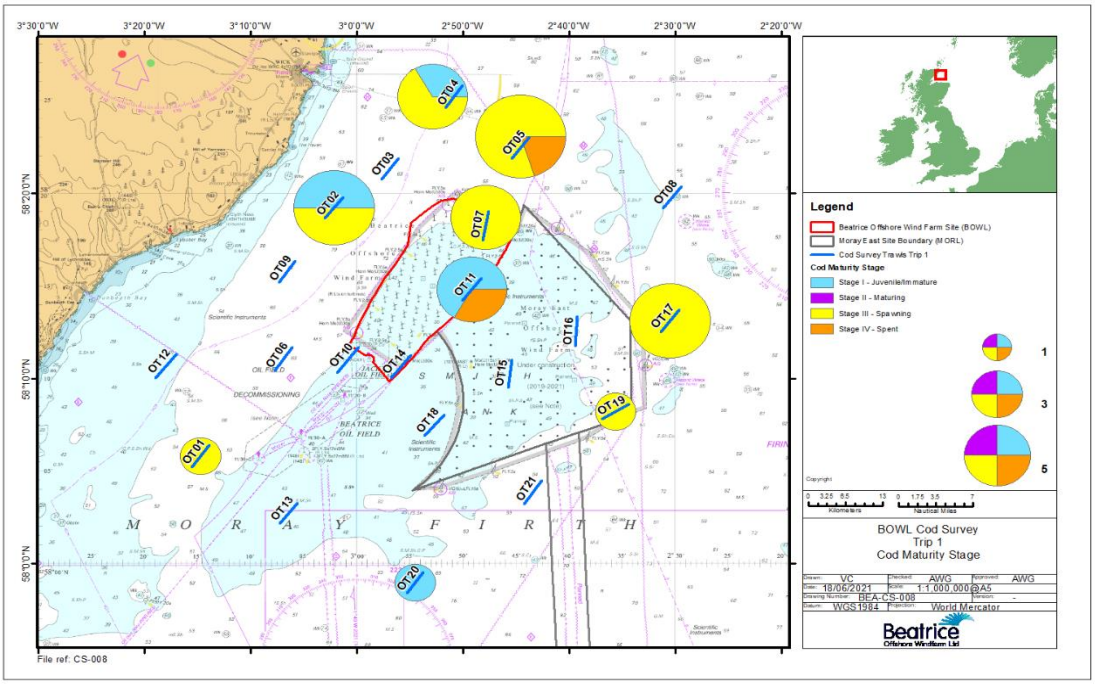

Figure 4.1 Cod Abundance by maturity stage (I - IV) by station - Trip 1

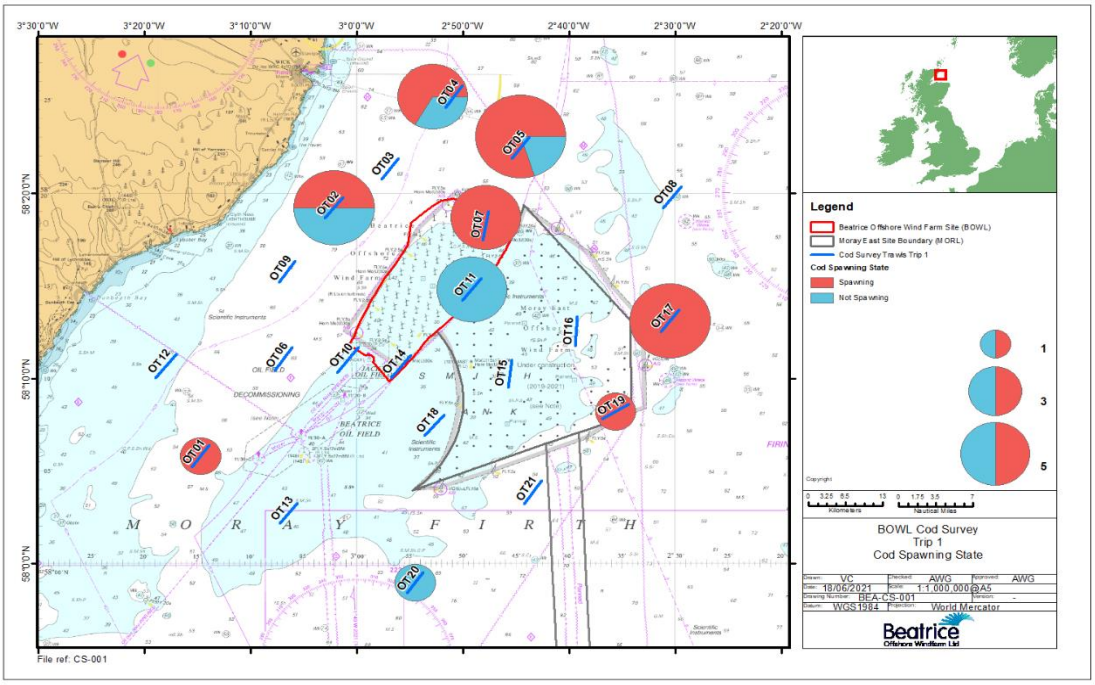

Figure 4.2 Cod abundance by spawning state (Spawning/Not Spawning) by station - Trip 1

4.1.2 Cod Spawning by CPUE

The CPUE (no. of cod/km^2) of cod by station is given in Table 4.2 and shown in Figure 4.3. and the overall CPUE for the survey trip is given in Table 4.5.

Of the 21 stations undertaken during Trip 1, cod were recorded at nine stations. Two stations (OT05 and OT17) had spawning cod CPUEs that are considered to indicate a “spawning area” (>75 spawning cod/km^2). These were found in the northern and eastern section of the survey area. Five stations had spawning cod CPUEs within the threshold “may be important” to spawning cod (>15 to ≤75 spawning cod/km^2) with the remaining two stations defined as “not important” for spawning cod (≤15 spawning cod/km^2). The 12 stations where no cod were caught have also been categorised as “not important” for spawning cod.

Table 4.2 Total number of cod and number of spawning cod/km^2 with spawning status assigned for each station during Trip 1

Station	Total No. Cod per km^2	No. Spawning Cod per km^2	Spawning Status Based on MSS Guidance
OT01	30	30	May be important
OT02	108	54	May be important
OT03	0	0	Not significant
OT04	75	50	May be important
OT05	134	107	Spawning area
OT06	0	0	Not significant
OT07	67	67	May be important
OT08	0	0	Not significant
OT09	0	0	Not significant
OT10	0	0	Not significant
OT11	72	0	Not significant
OT12	0	0	Not significant
OT13	0	0	Not significant
OT14	0	0	Not significant
OT15	0	0	Not significant
OT16	0	0	Not significant
OT17	105	105	Spawning area
OT18	0	0	Not significant
OT19	26	26	May be important
OT20	28	0	Not significant
OT21	0	0	Not significant

Table 4.3 Total number and CPUE (no. cod/km^2) for all cod caught and stage III cod caught

2021	Swept Area (km^2)	No. cod	No. cod/km^2	No. Stage III cod	Stage III cod cod/km^2
Trip 1	0.81026	25	30.9	16	19.7

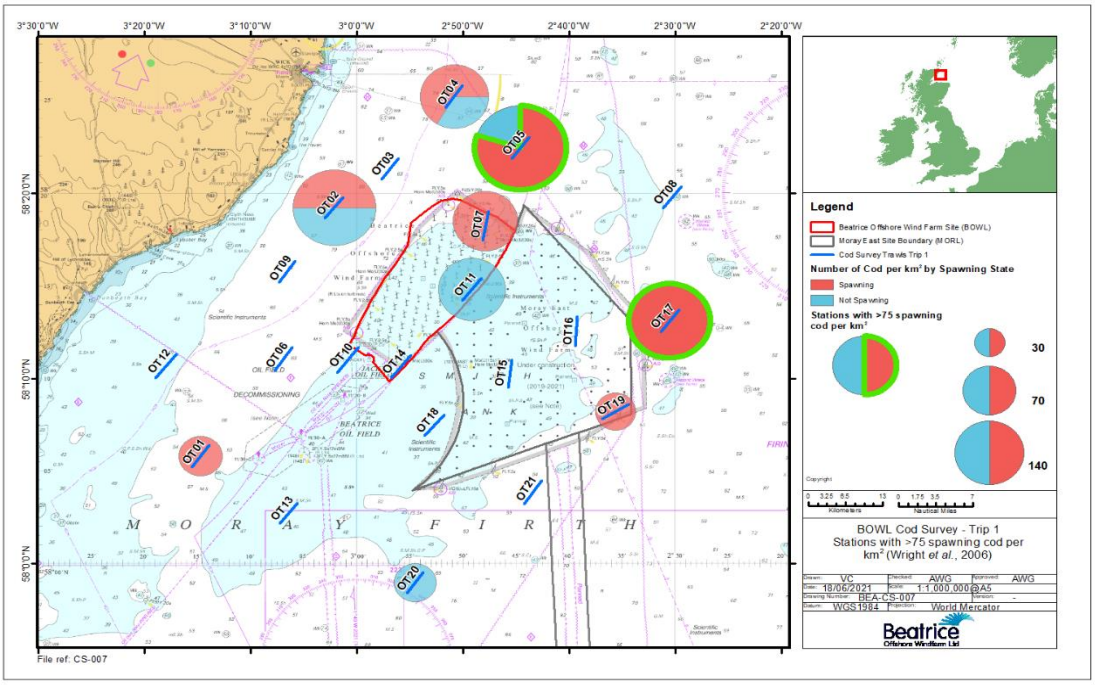

Figure 4.3 Cod CPUE (no. cod/km^2) for Trip 1 with stations considered "Spawning Areas" highlighted in green

4.2 Trip 2

4.2.1 Cod Abundance

The number of cod caught by station during Trip 2 together with the length, sex and maturity stage of each individual is shown in Table 4.4. The percentage contribution of cod of maturity stage III (spawning) to the total catch in each sampling station is also provided.

Cod were found in very low numbers during Trip 2 with only five individuals caught. Of these, two were spawning cod (Stage III). The remaining three individuals were immature/juvenile (Stage I), maturing (Stage II) and spent (Stage IV).

Figure 4.4 and Figure 4.5 give the spatial distribution of cod caught during Trip 2 by maturity stage (I to IV) and spawning state (spawning/not spawning), respectively.

Cod caught were only found in four out of the 21 stations sampled. Spawning individuals were recorded at two stations (OT04 and OT10) in the northern and central section of the survey area.

