Hornsea Project Four

Bycatch Reduction Technology Selection Phase Summary

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Revision Summary				
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Glossary

Term	Definition
Appropriate Assessment (AA)	An assessment to determine the implications of a plan or project on a European site in view of the site's Conservation Objectives. An AA forms part of the Habitats Regulations Assessment and is required when a plan or project is likely to have a significant effect on a European site.
Common guillemot biogeographic population	The north east Atlantic breeding population of guillemot which includes the *Uria aalge albionis* and *Uria aalge aalge* subspecies and includes individuals from the Flamborough and Filey Coast SPA (Stroud *et al.,* 2016). Proposed compensation measures will be undertaken within this populations breeding and migratory range.
Compensation / Compensatory Measures	If an Adverse Effect on the Integrity on a designated site is determined during the Secretary of State's Appropriate Assessment, compensatory measures for the impacted site (and relevant features) will be required. The term compensatory measures is not defined in the Habitats Regulations. Compensatory measures are however, considered to comprise those measures which are independent of the project, including any associated mitigation measures, and are intended to offset the negative effects of the plan or project so that the overall ecological coherence of the national site network is maintained.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
European site	A Special Area of Conservation (SAC) or candidate SAC (cSAC), a Special Protection Area (SPA) or a site listed as a Site of Community Importance (SCI). Potential SPAs (pSPAs), possible SACs (pSACs) and Ramsar sites are also afforded the same protection as European sites by the National Planning Policy Framework – para 176 (Ministry of Housing, Communities and Local Government, 2019). European offshore marine sites are also referred to as "European sites" for the purposes of this document.
Habitats Directive	European Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora
Habitats Regulations	The Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017
Habitats Regulations Assessment (HRA)	A process which helps determine likely significant effects and (where appropriate) assesses adverse impacts on the integrity of European sites. The process consists of up to four stages: screening, appropriate assessment, assessment of alternative solutions and assessment of imperative reasons of over-riding public interest (IROPI) and compensatory measures
Hornsea Project Four Offshore Wind Farm	The proposed Hornsea Project Four Offshore Wind Farm project. The term covers all elements of the project (i.e., both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and connection to the electricity transmission network. Hereafter referred to as Hornsea Four.
In-Combination Effect	The effect of Hornsea Four in-combination with the effects from other plans and projects on the same feature/receptor.
National Site Network	The network of European Sites in the UK. Prior to the UK's exit from the EU and the coming into force of the Conservation of Habitats and Species (Amendment) (EU Exit)

Term	Definition
	Regulations 2019 these sites formed part of the EU ecological network knows as "Natura 2000".
Nature Directives	The EU Habitats Directive (European Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora) and EU Wild Birds Directive (79/409/EEC amended in 2009 to become Directive 2009/147/EC)
Offshore Ornithology Engagement Group (OOEG)	The Hornsea Four Offshore Ornithology Engagement Group means the group that will assist, through consultation the undertaker in relation to the delivery of each compensation measures as identified in the kittiwake compensation plan, the gannet compensation plan and the guillemot and razorbill compensation plan. Matters to be consulted upon to be determined by the Applicant and will include site selection, project/study design, methodology for implementing the measure, monitoring, and adaptive management options as set out in the kittiwake compensation plan, the gannet compensation plan and the guillemot and razorbill compensation plan.
Orsted Hornsea Project Four Ltd.	The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO).
Razorbill biogeographic population	The breeding population of razorbill which includes *Alca torda islandica* and includes individuals from the Flamborough and Filey Coast SPA (Stroud *et al.,* 2016). Proposed compensation measures will be undertaken within this populations breeding and migratory range
Special Area of Conservation (SAC)	Strictly protected sites designated pursuant to Article 3 of the Habitats Directive (via the Habitats Regulations) for habitats listed on Annex I and species listed on Annex II of the directive.
Special Protection Area (SPA)	Strictly protected sites designated pursuant to Article 4 of the Birds Directive (via the Habitats Regulations) for species listed on Annex I of the Directive and for regularly occurring migratory species.

Acronyms

Term	Definition
CfD	Contracts for Difference
DCO	Development Consent Order
EM	Electronic Monitoring
FFC	Flamborough and Filey Coast
FID	Final Investment Decision
GCIMP	Gannet Compensation Implementation and Monitoring Plan
GLM	Generalised linear model
GLMM	Generalised linear mixed model
LEB	Looming Eyes Buoy
MMO	Marine Management Organisation
NFFO	National Federation of Fisheries Organisation
NGET	National Grid Electricity Transmission
NGO	Non-Governmental Organisation
OOEG	Offshore Ornithology Engagement Group
PINS	Planning Inspectorate
RSPB	Royal Society for the Protection of Birds
SNCBs	Statutory Nature Conservation Bodies
SoS	Secretary of State
SPA	Special Protection Area
WTG	Wind Turbine Generator
UK	United Kingdom

1 Introduction

1.1 Project background

1.1.1.1 Orsted Hornsea Project Four Limited (hereafter the 'Applicant') is proposing to develop Hornsea Project Four Offshore Wind Farm (hereafter 'Hornsea Four'). Hornsea Four will be located approximately 69 km offshore of East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone. Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm) including up to 180 wind turbine generators (WTGs), export cables to landfall, and connection to the National Grid Electricity Transmission (NGET) network at Creyke Beck. Detailed information on the project design can be found in **A1.4: Project Description (APP-010)**, with detailed information on the site selection process and consideration of alternatives described in **A1.3: Site Selection and Consideration of Alternatives (APP-009)** (submitted as part of the Development Consent Oder (DCO) application).