Table 4.4 Number of cod, sex and maturity stage by sampling station – Trip 2

Station	Length (cm)	Sex	Spawning Condition	Total No. Individuals	Total No. Spawning Cod	Percentage of Spawning Cod
OT04	46.0	M	Spawning (Stage III)	1	1	100.0%
OT05	30.5	M	Immature/Juvenile (Stage I)	2	0	0.0%
	45.5	M	Maturing (Stage II)			
OT10	33.0	M	Spawning (Stage III)	1	1	100.0%
OT11	29.0	M	Spent (Stage IV)	1	0	0.0%
Grand total				5	2	40.0%

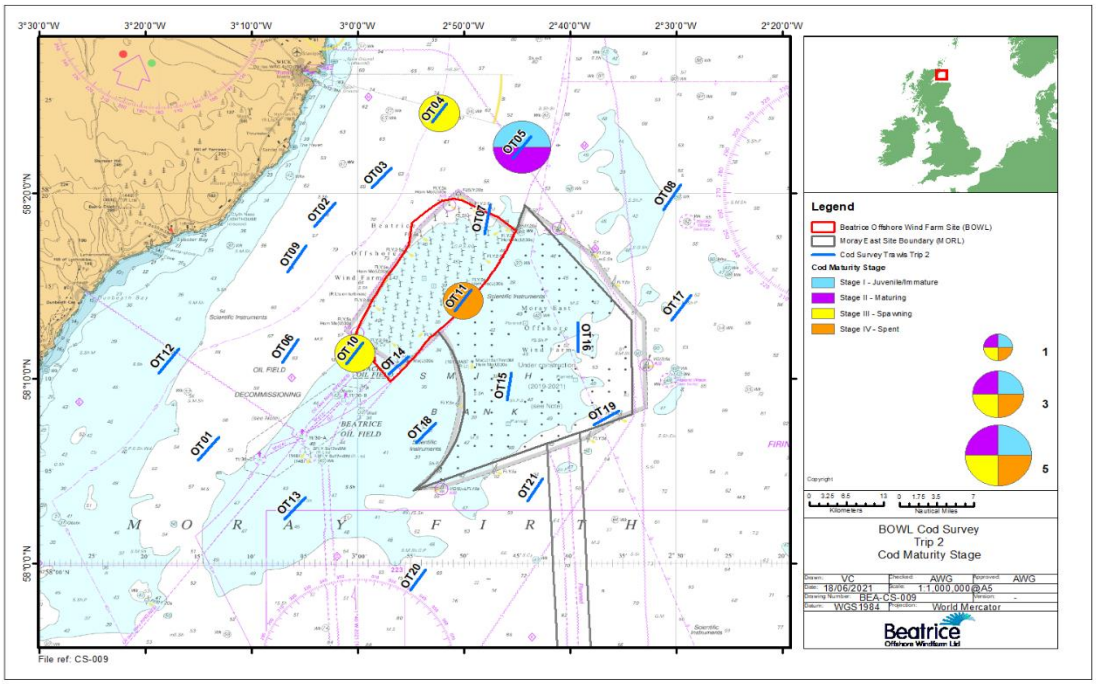

Figure 4.4 Cod abundance by maturity stage (I - IV) by station - Trip 2

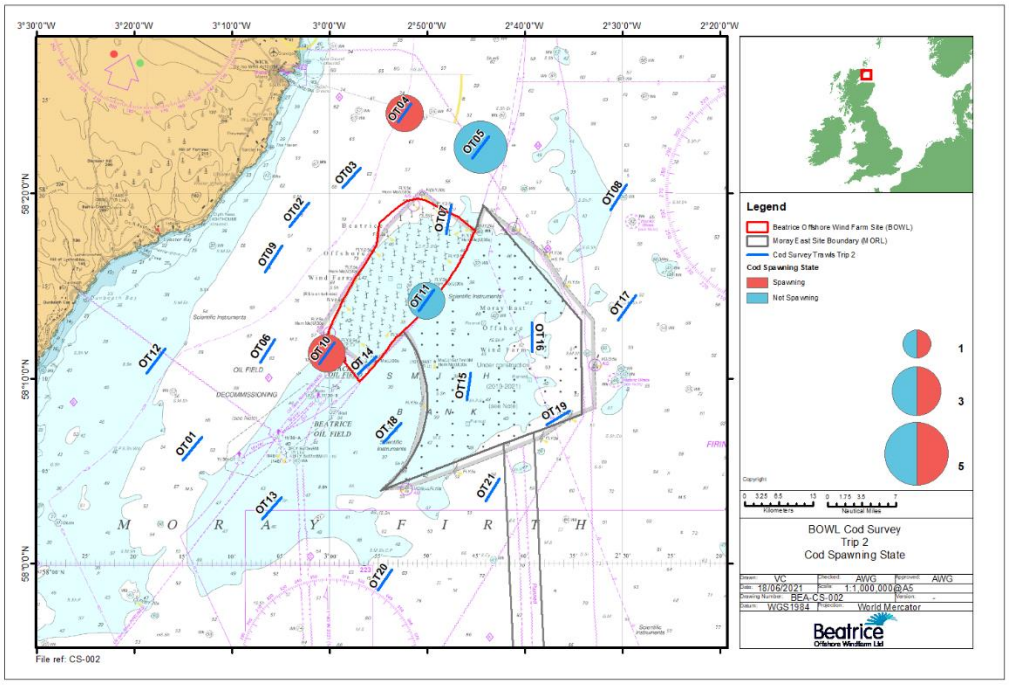

Figure 4.5 Cod abundance by spawning state (Spawning/Not Spawning) by station - Trip 2

4.2.2 Cod Spawning by CPUE

The CPUE (no. of cod/km^2) by station is given in Table 4.5 and shown in Figure 4.6, and the overall CPUE for the survey trip is given in Table 4.6.

As previously mentioned, cod were only found at four out of the 21 stations sampled during Trip 2 and in very low numbers (a total of five individuals were caught). Spawning cod was found at two of these stations, however, their CPUEs were not indicative of a "spawning area" (i.e. >75 spawning cod/km^2). The CPUEs of spawning cod at these two stations fall under the category "may be important to spawning cod". (>15 to ≤75 spawning cod/km^2). The 17 stations where no cod were caught have been categorised as "not important" for spawning cod.

Table 4.5 Total number of cod and number of spawning cod/km² with spawning status assigned for each station during Trip 2

Station	Total No. cod/km²	No. Spawning cod/km²	Spawning Status Based on MSS Guidance
OT01	0	0	Not significant
OT02	0	0	Not significant
OT03	0	0	Not significant
OT04	26	26	May be important
OT05	52	0	Not significant
OT06	0	0	Not significant
OT07	0	0	Not significant
OT08	0	0	Not significant
OT09	0	0	Not significant
OT10	29	29	May be important
OT11	30	0	Not significant
OT12	0	0	Not significant
OT13	0	0	Not significant
OT14	0	0	Not significant
OT15	0	0	Not significant
OT16	0	0	Not significant
OT17	0	0	Not significant
OT18	0	0	Not significant
OT19	0	0	Not significant
OT20	0	0	Not significant
OT21	0	0	Not significant

Table 4.6 Total number and CPUE for all cod caught and stage III cod caught

2021	Swept Area (km²)	No. cod	No. cod/km²	No. Stage III cod	Stage III cod/km²
Trip 2	0.80394	5	6.2	3	3.7

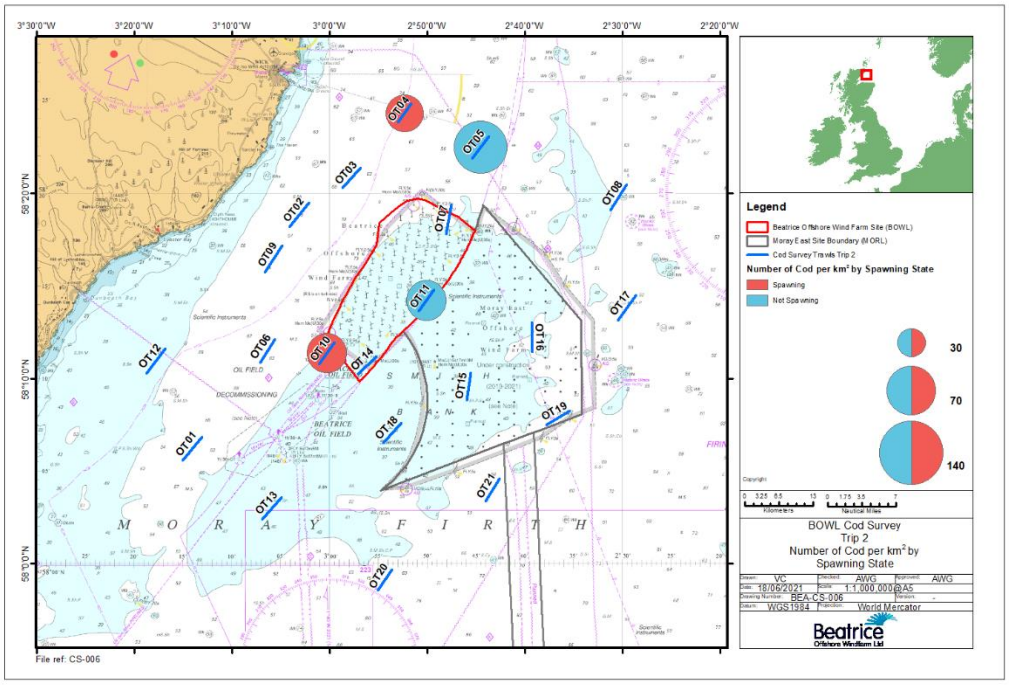

Figure 4.6 Cod CPUE (no. cod/km^2) - Trip 2

4.3 Cod Results Summary

Cod were caught during the survey in relatively low numbers with a total of 30 individuals recorded across the two trips. The majority were caught in Trip 1 (25 individuals) with Trip 2 only recording five cod. The overall CPUE for the survey by trip is given in Table 4.7.

Spawning cod (Stage III) accounted for the majority of the cod catch (19 individuals; 17 in Trip 1 and 2 in Trip 2). Catch rates of spawning cod which were indicative of the presence of a spawning area (>75 spawning cod/km^2) were only found during Trip 1. These were recorded at stations OT05 and OT17 which are located in the northern and eastern section of the survey area, respectively.

Immature/Juvenile cod (Stage I) were caught in low numbers (seven individuals; six in Trip 1 and one in Trip 2).

Table 4.7 Total number and CPUE for all cod caught and stage III cod caught by trip

2021	Swept Area (km^2)	No. cod	No. cod/km^2	No. Stage III cod	Stage III cod/km^2
Trip 1	0.81026	25	30.9	16	19.7
Trip 2	0.80394	5	6.2	3	3.7
Survey	1.61420	30	18.6	19	11.8

5 By-catch

In addition to cod, a total of 142,043 individuals of 30 fish and commercial shellfish species were caught as by-catch in the survey (Table 5.1 and Table 5.2).