1.1.1.2 In response to stakeholder consultation on potential effects from Hornsea Four on kittiwake (*Rissa tridactyla*), Northern gannet (*Morus bassanus*, hereafter referred to as 'gannet'), common guillemot (*Uria aalge*, hereafter referred to as 'guillemot') and razorbill (*Alca torda*) features of Flamborough and Filey Coast (FFC) Special Protection Area (SPA), the Applicant has proposed a range of compensation measures (as detailed within **B2.6: Compensation measures for Flamborough and Filey Coast (FFC) Special Protection Area (SPA): Overview (APP-183)**). For guillemot and razorbill, the proposed compensation measures are bycatch reduction and predator eradication, delivered within in the English Channel and Bailiwick of Guernsey (Channel Islands) respectively. This document has been prepared to support the 'without prejudice' compensatory measure of bycatch reduction.

1.1.1.3 The reduction of seabird bycatch will be achieved through the use of deterrent equipment attached to fishing nets at regular intervals. In **B2.8.1 Compensation measures for FFC SPA: Bycatch Reduction: Ecological Evidence (APP-194)**, the Applicant has set out the ecological evidence for types of bycatch reduction measures that can be used to reduce the interaction between birds and fishing equipment.

1.1.1.4 Looming Eyes Buoys (LEBs) were selected by the Applicant as the most promising deterrent equipment, as they are one of the most developed forms of above water deterrent, developed and trialed by BirdLife International/ RSPB in conjunction with Fishtek Marine (i.e. Rouxel *et al.*, 2021). Further information on the LEB is presented within **B2.8.1 Compensation measures for FFC SPA: Bycatch Reduction: Ecological Evidence (APP-194)** along with progress undertaken to date on developing the measure being presented within the Applicant's Bycatch Roadmap (Revision 4 of **B2.8.2: Compensation measures for Flamborough and Filey Coast (FFC) Special Protection Area (SPA): Guillemot and Razorbill Bycatch Reduction: Roadmap** (submitted at Deadline 5)).

1.1.1.5 The Applicant commenced a bycatch reduction technology selection phase in 2021/2022, focusing on the use of LEBs within an active gillnet fishery within the biogeographic range of guillemot and razorbill. This technology selection phase has been implemented within an area of high guillemot and razorbill bycatch (as determined by Northridge *et al.*, 2020) and bycatch risk mapping undertaken by the Applicant and presented in **B2.8.1 Compensation measures for FFC SPA: Bycatch Reduction: Ecological Evidence (APP-194)**. The bycatch reduction technology selection phase focuses on the non-breeding season when high densities of guillemot and razorbill occur along the south coast of the UK and overlap with high levels of gillnetting activity.

1.1.1.6 This document presents the methodology and provisional findings of the bycatch reduction technology selection phase undertaken during the non-breeding season 2021/2022.

1.2 Background

1.2.1.1 Seabirds are at risk from multiple anthropogenic threats, including bycatch in UK fisheries (Miles *et al.*, 2020). Bycatch – the incidental capture of non-target species in fisheries – can present a significant pressure on seabird populations (Miles *et al.*, 2020). Within recent decades, seabird populations have plummeted, largely due to commercial fisheries (direct competition and bycatch) (Croxall *et al.*, 2012). It has been estimated globally that hundreds of thousands of seabirds are killed each year in gillnets (400,000; Žydelis *et al.*, 2013) and longline fisheries (320,000; Anderson *et al.*, 2011).

1.2.1.2 Northridge *et al.* (2020) estimated annual ornithological bycatch using data from 21,000 hauls from UK vessels, carried out as part of the UK Bycatch Monitoring Programme since 1997. They estimated that between 1,800-3,300 guillemot are bycaught by UK vessels in UK waters per annum, mostly in static nets.

1.2.1.3 A wide range of bycatch reduction methods have been developed to reduce ornithological bycatch in fisheries (see for example Wiedenfeld *et al*. (2015) and Parker (2017)). The LEB, developed by Fishtek Marine (Rouxel *et al.*, 2021) was identified as being potentially suitable for use on inshore static net fisheries and following review of the evidence the Applicant considered it suitable to reduce the bycatch of guillemot and razorbill.