In general terms, haddock (*Melanogrammus aeglefinus*), and whiting (*Merlangius merlangus*), were the principal by-catch species found during the survey.

Haddock was the most abundant species in both survey trips (116,771 individuals) accounting for 82.2 % of the total by-catch, followed by whiting with 19,081 individuals (13.4 % of the total by-catch) The highest abundances for both species were recorded in Trip 1 (79,077 and 11,800 individuals respectively). Haddock and whiting are gadoids, with a similar morphology and life history to cod. The presence of high numbers of these species in the catch demonstrates the effectiveness of the gear used in the survey.

It is of note that as the larger haddock were being gutted to be sold at market the surveyors were able to observe that many were actively spawning.

The majority of the remaining by-catch species of fish and commercial shellfish species were recorded in relatively low numbers (<1,000 individuals per trip). An exception to this is *Loligo* sp., which include commercially important squid species in the Moray Firth. Squid were found in relatively high numbers (1,319 individuals) during Trip 2, predominantly on the south-east edge of the Smith Bank in the deeper water (Appendix 5 – By-catch; Figure 9.17).

In addition to the marine fish and shellfish species of commercial importance described above, various motile and sessile invertebrates of no commercial importance were caught during the survey. Details of these can be found in Table 5.3.

The spatial distribution of the top five by-catch species recorded in each survey is given in Appendix 5 – By-catch.

Table 5.1 Fish and commercial shellfish by-catch - Trip 1

Trip 1		Total No. of Individuals Caught
Common Name	**Scientific Name**	
Haddock	*Melanogrammus aeglefinus*	79,077
Whiting	*Merlangius merlangus*	11,800
Dab	*Limanda limanda*	711
Grey gurnard	*Eutrigla gurnardus*	398
Sprat	*Sprattus sprattus*	350
Plaice	*Pleuronectes platessa*	327
Squid	*Loligo sp.*	202
Long rough dab	*Hippoglossoides platessoides*	82
Bib	*Trisopterus luscus*	23
Herring	*Clupea harengus*	9
Greater sandeel	*Hyperoplus lanceolatus*	6
Norway pout	*Trisopterus esmarkii*	5
Red gurnard	*Chelidonichthys cuculus*	5
Lemon sole	*Microstomus kitt*	4
Sandeel sp	*Ammodytidae*	4
Coley (Saithe)	*Pollachius virens*	3
Bullrout	*Myoxocephalus scorpius*	2
Shrimp	*Decapoda*	2
Cuckoo ray	*Leucoraja naevus*	1
Flounder	*Platichthys flesus*	1
Horse mackerel	*Trachurus trachurus*	1
Lesser spotted dogfish	*Scyliorhinus canicula*	1
Little cuttlefish	*Sepiola atlantica*	1
Mackerel	*Scomber scombrus*	1
Spotted dragonet	*Calionymus maculata*	1
Total No. of Individuals		**93,017**

Table 5.2 Fish and commercial shellfish by-catch - Trip 2

Trip 2		Total No. of Individuals Caught
Common Name	**Scientific Name**	
Haddock	*Melanogrammus aeglefinus*	37,694
Whiting	*Merlangius merlangus*	7,281
Squid	*Loligo sp.*	1,319
Norway pout	*Trisopterus esmarki*	782
Dab	*Limanda limanda*	677
Plaice	*Pleuronectes platessa*	441
Grey gurnard	*Eutrigla gurnardus*	331
Sprat	*Sprattus sprattus*	257
Long rough dab	*Hippoglossoides platessoides*	120
Herring	*Clupea harengus*	74
Mackerel	*Scomber scombrus*	16

Trip 2		Total No. of Individuals Caught
Common Name	**Scientific Name**	
Greater sandeel	*Hyperoplus lanceolatus*	14
Lemon sole	*Microstomus kitt*	4
Long-spined Sea Scorpion	*Taurulus bubalis*	4
Hake	*Merluccius merluccius*	2
John Dory	*Zeus faber*	2
Lesser spotted dogfish	*Scyliorhinus canicula*	2
Scaldfish	*Arnoglossus lanterna*	2
Argentine	*Argentina silus*	1
Bib	*Trisopterus luscus*	1
Bullrout	*Myoxocephalus scorpius*	1
Horse mackerel	*Trachurus trachurus*	1
Poor cod	*Trisopterus minutus*	1
Queen scallop	*Aequipecten opercularis*	1
Red gurnard	*Chelidonichthys cuculus*	1
Sandeel sp.	*Ammodytidae*	1
		49,026

Table 5.3 Total number of motile and sessile invertebrate by-catch individuals caught

Species		Total No. of Individuals Caught
Common Name	**Scientific Name**	
Common Starfish	*Asterias rubens*	9
Jellyfish	*Scyphozoa*	3
Hermit crab	*Paguridae*	2
Urchin	*Echinoidea*	2
Anemone	*Actiniaria*	1
Gastropod	*Gastropoda*	1
Little Cuttlefish	*Sepiola atlantica*	1
Sea Mouse	*Aphrodita*	1
Dead Man's Fingers	*Alcyonium digitatum*	Present
Hornwrack	*Flustra foliacea*	Present
Sea Squirts	*Ascidacea sp.*	Present
Brown Seaweed	*Phaeophyceae*	Present
Hydroid	*Hydroid sp.*	Present
Sea Chervil	*Alcyonidium diaphanum*	Present

6 Comparison with the 2014 Pre-Construction Cod Survey

An overview of the key results from the pre- and post-construction surveys is given in Table 6.1. A comparison of the spatial distribution of cod (no. cod/km^2) recorded during the two surveys is provided in Figure 6.1.

The catch of cod was relatively low during both the pre-construction and post-construction surveys, with a maximum of 70 cod caught in a single survey trip (Trip 2, pre-construction). Overall, cod numbers were higher in the pre-construction survey (131 individuals compared to 30 individuals post-construction). To some extent this is a result of the relatively higher number of juvenile/immature fish that were caught pre-construction (77 immature/juvenile fish pre-construction compared to seven post-construction). In this context, it is important to note that a 40 mm blinder was used for the post-construction survey instead of the 20 mm blinder used pre-construction. As is evident from the cod catch and by-catch data (Section 4 and Section 5) the use of a 40 mm blinder did not result in smaller adult catches overall, however, fewer juvenile cod were caught post-construction.

The CPUE of spawning cod was also higher during the pre-construction survey. The post-construction spawning cod CPUE during Trip 1 (19.7 spawning cod/km^2) was however similar in range to the CPUEs recorded pre-construction (36.2 and 29.4 spawning cod/km^2 for Trip 1 and Trip 2 respectively). Cod spawning CPUE, and cod abundance in general, were comparatively low during post-construction Trip 2. It should be noted that post-construction Trip 2 was undertaken between 22nd and 29th March 2021, approximately two weeks later in the year than pre-construction Trip 2 (undertaken between 3rd and 13th March 2014).

Table 6.1 Comparison between 2014 and 2021 cod surveys

Item	2014		2021	
	Trip 1	Trip 2	Trip 1	Trip 2
Survey dates	20/02/2014 – 25/02/2014	09/03/2014 – 13/03/2014	01/03/2021 – 07/03/2021	22/03/2021 – 29/03/2021
Number of stations where cod were caught / total number of stations sampled	19/40	15/42	9/42	4/42
Total number of cod individuals	61	70	25	5
Immature/Juvenile Cod (Stage I)	33	39	6	1
Spawning Cod (Stage III)	25	22	17	2
Cod CPUE (no. cod/km^2)	88.2	93.5	30.9	6.2
Spawning Cod CPUE (no. cod/km^2)	36.2	29.4	19.7	3.7
Stations classified as spawning areas under MSS guidance	3	4	2	0
Total no. of by-catch individuals	29,353	30,460	93,017	49,026
Number of by-catch species (fish and commercial shellfish) caught	34	36	25	25

No clear pattern with regard to spawning locations is apparent. Only a few stations have been identified as “spawning areas” during the surveys based on analysis of spawning cod CPUE (a maximum of four in pre-construction Trip 2) and these have not been consistent across trips within the same survey nor between the pre- and post-construction overall surveys (Figure 6.1).

As shown in Appendix 6 – Comparison of Swept Areas Pre and Post-construction, swept areas

covered during the pre- and post-construction surveys were broadly similar, despite the use of a smaller survey vessel post-construction (16.75 m in length compared to 27.41 m in 2014).

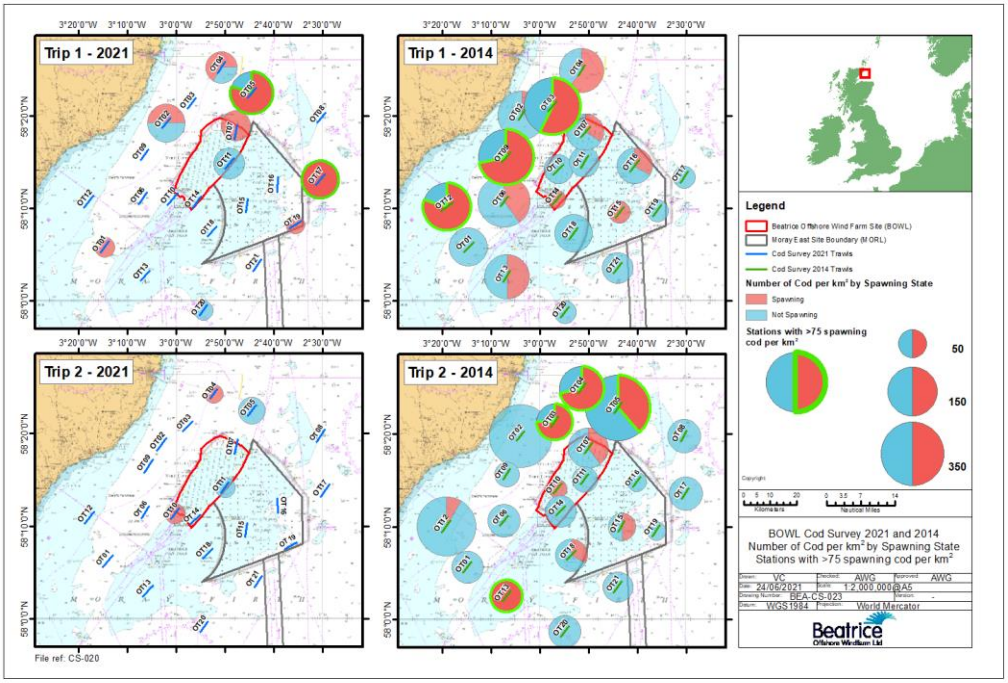

Figure 6.1 Comparison of Cod CPUE (no. cod/km^2) in 2014 and 2021 with stations considered "Spawning Areas" highlighted in green

An indication of the principal by-catch species recorded in the pre-construction and post-construction surveys is provided in Table 6.2 and Table 6.3, respectively. As shown, gadoids such as whiting and haddock were present in high numbers throughout both surveys.

Haddock had the highest catch rate post-construction, whilst dab was the principal by-catch species during the pre-construction survey.

Table 6.2 Top five species catch rates by CPUE (no./km^2) in 2014

2014		Total Number Per km^2
Common Name	**Scientific Name**	
Dab	*Limanda limanda*	22,282
Plaice	*Pleuronectes platessa*	17,635
Norway Pout	*Trisopterus esmarki*	3,552
Haddock	*Melanogrammus aeglefinus*	2,991
Whiting	*Merlangius merlangus*	2,039

Table 6.3 Top five species catch rates by CPUE (no./km^2) 2021

2021		Total Number Per km^2
Common Name	**Scientific Name**	
Haddock	*Melanogrammus aeglefinus*	72,340
Whiting	*Merlangius merlangus*	11,821
Squid	*Loligo sp.*	1,084
Dab	*Limanda limanda*	860
Norway pout	*Trisopterus esmarki*	488

7 Conclusion

The pre- and post-construction surveys have provided high resolution information on cod spawning in the central Moray Firth.

No clear pattern with regard to spawning locations is apparent from the survey results. Few stations have been identified as “spawning areas” based on analysis of spawning cod CPUE (a maximum of four stations, found in pre-construction Trip 2) and these have not been consistent across trips within the same survey nor between the pre- and post-construction overall surveys.

The results of the surveys suggest that cod spawning occurred in the survey area pre-construction and that this continues to be the case post-construction. Both surveys found cod in relatively low numbers.

Previous cod surveys have been undertaken within the Moray Firth following a similar methodology (MORL, 2013 and MOWEL, 2019). These data could allow some comparisons to be made with this report’s data, with scope to provide a broader overview of cod spawning activity in the Moray Firth.

8 References

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9 Appendices

9.1 Appendix 1 – Health and Safety

Personnel

Brown and May Marine (BMM) staff followed the standard health and safety protocol outlined in the BMM "Offshore Operational Procedures for Surveys using Commercial Fishing Vessels".

All BMM staff have completed a Sea Survival course approved by the Maritime and Coastguard Agency, meeting the requirements laid down in: **STCW 95 Regulation VI/1 para 2.1.1 and STCW Code section A- VI/1** before boarding any vessel conducting works for the company. Employees are also required to have valid medical certificates (ENG1).

Vessel Induction

Before boarding the survey team were shown how to safely board and disembark the vessel. Prior to departure the skipper briefed surveyors on the whereabouts of the safety equipment, including the life raft, emergency flares and fire extinguishers, and the location of the emergency muster point. The safe deck areas, man-overboard procedures and emergency alarms were also discussed. The survey team was warned about the possible hazards, such as slippery decks and obstructions whilst aboard. Surveyors were briefed about trawling operations and the need to keep clear of all winches when operational. All hazards were assessed prior to the survey in the BMM health and safety risk assessment.

Daily Safety Checks

The condition of the life jackets, PLB's, and life raft were inspected were inspected daily prior to departure. Daily checks were undertaken in the survey team working areas, including the deck and the wheelhouse, to ensure these areas were clear of hazards such as clutter and obstructions.

Post Trip Survey Review

Upon completion of the survey a "Post Trip Survey Review" was filled, see Table 9.1 below.

Table 9.1 Post trip survey review

Project: BOWL Cod Survey March 2021	**Vessel:** Reaper
Surveyors: Alex Winrow-Giffin / Zoe Lawrence	**Skipper:** Donald Anderson
Survey Area: Moray Firth	**Total Time at Sea:** 15 Days
Dates at Sea: 01/03/21 – 07/03/21 and 22/03/21 – 2903/21	

	Comments	Actions
Did vessel comply with pre trip safety audits?	Yes (audited by Alasdair Noble on 05/06/20)	N/A
Skipper and crew attitude to safety?	Good	N/A
Vessel machinery failures?	None	N/A
Safety equipment failures?	None	N/A
Accidents?	None	N/A
Injuries?	None	N/A

9.2 Appendix 2 - Log of Events

A summarised log of events is given below in Table 9.2 for Trip 1 and in Table 9.3 overleaf for Trip 2.

Table 9.2 Summarised log of events for Trip 1: 28th February to 7th March 2021

28th February 2021
BMM surveyor travels from office to Inverness
1st March 2021
BMM surveyors transit to Fraserburgh.
Vessel met at 1400 and sampling gear loaded on board the vessel. Vessel induction, HSE briefing conducted.
Vessel departed port at 1800
2nd March 2021
Otter Trawls: OT20 (1 x cod), OT13, OT01 (1 x cod) and OT12
Weather: BF 1-2, E, slight
3rd March 2021
Otter Trawls: OT06, OT10, OT09, OT02 (4 x cod)
Weather: BF 2-3, NE, slight
4th March 2021
Otter Trawls: OT03, OT08, OT17 (4 x cod)
Weather: BF 2-3, N, slight
5th March 2021
Otter Trawls: OT16, OT19 (1 x cod), OT15
Weather: BF 2-3, NW
6th March 2021
Otter Trawls: OT21, OT18, OT14, OT11 (3 x cod)
Weather: BF 3-4, W
7th March 2021
Otter Trawls: OT04 (3 x cod), OT05 (5 x cod), OT07 (3 x cod)
Survey completed
Vessel steamed to Fraserburgh for BMM surveyors to disembark; Trip 1 demobilised

Table 9.3 Summarised log of events for Trip 2: 22nd March to 29th March 2021

22nd March 2021
Surveyors transit to Fraserburgh
1530 Equipment loaded on board the vessel. Survey HSE and vessel induction carried out.
Steamed overnight to first survey location.
Weather: BF 3, SSW
23rd March 2021
Otter Trawls: OT04 (1 x cod), OT05 (2 x cod)
Weather: BF 3-5, SSW

24th March 2021
Otter Trawls: OT03, OT10 (1 x cod), OT14, OT13
Weather: BF 5, SW
25th March 2021
Otter Trawls: OT01, OT12, OT09, OT06
Weather: BF 3-4, SW
26th March 2021
Otter Trawls: OT08, OT17
Weather: BF 4-5, SW
27th March 2021
Otter Trawls: OT02, OT08, OT11 (1 x cod), OT07
Weather: BF 3-5, SW
28th March 2021
Otter Trawls: OT16, OT15, OT19
Weather: BF 5-6, SW
29th March 2021
Otter Trawls: OT20, OT21
Weather: BF 5-6, SW
Vessel steamed to Fraserburgh for BMM surveyors to disembark; Trip 2 completed, survey demobilised

9.3 Appendix 3 – Times and Coordinates

The date, times, coordinates and depth for each station are given below in Table 9.4 for Trip 1 and in Table 9.5 for Trip 2.

Table 9.4 Start and end times, coordinates and duration of each otter trawl - Trip 1

Cod Survey Trip 1											
Station	Date	Otter Trawl Start				Otter Trawl End				Duration (mm:ss)	Length (km)
		Time (GMT)	UTM30N		Depth (m)	Time (GMT)	UTM30N		Depth (m)		
			Latitude	Longitude			Latitude	Longitude			
OT01	02/03/2021	13:52:10	58° 05.2155	-3° 15.5577	33.2	14:22:36	58° 06.4220	-3° 13.8972	33.0	30:26	2.7701
OT02	03/03/2021	16:22:07	58° 19.7739	-3° 01.2752	38.3	16:52:22	58° 18.6705	-3° 02.9724	34.9	30:15	2.6340
OT03	04/03/2021	08:39:10	58° 21.8872	-2° 56.0790	35.7	09:09:11	58° 20.7671	-2° 57.6976	38.5	30:01	2.6101
OT04	07/03/2021	08:21:08	58° 24.5924	-2° 51.6054	35.8	08:51:13	58° 25.7977	-2° 50.0654	33.7	30:05	2.6927
OT05	07/03/2021	10:41:10	58° 23.0217	-2° 43.7350	32.2	11:11:24	58° 21.8863	-2° 45.4041	32.3	30:14	2.6621
OT06	03/03/2021	08:22:08	58° 10.4490	-3° 07.7528	33.7	08:53:49	58° 11.7124	-3° 06.0983	37.2	31:41	2.8505
OT07	07/03/2021	13:13:09	58° 17.4780	-2° 48.1310	27.0	13:43:41	58° 19.0321	-2° 47.6331	28.1	30:32	2.9246
OT08	04/03/2021	14:24:11	58° 19.2141	-2° 31.1346	28.7	14:54:23	58° 20.3633	-2° 29.4417	31.8	30:12	2.6978
OT09	03/03/2021	13:18:04	58° 15.2038	-3° 07.3037	35.0	13:48:26	58° 16.3553	-3° 05.8161	36.0	30:22	2.5850
OT10	03/03/2021	10:54:08	58° 11.6980	-2° 59.8287	19.5	11:24:22	58° 10.3429	-3° 01.8153	26.3	30:14	3.1802
OT11	06/03/2021	15:19:12	58° 14.2457	-2° 50.0829	22.3	15:49:09	58° 15.4084	-2° 48.2689	24.9	29:57	2.7937
OT12	02/03/2021	16:03:08	58° 10.0468	-3° 18.9810	27.7	16:34:06	58° 11.3530	-3° 16.9948	27.4	30:58	3.1089
OT13	02/03/2021	11:35:08	58° 02.1854	-3° 07.2531	26.3	12:05:27	58° 03.2594	-3° 05.6013	26.4	30:19	2.5716
OT14	06/03/2021	12:44:10	58° 11.2760	-2° 54.9293	21.7	13:14:19	58° 10.0301	-2° 56.7625	19.9	30:09	2.9282
OT15	05/03/2021	15:13:13	58° 09.5442	-2° 45.7741	24.0	15:43:31	58° 11.0001	-2° 45.4153	24.2	30:18	2.7244
OT16	05/03/2021	10:27:07	58° 13.3698	-2° 39.2710	27.0	10:57:13	58° 11.7652	-2° 39.4304	28.4	30:06	2.9816
OT17	04/03/2021	08:07:08	58° 13.7109	-2° 29.6696	29.0	08:37:18	58° 12.5499	-2° 31.3856	27.4	30:10	2.7321
OT18	06/03/2021	10:53:06	58° 06.9214	-2° 53.6326	20.1	11:23:13	58° 08.0629	-2° 51.8104	18.3	30:07	2.7725
OT19	05/03/2021	12:34:05	58° 07.8145	-2° 36.9487	29.0	13:04:11	58° 08.6280	-2° 34.3687	29.8	30:06	2.9478
OT20	02/03/2021	08:01:42	57° 58.3934	-2° 55.2844	39.7	08:31:18	57° 59.5118	-2° 53.7436	37.6	29:36	2.5716
OT21	06/03/2021	08:19:18	58° 04.5105	-2° 42.5930	29.9	08:49:21	58° 03.2179	-2° 44.2322	34.0	30:03	2.8899