1.2.1.4 The LEB is a rotating device (approximately 200mm wide) with two panels which simulate predator eye patterns mounted on a pole to a fishing buoy. The opposite face of each LEB panel exhibits eyes of a difference size which creates a 'looming' effect when the panels rotate. The LEB is designed to rotate using wind power which provides unpredictable movements and speed rotations, which intensify the likelihood of behavioural responses by seabirds and reduces the chances of habituation (Gregor *et al*., 2014).

1.2.1.5 To test the LEB on inshore gillnet fisheries, and thus the suitability of the device for preventing guillemot bycatch, the Applicant has undertaken a bycatch reduction technology selection phase, as part of which the LEBs are implemented within active fisheries at sea.

1.2.1.6 This document presents the methodology and summary of the findings from the bycatch reduction technology selection phase undertaken during the non-breeding season 2020/2021, focusing in particular on guillemot bycatch. Due to some concerns raised by the fishers during consultation regarding the sensitivity of bycatch, this study was only allowed to operate if fishers were given confidence that data would be treated confidentially by the Applicant. Therefore, the Applicant entered into a contractual agreement with the fishers that only the reduction in seabird bycatch rate will be reported. Despite these information sharing constraints, the Applicant is able to provide confidence that the LEB has and can reduce guillemot bycatch within the following sections of this report.

2 Methods

2.1 Vessels

2.1.1.1 Ten vessels, all <10m in length, were recruited to participate in the bycatch reduction technology selection phase. Orsted Fisheries Liaison Officers approached owners of vessels that use static nets in the south east and south west of England, and invited them to one of several local information sessions where the aims of the project were discussed. Attendees at these events included local fishing industry representatives, vessel owners, vessel crew, Orsted managers and SeaScope managers. Attendees were first identified via a fisher questionnaire which was developed by the Applicant and distributed to focal fishing ports along the south coast. The questionnaires were reviewed and checked by independent (Exeter University) social scientists.

2.1.1.2 The LEB (see **Section 2.2**) was demonstrated at the sessions, and the fishers provided advice on the best approaches for rigging and deploying the LEBs. Following the sessions, ten vessels were invited to participate, and participation contracts were signed.

2.1.1.3 Fishers were requested to fish following their normal practice including with regards to location, but to deploy a minimum of a control net and an experimental net with LEBs (see **Section 2.2**) on each hauling trip. The control nets were identical to the experimental LEB net in terms net length, mesh size, and net rigging, with soak times being similar durations. The control and experimental nets were set in similar locations to each other, ideally within 2000m, but no closer than 100m wherever possible. This was to ensure that the nets were exposed to similar bird populations and conditions, but that the LEBs fitted to the experimental nets did not affect the control nets.

2.1.1.4 Vessels were also allowed to set additional "other" nets as they saw fit, to continue their normal fishing practices. Some vessels limited net deployments to the control and experimental nets only whilst others deployed up to 10 additional other nets per day to target a range of species.

2.2 LEBs

2.2.1.1 LEBs consist of a head unit fixed to a dahn buoy with a counterweight (Rouxel *et al.*, 2021). The head unit is raised approximately 1m above sea level (**Figure 1**). The head unit, pictured in **Figure 2**, is approximately 200mm wide and two-sided, each side fitted with two large black circular eye-like patterns. The eye-print is larger on one side, and the head unit is designed to rotate in the wind using ceramic bearings. When deployed, an illusion of eyes travelling towards the viewer is created from the effect caused by the rotation and different-sized eye patterns. The design of the LEB elicits a bird's natural flight response, triggered by the threat of an object rapidly moving towards them. The LEB is designed to rotate using wind power which provides unpredictable movements and speed rotations, which intensify the likelihood of behavioural responses by seabirds and reduce the chances of habituation (Gregor *et al.*, 2014).

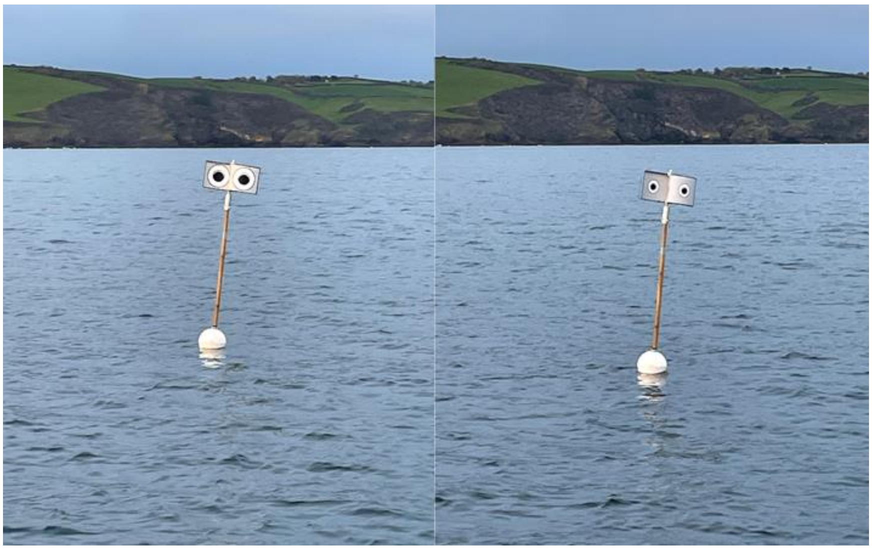

Figure 1: The different sides of the LEB, showing the two "eye" size differences and the height above sea level achieved through the use of dahn buoys (images courtesy of a participating fisher).