Table 9.5 Start and end times, coordinates and duration of each otter trawl - Trip 2

Cod Survey Trip 2											
Station	Date	Otter Trawl Start				Otter Trawl End				Duration (mm:ss)	Length (km)
		Time (GMT)	UTM30N		Depth (m)	Time (GMT)	UTM30N		Depth (m)		
			Latitude	Longitude			Latitude	Longitude			
OT01	25/03/2021	07:53:09	58° 05.5905	-3° 15.0898	32.7	08:23:40	58° 06.8512	-3° 13.0847	31.5	30:31	3.0581
OT02	27/03/2021	08:38:15	58° 19.5019	-3° 02.0861	38.2	09:08:28	58° 18.1907	-3° 04.0788	34.1	30:13	3.1155
OT03	24/03/2021	08:37:11	58° 21.3717	-2° 56.8188	38.4	09:07:20	58° 20.2896	-2° 58.6602	42.3	30:09	2.6943
OT04	23/03/2021	12:27:09	58° 24.8069	-2° 51.6388	35.8	12:58:02	58° 23.8028	-2° 53.0283	39.1	30:53	2.3029
OT05	23/03/2021	15:00:12	58° 23.0742	-2° 43.6829	33.8	15:30:16	58° 21.8890	-2° 45.4369	31.8	30:04	2.7858
OT06	25/03/2021	15:20:16	58° 10.8607	-3° 07.1420	34.7	15:50:18	58° 12.1364	-3° 05.6269	38.1	30:02	2.7942
OT07	27/03/2021	17:18:10	58° 17.8178	-2° 48.0792	26.6	17:48:16	58° 19.3819	-2° 47.5000	28.4	30:06	2.9570
OT08	26/03/2021	12:13:10	58° 19.0864	-2° 31.2247	28.2	12:43:15	58° 20.4514	-2° 29.5994	31.1	30:05	2.9888
OT09	25/03/2021	12:27:53	58° 15.7589	-3° 06.6031	35.4	12:59:39	58° 17.1987	-3° 04.8271	34.6	31:46	3.1863
OT10	24/03/2021	12:05:09	58° 11.9510	-2° 59.5246	20.1	12:35:13	58° 10.8133	-3° 01.0834	25.8	30:04	2.6058
OT11	27/03/2021	15:05:11	58° 14.7930	-2° 49.3101	23.3	15:35:13	58° 13.6453	-2° 50.8849	20.8	30:02	2.6288
OT12	25/03/2021	10:06:12	58° 10.2924	-3° 18.7794	27.7	10:36:19	58° 11.6146	-3° 16.8399	27.3	30:07	3.1038
OT13	24/03/2021	16:27:00	58° 02.4037	-3° 06.9019	24.7	16:57:34	58° 03.5905	-3° 04.9030	25.3	30:34	2.9524
OT14	24/03/2021	14:02:11	58° 11.2087	-2° 55.1851	21.8	14:32:18	58° 10.2549	-2° 57.1256	20.5	30:07	2.5983
OT15	28/03/2021	13:03:07	58° 10.3311	-2° 45.5790	24.2	13:33:16	58° 08.8288	-2° 45.9507	24.5	30:09	2.8114
OT16	28/03/2021	09:47:08	58° 13.0461	-2° 39.3416	29.6	10:17:15	58° 11.4369	-2° 39.2331	29.7	30:07	2.9880
OT17	26/03/2021	15:04:14	58° 13.1491	-2° 30.5099	29.2	15:34:11	58° 14.5253	-2° 28.6212	28.9	29:57	3.1527
OT18	27/03/2021	11:59:09	58° 07.6005	-2° 52.6343	21.8	12:29:18	58° 06.5337	-2° 54.5089	20.9	30:09	2.7031
OT19	28/03/2021	15:05:03	58° 08.2654	-2° 35.4113	30.0	15:35:34	58° 07.5084	-2° 37.8323	30.1	30:31	2.7604
OT20	29/03/2021	06:52:08	57° 58.5388	-2° 55.0638	39.5	07:22:22	57° 59.6795	-2° 53.6474	37.0	30:14	2.5355
OT21	29/03/2021	09:22:08	58° 03.3661	-2° 44.0611	34.0	09:52:21	58° 04.5991	-2° 42.5758	30.7	30:13	2.7144

9.4 Appendix 4 - Examples of Cod Maturity Stages

Trip 1

Stage I – Immature

Figure 9.1 OT11 Female 34.0 cm Stage I

Stage II – Maturing

Figure 9.2 OT02 Male 36.0 cm Stage II

Stage III – Spawning

Figure 9.3 OT05 Female 34.0 cm Stage III

Figure 9.4 OT07 Male 40.5 cm Stage III

Stage IV – Spent

Figure 9.5 OT05 Male 37.5 cm Stage IV

Trip 2

Stage 1 – Juvenile/Immature

Figure 9.6 OT05 Male 30.5 cm Stage 1

Stage III – Spawning

Figure 9.7 OT04 Male 46.0 cm Stage III

Stage IV – Spent

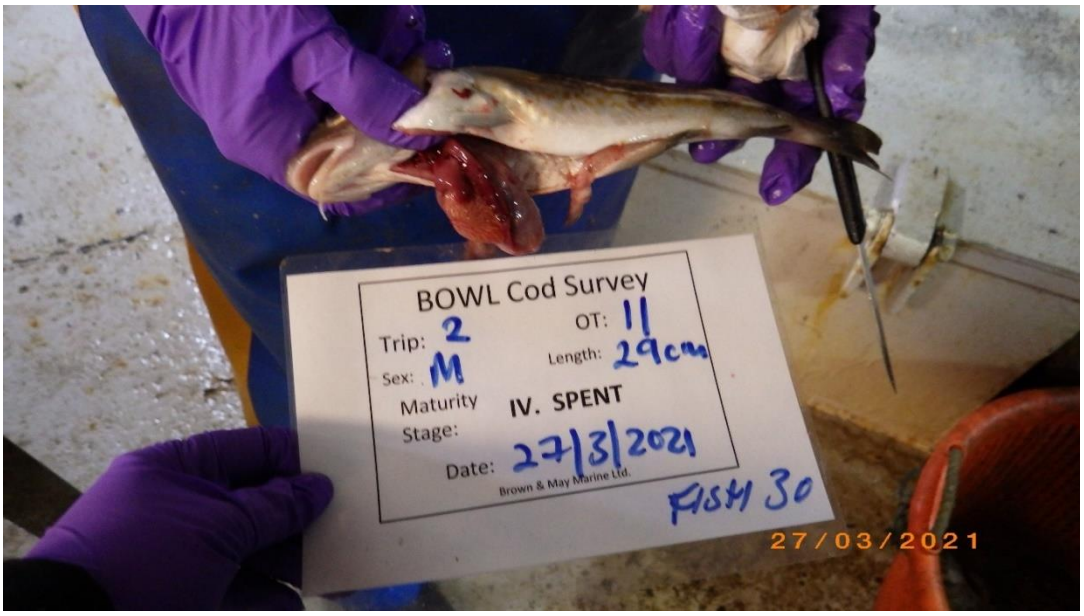

Figure 9.8 OT11 Male 29.0 cm Stage IV

9.5 Appendix 5 – By-catch

The spatial distribution of the principal fish by-catch species (no of individuals) are given in Figure 9.9 to Figure 9.18. by survey trip.