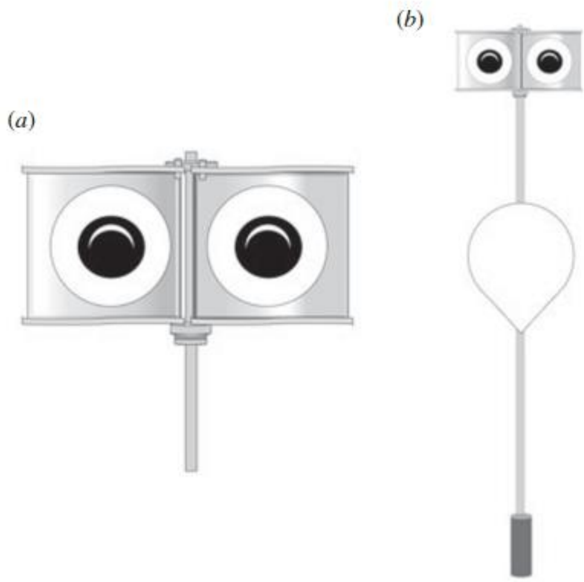

Figure 2: Design of the LEB. Showing the rotating head unit (a) and the head unit attached to a dahn buoy with counterweight (b) (Rouxel *et al.*, 2021).

2.2.1.2 The experimental nets were fitted with LEBs at each end. However, the effective range of the LEB is up to approximately a 50m radius (Rouxel *et al.*, 2021), with the length of nets used being between 100m and 500m in length. To ensure full coverage across the whole experimental net of the LEB's deterrent effects (i.e. 50m in all directions), additional LEBs spaced 100m apart are thus needed on nets longer than 100m. Fixing additional LEBs every

100m directly to nets was not possible due to the effect the LEBs would have on the net, causing pull and/or lift, and affecting the hauling process. As such, free-standing LEBs with individual ropes and anchors were deployed during or after net deployment every 100m along the length of the net.

2.2.1.3 It should be noted that whilst most LEBs were in place within close proximity (within 10m) of the net, currents, tides, wind, poor weather, sea state and net visibility meant that some LEBs may have moved out of position, thus reducing its deterrent effects.

2.3 Bycatch monitoring equipment

2.3.1.1 Bycatch events were monitored using electronic monitoring (EM) equipment fitted on each vessel participating in the bycatch reduction technology selection phase. The use of EM, rather than the use of on-board observers, was selected because EM is more cost-effective, meaning higher monitoring coverage levels (continuous monitoring on each vessel) could be achieved. This in turn is thought to lead to higher levels of data precision, given that bycatch events are infrequent, and the higher coverage achieved by EM is thus more likely to capture bycatch events. In addition, safety risks associated with sending observers to sea meant EM represented a lower-risk option. Furthermore, the other option of self-reporting of bycatch by fishers may lead to under reporting of bycatch due to the sensitivity of bycatch. Therefore, EM presented the best option for monitoring bycatch.

2.3.1.2 The EM system selected was a V5 EMObserve system, with complementary EMInterpret analysis software, supplied by the Canadian company Archipelago Marine Research. The EM comprised of digital CCTV cameras (usually 2 per vessel), a control box to house the electronics and storage devices, a display monitor, and a GPS. The video and GPS data collected by the EM system were stored on encrypted removable hard drives. **Figure 3** shows an example of the camera equipment and GPS fitted on one of the participating vessels.

Figure 3: CCTV cameras and GPS fitted on one of the participating vessels.

2.3.1.3 Archipelago EMI Pro software was used to process the EM data. This software collates the recorded time and GPS data into a clear overview of fishing effort, and links screenshots of bycatch events to the fishing data. This information is then combined into a visual timeline to aid data analysis.

2.3.1.4 Screenshots of bycatch events were processed manually by an observer to identify the bycaught bird species and sent to experienced ornithologists to verify.

2.3.1.5 In addition to EM, fishers also self-declared bycatch events, as well as recording gear type, net length (including tiers), soak time, net mesh size, net set depth and hauling start time for each net and target catch species, sea state, wind speed and wind direction per hauling trip.

2.4 Field study

2.4.1.1 The at-sea implementation of LEBs, as part of the bycatch reduction technology selection phase, was carried out from November 2021 until March 2022. The study took place in the south of England (three vessels in the southeast, seven in the southwest). As stated above, these locations were determined based on bycatch risk mapping undertaken by the Applicant and research by Northridge et al. (2020). Due to weather, large use of different gear type and technical failures one vessel in the southeast was unable to collect data during the study period relevant to the bycatch reduction technology selection phase, therefore the analysis has been completed using data from the remaining nine fishing vessels.

2.4.1.2 Alongside, the recording of bycatch by EM, additional factors were recorded for each net by the EM including setting and hauling times, setting and hauling location, length of net (excluding tiers) and soak time.

2.5 Analysis

2.5.1 Descriptive analyses

2.5.1.1 Descriptive analyses have been undertaken to assess the potential to use LEBs to reduce guillemot bycatch in gillnets. Firstly, this report presents a comparison of proportion of guillemot bycatch in control versus LEB nets in order to assess the potential for LEBs to reduce guillemot bycatch in gillnets.

2.5.1.2 Additionally, this report explores potential factors which may impact the proportion of guillemot bycatch between LEB and control nets. The following variables have been considered in this report;

- Sea state;
- Wind speed; and
- Time of day.

2.5.1.3 These variables will be used to identify potential factors that may influence guillemot bycatch when comparing control and LEB nets with recorded guillemot bycatch in order to assess if guillemot are more likely to be caught in either control or LEB nets depending on these factors (it should be noted that for both of these analyses, where guillemot bycatch were recorded more than once for an individual net, these were considered as separate catching events).

2.5.1.4 Other variables have been recorded by fishers so they can be analysed following the use of the LEB during the non-breeding season 2022/2023 with a larger dataset. This report focuses on variables considered likely to impact guillemot bycatch between experimental and control nets.

2.5.1.5 In the descriptive analysis, where data was unknown for each variable, these nets were excluded from the analysis on a variable by variable basis. Where fishers had recorded variables via differing methods to standard procedure, these were reviewed and applied to the standard methodologies if possible and appropriate in order for these results to be included within the analysis.

2.5.2 Statistical analysis

2.5.2.1 Statistical analyses were performed to determine whether the LEB successfully reduced the number of guillemot bycaught in the experimental nets compared to the control nets. Generalised linear mixed models (GLMMs) were selected as the most appropriate analysis for the data. GLMMs are a type of regression model; they assess how a response variable (in this case bycatch occurrence) changes in response to explanatory variables and random effects (see paragraph 2.5.2.2 for the explanatory variable and random effect included in this analysis). GLMMs are particularly well-suited to dealing with data that are not normally-distributed, as is the case for the data collected in the bycatch reduction technology selection phase (see paragraph 2.5.2.2).

2.5.2.2 GLMMs were performed in the statistical software R (R Core Team, 2021) using the lme4 package (Bates *et al.*, 2015). Within the model bycatch occurrence was set as the response variable and net treatment (control or treatment) as the explanatory variable. Vessel trip ID was included as a random effect variable, which allowed the model to account for the control and treatment nets being paired during each trip. Chi-square and F statistics were calculated using the car package (Fox & Weisberg, 2011), model fit was assessed using the DHARMa package (Hartig, 2020) and post hoc tests were conducted using the emmeans package (Lenth, 2022).

2.5.2.3 In addition, a Generalised Linear Model (GLM) was used to test whether bycatch occurrence (i.e. the response variable in the model) changes in relation to a number of parameters such as wind speed and sea state (the explanatory variables in the model).

3 Results

3.1 Guillemot bycatch in LEB versus control nets

3.1.1.1 There was guillemot bycatch recorded in all net types, namely control, LEB and 'other' nets. However, when comparing guillemot bycatch in control and LEB nets, there was considerably less bycatch in the experimental nets than control, resulting in a 25% (24.9%) decrease in bycatch of guillemot in LEB nets (**Table 1**).

Table 1. Proportion of guillemot bycatch in LEB and control nets and resultant percentage change between the two nets.

Species	Proportion of bycatch in LEB nets	Proportion of bycatch in control nets	Percentage change
Guillemot	42.9%	57.1%	24.9% decrease

3.2 Influence of variables on guillemot bycatch

3.2.1.1 There are three factors considered in this report which could impact the proportion of guillemot caught in control versus experimental nets, also assessed in the following sections. These three variables are the following:

- Sea state;
- Wind speed; and
- Time of day.

3.2.1.2 The following sections analyse the potential impact of these variables on bycatch occurrence.

3.2.2 Sea state

3.2.2.1 **Table 2** shows that the majority of guillemot bycatch is in calm-smooth conditions (47%) and moderate-rough conditions (53%, with the majority of these in rough conditions). In comparison, 62% of the nets were in calm-smooth conditions and 31% in moderate-rough conditions. These results therefore suggest that guillemot bycatch is more likely to occur in rougher conditions and less likely to occur in calm-smooth conditions, as the number of birds bycaught in rough conditions was proportionally higher than the total number of nets set in these conditions, and the number of birds bycaught in calm-smooth conditions was proportionally lower.