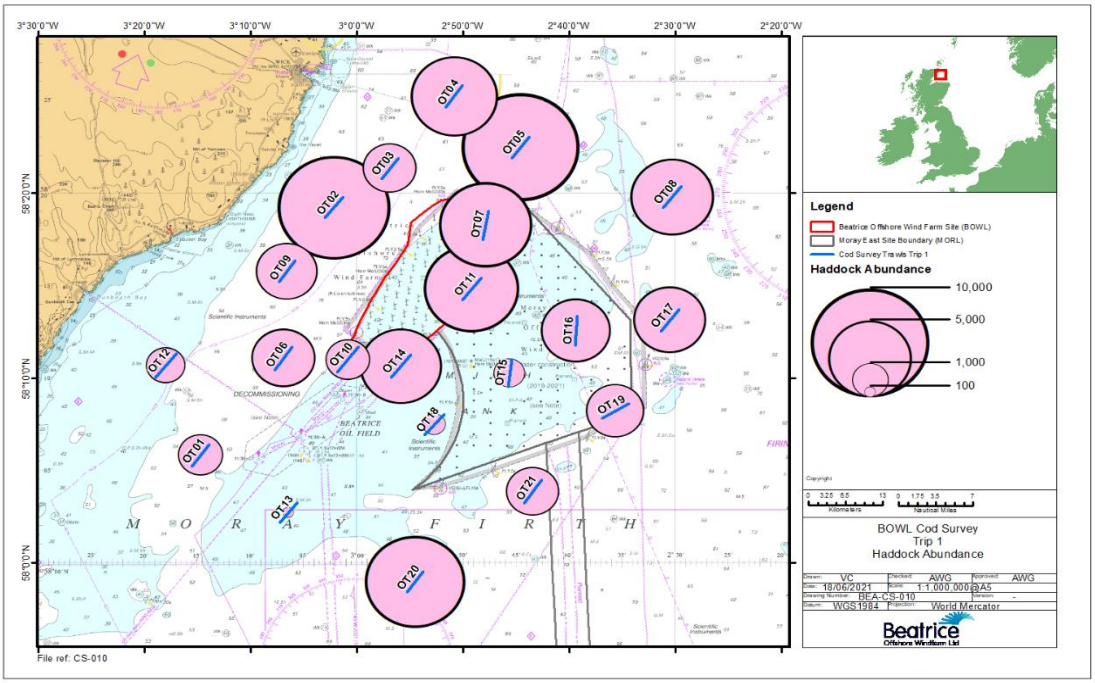

Figure 9.9 Haddock Abundance by Station – Trip 1

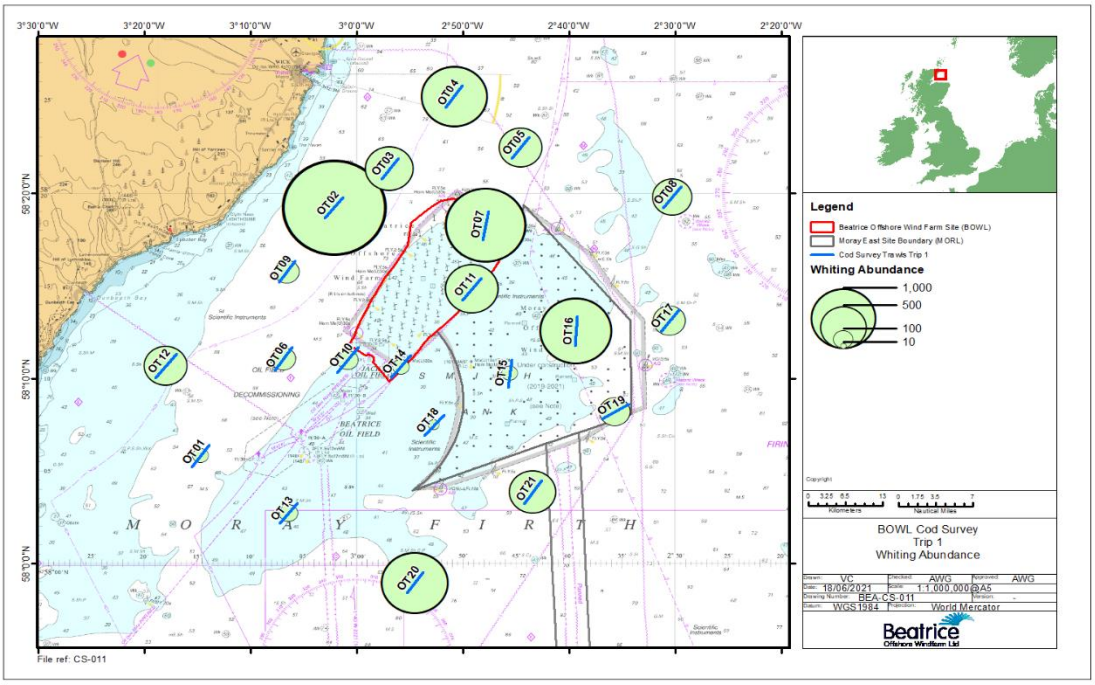

Figure 9.10 Whiting Abundance by Station - Trip 1

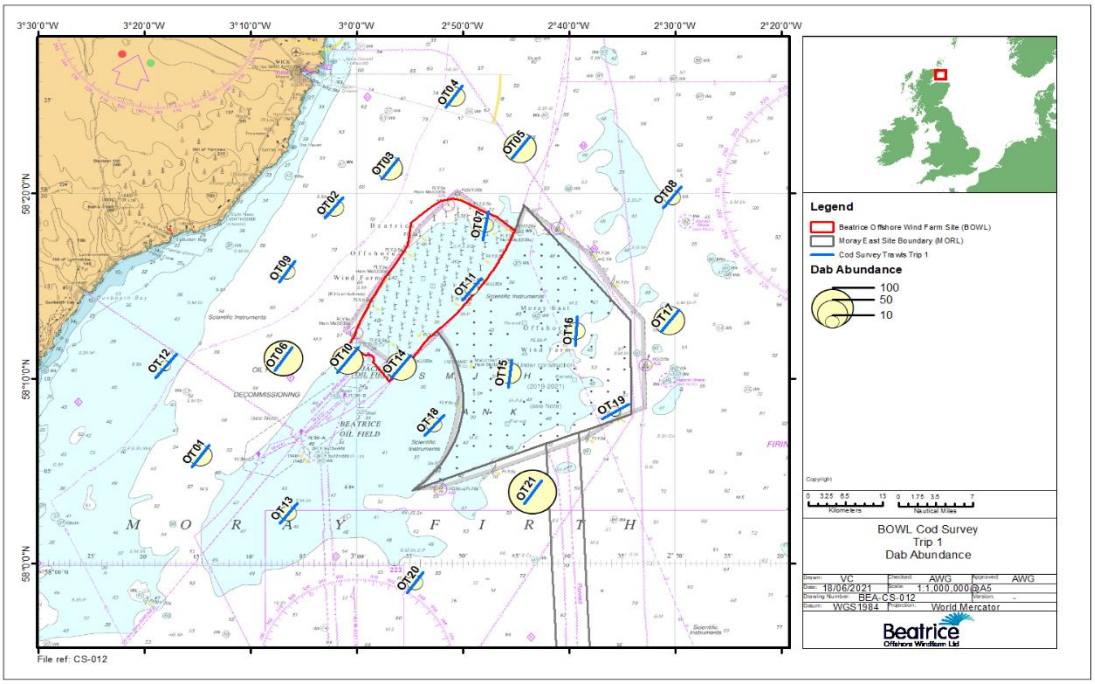

Figure 9.11 Dab Abundance by Station - Trip 1

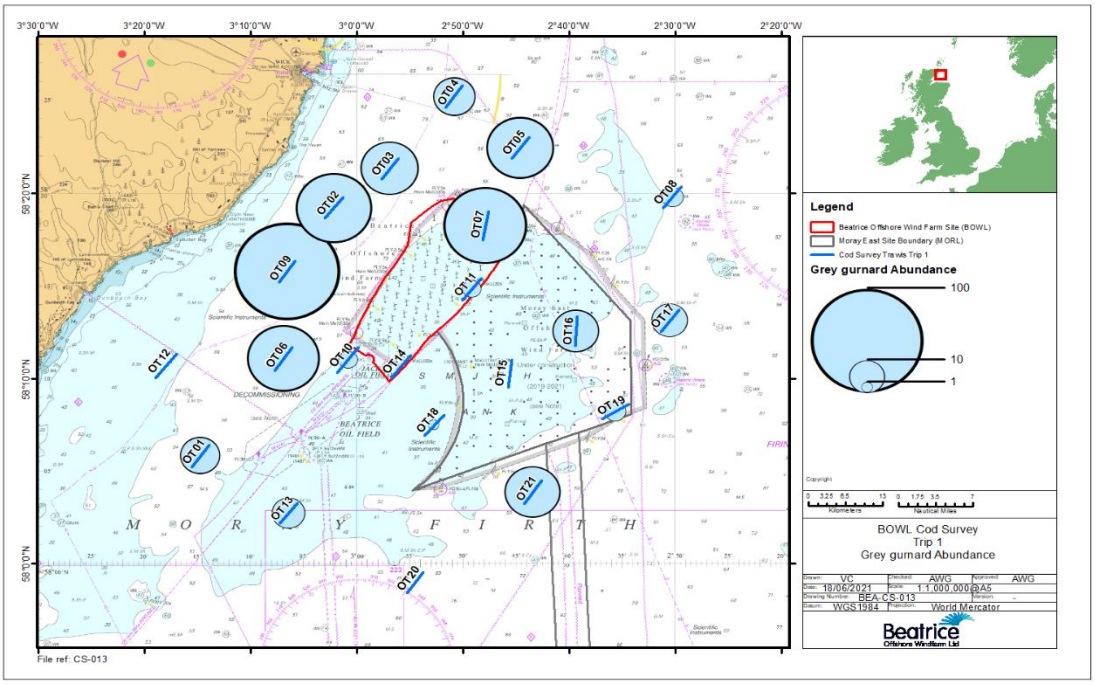

Figure 9.12 Grey Gurnard Abundance by Station - Trip 1

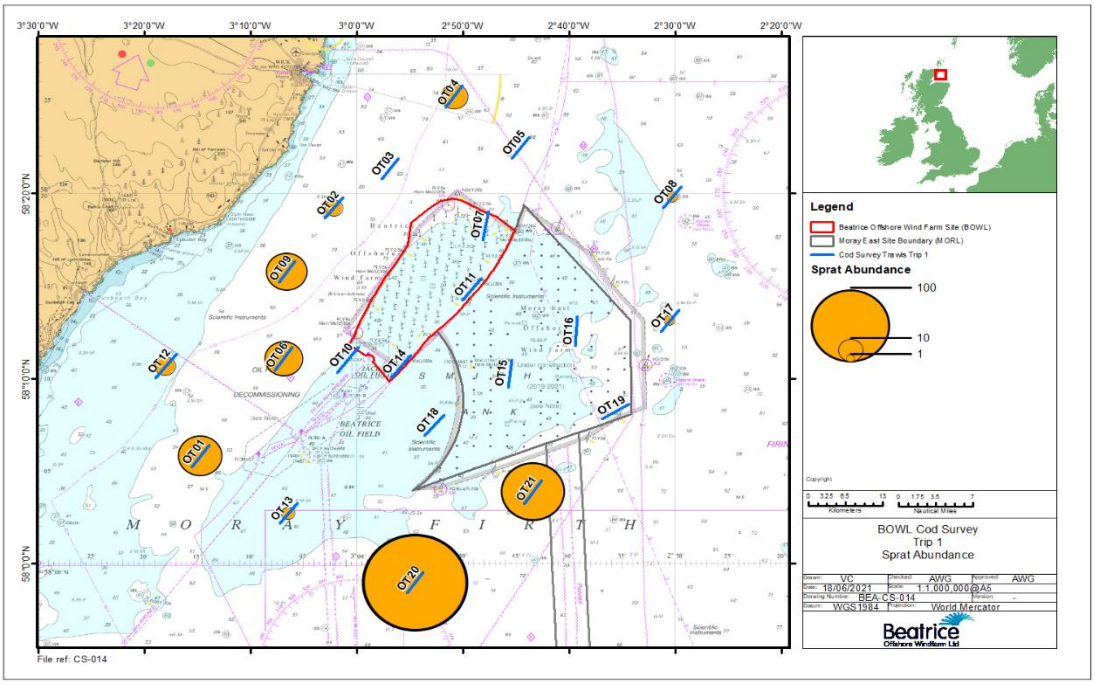

Figure 9.13 Sprat Abundance by Station - Trip 1

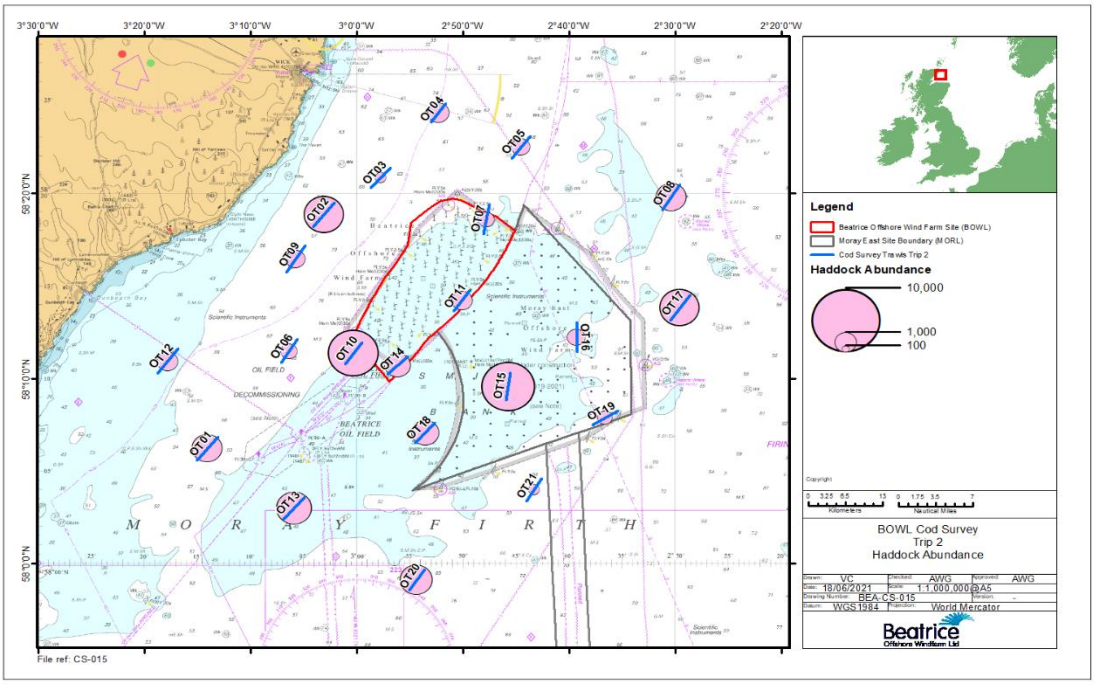

Figure 9.14 Haddock Abundance by Station - Trip 2