3.2.2.2 In general, higher bycatch in rougher weather conditions could, as a result of increased net movement or increase in turbidity, lead to reduced water clarity, therefore affecting the ability for seabirds to detect nets (Northridge *et al.*, 2016). However, due to differing net types being used throughout the study (i.e. control, experimental and other), it is important to disentangle the impacts of guillemot bycatch in LEB versus control nets during different sea states to understand if guillemot bycatch is higher in higher sea states in general, or whether experimental, control or other nets are likely to experience higher bycatch levels. This is explored further in **Section 3.2.2.3**.

Table 2. Percentage of all nets and nets with guillemot bycatch within each recorded sea state.

Sea State	Percentage of nets	
	All nets	*Guillemot bycatch nets only*
Calm	46	21
Calm-Smooth	15	21
Smooth	1	5
Slight	4	0
Slight-Moderate	1	0
Moderate	21	11
Moderate-Rough	4	0
Rough	4	42
Mixed	3	0

3.2.2.3 There was highest guillemot bycatch in LEB nets during rough conditions (67%) than under any other condition (**Table 3**). When comparing guillemot bycatch proportions between control and LEB nets in different sea conditions, there were proportionally more guillemot caught in the control nets during calmer conditions, suggesting that LEBs work most effectively during calmer conditions as opposed to rougher conditions (**Table 3**). It is expected that in rough conditions, on average, wind speed will also be greater (wind speed is considered in **Section 3.2.3**), therefore these results are in line with reports from fishers during the study that during high wind speeds, LEBs were not creating the looming eye effect and were thus not expected to be as efficient as during calmer conditions.

Table 3. Percentage of guillemot bycatch caught in control versus LEB nets during each sea state condition.

Sea State	Percentage of nets	
	Guillemot bycatch in control nets	*Guillemot bycatch in LEB nets*
Calm	13	17
Calm-Smooth	38	0
Smooth	0	17
Slight	0	0
Slight-Moderate	0	0
Moderate	25	0
Moderate-Rough	25	0
Rough	0	67
Mixed	0	0

3.2.3 Wind speed

3.2.3.1 Table 4 shows that all guillemot bycatch is distributed within wind speeds of 1 to 31mph (Beaufort Wind Force of 1-6 or light air to strong breeze) with the highest bycatch at 19 to 31 mph (Beaufort Wind Force of 5 to 6, i.e. fresh breeze to strong breeze) (Table 4). When comparing guillemot bycatch to proportions of wind speeds in all nets, the majority were in wind speeds of 1 to 31 mph, similar to the distributions of guillemot bycatch nets. However, where highest proportions of bycatch were in 19 to 31 mph, a considerably smaller proportion of all nets were set in these conditions. Therefore, there may be a trend that higher wind speeds lead to greater guillemot bycatch in gillnets, which is supported by Northridge *et al*. (2016), as increased wind speed could lead to increase net movement, resulting in greater turbidity leading to reduced water clarity and therefore seabird bycatch risk increases.

Table 4. Percentage of all nets and nets with guillemot bycatch within each recorded wind speed.

Wind speed (Beaufort Wind Force)	Percentage of nets	
	All nets	*Guillemot bycatch nets only*
Calm	1	0
Light air – light breeze	13	10
Light breeze – gentle breeze	26	26
Gentle breeze – moderate breeze	26	16
Moderate breeze – fresh breeze	16	11
Fresh breeze – strong breeze	11	37
Strong breeze – near gale	5	0
Near gale	1	0
Variable	2	0

3.2.3.2 There was highest guillemot bycatch in LEB nets during 19-31mph wind speeds (fresh to strong breeze) with most other wind speeds not recording any guillemot bycatch in LEB nets (Table 5). In comparison, control nets caught guillemot in wind speeds ranging from 4 to 31mph (light to strong breeze) with no guillemot bycatch in wind speeds <4mph or >31mph in the control nets. 25% of guillemot bycatch was caught in control nets set during 19-31mph winds compared to 67% in LEB nets, strongly suggesting that LEB nets are less effective during windier conditions than in slower wind speeds. This is in line with reports from fishers during the study, who commented that during high wind speeds, LEBs were not creating the looming eye effect and were ultimately not expected to be as efficient as during calmer conditions.

Table 5. Percentage of guillemot bycatch caught in control versus LEB nets during differing wind speeds.

Wind speed (Beaufort Wind Force)	Percentage of nets	
	Guillemot bycatch in control nets	*Guillemot bycatch in LEB nets*
Calm	0	0
Light air – light breeze	0	0
Light breeze – gentle breeze	38	33
Gentle breeze – moderate breeze	25	0
Moderate breeze – fresh breeze	13	0
Fresh breeze – strong breeze	25	67
Strong breeze – near gale	0	0
Near gale	0	0
Variable	0	0

3.2.4 Time of day

3.2.4.1 Guillemot bycatch was highest when nets were set all day, as opposed to part of a day, (Table 6), thus making it difficult to distinguish bycatch rates between different times of the day. Due to the small sample size in this study, investigating time of day further is not considered feasible at this stage.