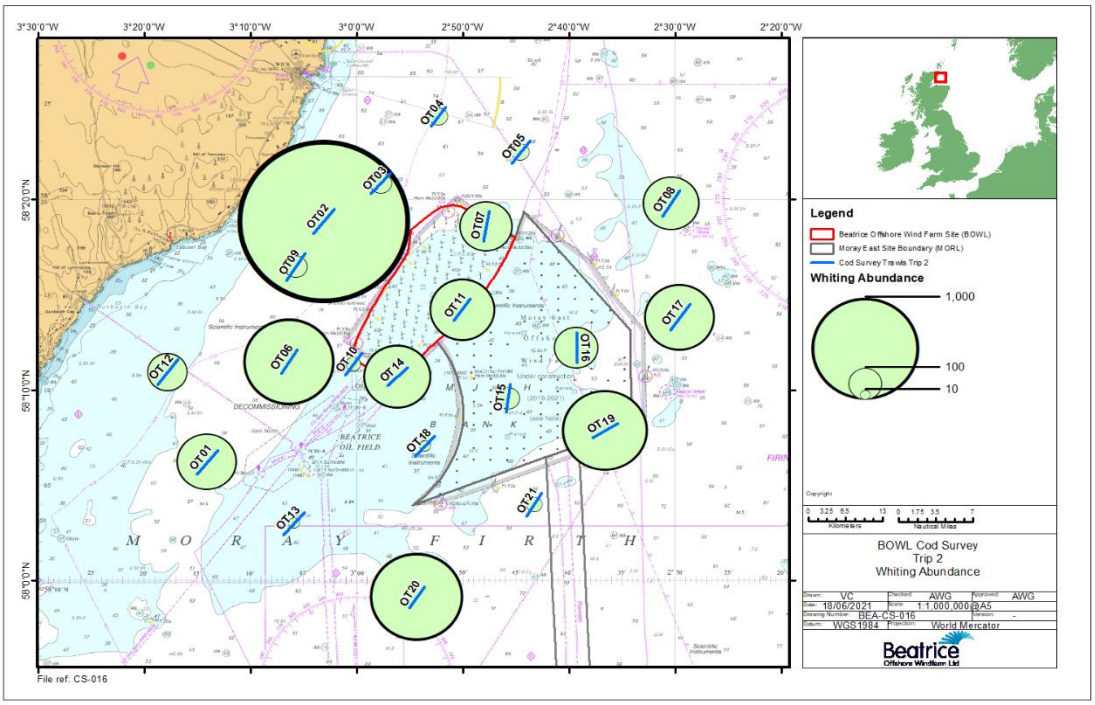

Figure 9.15 Whiting Abundance by Station - Trip 2

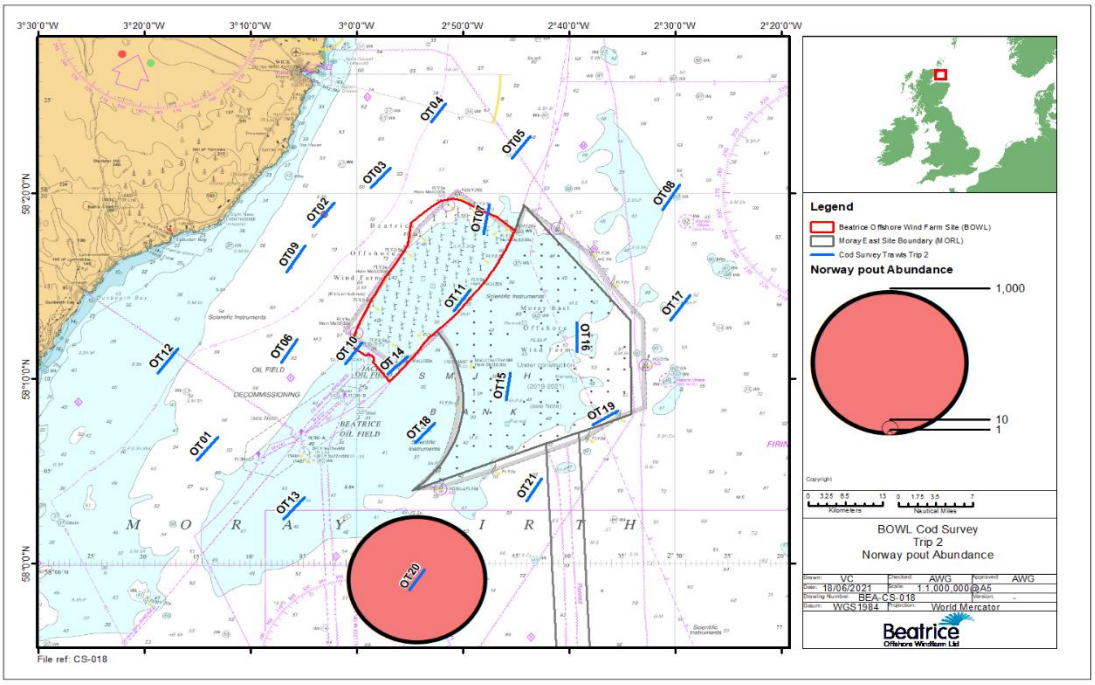

Figure 9.16 Norway Pout Abundance by Station - Trip 2

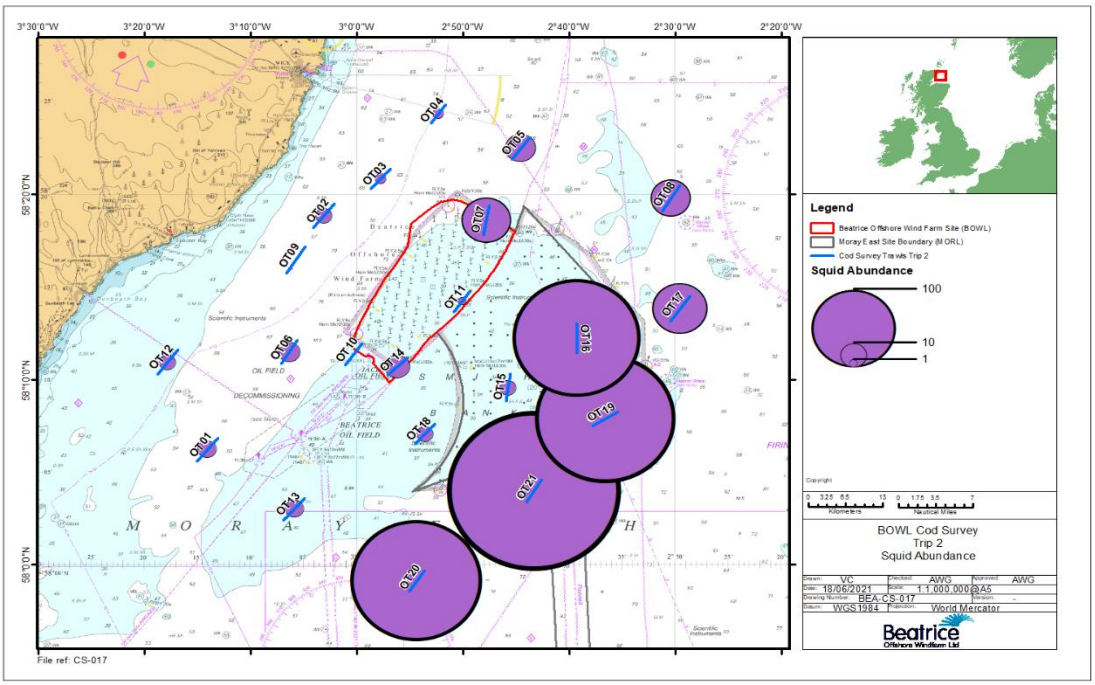

Figure 9.17 Squid Abundance Recorded by Station - Trip 2

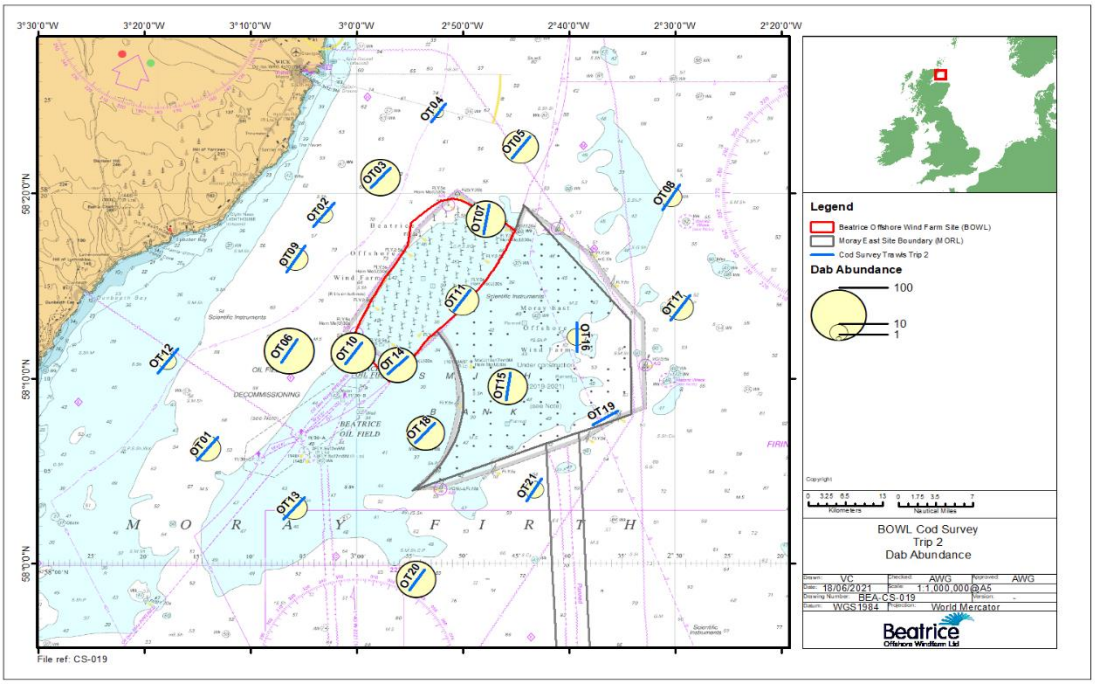

Figure 9.18 Dab Abundance Recorded by Station - Trip 2

9.6 Appendix 6 – Comparison of Swept Areas Pre and Post-construction

Table 9.6 Comparison of swept areas in the pre-construction (2014) and post-construction (2021) surveys

Trip	Trawl	Swept Area km^2	
		2014	2021
1	OT01	0.0340	0.0338
1	OT02	0.0352	0.0370
1	OT03	0.0360	0.0389
1	OT04	0.0425	0.0400
1	OT05	-	0.0373
1	OT06	0.0303	0.0405
1	OT07	0.0375	0.0446
1	OT08	-	0.0343
1	OT09	0.0368	0.0333
1	OT10	0.0397	0.0443
1	OT11	0.0372	0.0419
1	OT12	0.0361	0.0435
1	OT13	0.0330	0.0338
1	OT14	0.0468	0.0408
1	OT15	0.0344	0.0385
1	OT16	0.0400	0.0376
1	OT17	0.0337	0.0381
1	OT18	0.0352	0.0385
1	OT19	0.0339	0.0389
1	OT20	0.0339	0.0358
1	OT21	0.0351	0.0392
2	OT01	0.0351	0.0419
2	OT02	0.0335	0.0431
2	OT03	0.0366	0.0401
2	OT04	0.0422	0.0382
2	OT05	0.0364	0.0386
2	OT06	0.0339	0.0397
2	OT07	0.0362	0.0402
2	OT08	0.0330	0.0390
2	OT09	0.0380	0.0452
2	OT10	0.0347	0.0347
2	OT11	0.0362	0.0338
2	OT12	0.0410	0.0422
2	OT13	0.0346	0.0388
2	OT14	0.0367	0.0329
2	OT15	0.0320	0.0349
2	OT16	0.0327	0.0391
2	OT17	0.0320	0.0414
2	OT18	0.0346	0.0335
2	OT19	0.0351	0.0349
2	OT20	0.0346	0.0359
2	OT21	0.0395	0.0359

9.7 Appendix 7 - MSS Guidance for Defining Cod Spawning

Defining cod spawning areas based on CPUE (pers.com A. Kafas (MSS) 7th April 2014):

Wright et al. (2006) used a variety of approaches to define general areas of cod spawning, including the number of spawning cod caught per hour by MRV Scotia in the GOV. The threshold for defining spawning areas in that paper was CPUE values > 2 spawning cod per hour, although > 10 spawning cod per hour provides a more definitive evidence of spawning. The average swept area (wing spread x distance travelled) of 1,330 hauls conducted on Scotia during Q1 and Q4 west coast surveys, 2000-2011 was estimated to be 66039.14 m^2, for a 30 minute tow. The following averages were used to standardise the gear raising factors: Headline height = 5 m and wing spread = 20 m. On average then the GOV covers 0.132 km^2 in 1 hour. So for the GOV, 2 running cod per hour is approximately equal to 15 spawning cod per km^2 swept (i.e. 2 x (1/0.132)) and 10 running cod per hour is approximately equal to 75 spawning cod per km^2 swept. Three other trawl surveys targeted at cod in early spring caught mature cod in 55 out of 207 stations. Of these 55 stations with mature cod, 25 contained spawning cod ranging from 5 - 360 spawning cod per km^2 swept. Of the 25 spawning cod stations, 16 had >15 spawning cod per km^2 swept with only 2 stations > 75 spawning cod per km^2 swept.

So, as a guideline **the presence of >15 spawning cod per km^2 should give some concern that the area may be important to spawning cod. Whereas > 75 spawning cod per km^2 swept should provide a clear indication of a spawning area.** It should also be noted that spawning cod generally represent a small percentage of the mature cod in a haul (on average 9%) and so we would expect that swept area estimates of mature cod numbers would be higher than this but the presence of spawning (running cod) gives the clearest indication of a spawning site.

9.8 Appendix 8 - Calculations Using Simrad TV80 Logging Tow Data

Tow data obtained from the net sensors were used to multiply up the number of cod caught at each station to the number of cod caught per km^2 for Trip 1 (Table 9.7) and Trip 2 (Table 9.8). Using the MSS guidance spawning status was allocated in the below tables as L = not important for spawning cod, M= may be important to spawning cod and S = spawning area.

Table 9.7 Trip 1 Simrad TV80 data logging and cod abundance data used to calculate no. of spawning (stage III) cod per km^2

Station	Date	Tow Duration (mm:ss)	Av. Headline Height (m)	Av. Wing Spread (m)	Swept Distance (km)	Swept Area (km^2)	No. Cod	No. Spawning Cod	% Spawning Cod	No. Cod/km^2	No. Spawning Cod/km^2	Spawning Status
OT01	02/03/2021	30:26	5.184	12.20	2.770	0.03379	1	1	100.0%	30	30	M
OT02	03/03/2021	30:15	4.659	14.04	2.634	0.03698	4	2	50.0%	108	54	M
OT03	04/03/2021	30:01	4.781	14.89	2.610	0.03887	0	0	0.0%	0	0	L
OT04	07/03/2021	30:05	5.101	14.85	2.693	0.03999	3	2	66.7%	75	50	M
OT05	07/03/2021	30:14	4.977	14.01	2.662	0.03729	5	4	80.0%	134	107	S
OT06	03/03/2021	31:41	4.904	14.22	2.851	0.04052	0	0	0.0%	0	0	L
OT07	07/03/2021	30:32	4.841	15.25	2.925	0.04460	3	3	100.0%	67	67	M
OT08	04/03/2021	30:12	5.050	12.71	2.698	0.03428	0	0	0.0%	0	0	L
OT09	03/03/2021	30:22	4.733	12.87	2.585	0.03327	0	0	0.0%	0	0	L
OT10	03/03/2021	30:14	5.114	13.91	3.180	0.04425	0	0	0.0%	0	0	L
OT11	06/03/2021	29:57	4.663	14.99	2.794	0.04187	3	0	0.0%	72	0	L
OT12	02/03/2021	30:58	5.209	13.98	3.109	0.04345	0	0	0.0%	0	0	L
OT13	02/03/2021	30:19	5.187	13.13	2.572	0.03375	0	0	0.0%	0	0	L
OT14	06/03/2021	30:09	5.095	13.93	2.928	0.04079	0	0	0.0%	0	0	L
OT15	05/03/2021	30:18	4.732	14.13	2.724	0.03849	0	0	0.0%	0	0	L
OT16	05/03/2021	30:06	4.842	12.59	2.982	0.03755	0	0	0.0%	0	0	L
OT17	05/03/2021	30:10	4.960	13.94	2.732	0.03808	4	4	100.0%	105	105	S
OT18	06/03/2021	30:07	5.312	13.90	2.772	0.03853	0	0	0.0%	0	0	L
OT19	05/03/2021	30:06	4.953	13.18	2.948	0.03886	1	1	100.0%	26	26	M
OT20	02/03/2021	29:36	5.021	13.93	2.572	0.03583	1	0	0.0%	28	0	L
OT21	06/03/2021	30:03	5.208	13.56	2.8898668	0.03920	0	0	0.0%	0	0	L

Table 9.8 Trip 2 Simrad TV80 data logging and cod abundance data used to calculate no. of spawning cod (Stage III) per km^2

Station	Date	Tow Duration (mm:ss)	Av. Headline Height (m)	Av. Wing Spread (m)	Swept Distance (km)	Swept Area (km^2)	No. Cod	No. Spawning Cod	% Spawning Cod	No. Cod/km^2	No. Spawning Cod/km^2	Spawning Status
OT01	25/03/2021	30:31	4.638	13.72	3.058	0.04194	0	0	0.0%	0	0	L
OT02	27/03/2021	30:13	5.029	13.82	3.116	0.04306	0	0	0.0%	0	0	L
OT03	24/03/2021	30:09	4.861	14.88	2.694	0.04010	0	0	0.0%	0	0	L
OT04	23/03/2021	30:53	5.288	16.59	2.303	0.03820	1	1	100.0%	26	26	M
OT05	23/03/2021	30:04	5.089	13.84	2.786	0.03856	2	0	0%	52	0	M
OT06	25/03/2021	30:02	5.259	14.20	2.794	0.03968	0	0	0.0%	0	0	L
OT07	27/03/2021	30:06	4.930	13.60	2.957	0.04021	0	0	0.0%	0	0	L
OT08	26/03/2021	30:05	4.873	13.06	2.989	0.03903	0	0	0.0%	0	0	L
OT09	25/03/2021	31:46	4.888	14.18	3.186	0.04519	0	0	0.0%	0	0	L
OT10	24/03/2021	30:04	5.192	13.33	2.606	0.03474	1	1	100.0%	29	29	M
OT11	27/03/2021	30:02	4.771	12.84	2.629	0.03375	1	0	0.0%	30	0	L
OT12	25/03/2021	30:07	4.901	13.60	3.104	0.04220	0	0	0.0%	0	0	L
OT13	24/03/2021	30:34	4.756	13.16	2.952	0.03884	0	0	0.0%	0	0	L
OT14	24/03/2021	30:07	5.430	12.64	2.598	0.03285	0	0	0.0%	0	0	L
OT15	28/03/2021	30:09	4.813	12.40	2.811	0.03487	0	0	0.0%	0	0	L
OT16	28/03/2021	30:07	5.657	13.09	2.988	0.03911	0	0	0.0%	0	0	L
OT17	26/03/2021	29:57	4.850	13.13	3.153	0.04140	0	0	0.0%	0	0	L
OT18	27/03/2021	30:09	5.321	12.38	2.703	0.03347	0	0	0.0%	0	0	L
OT19	28/03/2021	30:31	5.029	12.65	2.760	0.03491	0	0	0.0%	0	0	L
OT20	29/03/2021	30:14	4.847	14.15	2.536	0.03588	0	0	0.0%	0	0	L
OT21	29/03/2021	30:13	4.708	13.24	2.714	0.03595	0	0	0.0%	0	0	L