Table 6. Percentage of all nets and nets with guillemot bycatch at different times of the day when nets were out.

Time of day	Percentage of nets	
	All nets	*Guillemot bycatch nets only*[1]
Dawn	6	0
Day	4	0
Dusk	4	0
Night	4	0
Dawn+Day	15	21
Day+Dusk	3	0
Dusk+Night	6	0
Night+Dawn	7	0
Dawn+Day+Dusk	1	0
Day+Dusk+Night	2	5
Dusk+Night+Dawn	1	5
Night+Dawn+Day	6	0
Dawn+Day+Dusk+Night	40	68

[1] Please note the numbers do not sum to 100 in the table due to rounding to the nearest whole number.

3.2.4.2 Additionally, when comparing LEB versus control nets, the majority of guillemot bycatch is when nets were set all day (83%). There is no other considerable differences in bycatch rate for other periods of the day.

4 Discussion

4.1 Findings

4.1.1.1 The Applicant's bycatch reduction technology selection phase is the first study of its kind using the LEB in an active fishery while also employing EM devices to monitor bycatch events. This study has built upon the first published trial of the LEB which was undertaken by Rouxel *et al.,* (2021) within an experimental setting (i.e. not an active fishery or using nets) and not focusing on guillemot or razorbill. Within that study the authors showed that the abundance of long-tailed duck (*Clangula hyemalis*) declined by approximately 20–30% within a 50 m radius of the LEB.

4.1.1.2 Furthermore, within the study the authors (Rouxel *et al.,* 2021) suggested:

> *"Follow-up testing of this device* [the LEB] *is needed to confirm its potential in tackling seabird bycatch in commercial fishing conditions, using a paired-trial experiment to compare control and experimental nets, ideally over an extended-time period to examine potential habituation effects."*

4.1.1.3 The Applicant has involved the authors of Rouxel *et al.,* (2021) during the study planning process to ensure best practice and approach to undertaking the bycatch reduction technology selection phase. The Applicant has hosted workshops to set out its approach, received feedback, and engaged with key players in bycatch (including BirdLife International, RSPB, Natural England, Defra, SeaScope, FishTek Marine and the National Federation of Fishermen's Organisations (NFFO)). The Applicant has received positive engagement and feedback from all parties to date and has used this to undertake an industry and scientific first in a bycatch reduction technology selection phase for compensation measures to reduce the direct mortality of sensitive seabirds as a result of bycatch in UK fisheries.

4.1.1.4 The results from this bycatch reduction technology selection phase have shown that LEBs have reduced the level of bycatch of guillemot within a commercial gillnet fishery by approximately 25% within a 50 m radius. The use of the LEB within gillnet fisheries, as proposed by the Applicant as a primary compensation measure, could therefore have the ability to save a large number of auks each year over the course of the Hornsea Four project lifetime of 35 years.

4.1.1.5 The results from this study have shown very similar results to those presented within Rouxel *et al.,* (2021) for a different species. A 50 m radius was selected by Rouxel *et al*., (2021) based on guillemot and razorbill tracking data, which suggested neither species travelled horizontally more than 50 m under water in a single dive (Browning et al., 2018 & Wakefield et al., 2017). Based on this evidence, it was therefore appropriate to assume a 50 m radius within the bycatch reduction technology selection phase. While potential deterrent distances could increase with modifications to the LEB, 50m provides a basis for further implementation of the LEB.

4.1.2 Habituation considerations

4.1.2.1 Habituation is an important consideration when planning bird deterrent deployment. If birds are to become used to the deterrent (in this case the LEB) then its effectiveness in reducing seabird mortality diminishes. Gillnet fishers are not tied to certain locations in terms of where their nets are set which adds a degree of randomness to the deployment of the LEB, therefore reducing the likelihood of habituation. Furthermore, LEBs are powered by wind and therefore move dependent on windspeeds. This therefore varies the rotation speed and subsequent looming effect, meaning the LEBs movements are not predictable. Wave action also influences movement and therefore when coupled with wind speed variability, the LEB acts randomly, limiting the chances of birds habituating to it.

4.1.2.2 Rouxel *et al.*, (2021) suggested potential habituation by the study species (long-tailed duck) during their experimental LEB trial. However, this is likely to be a result of the species diving range for bivalves which are a stationary, benthic prey. Guillemot and razorbill largely feed on ephemeral prey, such as forage fish species, and are therefore nomadic and not fixed to specific water depths or distance from shore. This difference in foraging ecology suggests habituation is less likely to be seen in future deployments of the LEB for the guillemot and razorbill.

4.1.3 Monitoring of bycatch

4.1.3.1 The Applicant recognises the importance of monitoring of the compensation measures. As outlined within the methods section of this report, the bycatch reporting system used during the bycatch reduction technology selection phase employed a dual camera system with GPS, fitted to each fishing vessel. Similar systems have been used by Glemarec *et al.,* (2020) which have been shown to reduce costs and observer effects (bias) while increasing coverage. Quality EM data requires the full cooperation of the participating fishing vessels as fishers must keep a clear and unobstructed view for the cameras, and not withdraw information by switching off the monitoring system (Glemarec *et al.*, (2020). The bycatch reduction technology selection phase undertaken by the Applicant showed seamless use of EM systems, with all fishers willingly participating. In many cases, fishers held bycaught species up to the cameras to aid identification, although this wasn't necessary due to the high resolution of the EM system.

4.1.3.2 The resolution of the images allowed identification of all bycatch to species level, reducing ambiguity around results and proved the EM system can be effective for monitoring bycatch reduction as a compensation measure for Hornsea Four. Due to the high resolution of the camera system used during the bycatch reduction technology selection phase, the same system may be used at times during the lifetime of the project to complement the other monitoring measures.

4.1.4 Absence of razorbill and bycatch of other species

4.1.4.1 Despite no razorbill being recorded as bycatch during the bycatch reduction technology selection phase, razorbill are known to be bycaught in gillnets (as reported by Northridge *et al.,* 2020). The likely reason behind the absence of razorbill as bycatch is likely due to the much lower razorbill numbers. For example, Irwin *et al.* (2019) surveyed the waters off the south east of England and found guillemot density to be 350% higher than razorbill. The Applicant has committed to using the LEB on vessels during the non-breeding season 2022/2023, which aims to continue to collect high quality data of all seabird species bycatch within active fisheries.

4.1.4.2 Guillemot and razorbill have been the focus of this bycatch reduction technology selection phase as they are the species which may require compensation as a result of Hornsea Four. Whilst shag, cormorant and great northern diver were bycaught during the study, a number of other seabird species will also be present within the waters along the south coast of England, and will therefore be exposed and potentially sensitive to fisheries bycatch.

4.1.4.3 It is important to note that the applicant is proposing to use the same EM system and review process as used during the 2021/2022 bycatch reduction technology selection phase during the use of the LEBs during the 2022/2023 non-breeding season, which therefore provides confidence that data will be consistent and robust. The use of the LEBs on vessels during the non-breeding season 2022/2023 will gather information to assist the implementation of the compensation measure and will also be used to determine if there are any impacts on other seabird species. The Applicant will inform any potential adaptive management measures that could be needed. This may for example involve focusing use of LEBs in certain locations or the testing and use of other bycatch reduction techniques, and will be undertaken in consultation with the projects Offshore Ornithology Engagement Group which will include key stakeholders.

5 Next steps

5.1.1.1 The Applicant has confirmed it will use the LEBs on vessels during the non-breeding season during 2022/2023. This will follow on from the bycatch reduction technology selection phase and will continue to collect further data on seabird bycatch, and continue to secure the commitment of the fishers. The Applicant to date has managed to secure 9 fishers to continue with their use of the LEB from the bycatch reduction technology selection phase and has currently secured a further 13 participants for the non-breeding study 2022/2023 (22 vessels in total to date).

5.1.1.2 As has been identified within the results section of this report, wind speed can influence bycatch with the majority of the guillemot bycatch in the LEB net during high winds. Feedback from the fishers using the LEB noted that high wind speeds reduced the looming effect of the LEB and therefore reduced the efficiency of the method. The Applicant will therefore take the feedback onboard and consult the LEB developers (FishTek Marine) to understand if modifications can be made to reduce rotation speed and therefore increase the bycatch reduction even further than 24.9%. This will be factored into the planning and data review of the bycatch implementation during 2022/2023 and following the Secretary of State's DCO decision.

6 Conclusion

6.1.1.1 The Applicant has undertaken a significant amount of work in advancing the scientific and industry knowledge base of seabird bycatch reduction to inform the "without prejudice" compensation measure for Hornsea Four. This report has summarised the bycatch reduction technology selection phase undertaken during the 2021/2022 non-breeding season. This has been the first of its kind to use the LEB in an active fishery while also employing EM devices to monitor bycatch events.

6.1.1.2 The bycatch reduction technology selection phase has provided evidence that the LEB has and can reduce auk bycatch in active fisheries, and as a result can prevent the accidental death of a large number of seabirds in the UK each year. The Applicant has committed to using the LEBs on vessels during the non-breeding season for bycatch reduction implementation during 2022/2023 and if required as a compensation measure, which will collect further data and build upon this positive selection phase. This follows the approach as set out in Revision 4 of **B2.8.2: Compensation measures for Flamborough and Filey Coast (FFC) Special Protection Area (SPA): Guillemot and Razorbill Bycatch Reduction: Roadmap** (submitted at Deadline 5).

6.1.1.3 The Applicant is therefore confident that the LEB can be implemented as a compensation measure within active gillnet fisheries to compensate for impacts to guillemot and razorbill as a result of Hornsea Four.

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