Marine Futures
In partnership with

Cormorant Roosting in Offshore Wind Farms

An investigation into bird behaviour, conflicts, and mitigation measures at Burbo Bank.

Report 2: Environmental Distribution & Solution Design
28th April 2021

Project Details

Foreword

This report details the second phase of the research project *"Cormorant Roosting in Offshore Wind Farms: an investigation into bird behaviour, conflicts, and mitigation measures at Burbo Bank."* which was carried out in collaboration with the North West Wildlife Trusts, The Crown Estate, Ørsted, and Natural England as part of the Marine Futures Internship.

It follows on from a previous report titled *"Report 1: Initial Scoping Investigation",* which details cormorant roosting behaviour, the current situation at Burbo Bank, and guano mitigation measures trialled to date.

It is the intention of the authors that Report 1 and Report 2 should be read together, to provide full context to the issue and to properly reflect the structure of the project and its findings. Report 1 can be found under the following reference:

Clifford, D., and Mather, L., (2021a), 'Report 1: Initial Scoping Investigation', *Cormorant Roosting in Offshore Wind Farms – An Investigation into Bird Behaviour, Conflicts and Mitigation Measures at Burbo Bank*, Internal Ørsted report, Unpublished.

This report should be cited as:

Clifford, D., and Mather, L., (2021b), 'Report 2: Environmental Distribution & Solution Design', *Cormorant Roosting in Offshore Wind Farms – An Investigation into Bird Behaviour, Conflicts and Mitigation Measures at Burbo Bank*, Internal Ørsted report, Unpublished.

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The following report was produced as part of the Marine Futures Internship; a collaborative project between Natural England, Ørsted, The Crown Estate and the North West Wildlife Trusts, which is funded by The Crown Estate and managed by Cumbria Wildlife Trust. The project aims to improve communication and understanding between the offshore wind industry and marine conservation organisations.

Any questions regarding the Marine Futures Internship can be directed to livingseasnw@cumbriawildlifetrust.org.uk

Executive Summary

The following report details the second phase of the research project investigating the causes and impacts of cormorant roosting on offshore windfarms. This phase aims to define the environmental factors driving cormorant distribution in the wind farm and propose mitigation solutions to allow operational teams to tackle the issue of guano accumulation. The report is split into three sections:

Environmental Distribution Factors

In order to enable developers to predict which areas may be most affected by guano accumulation, and thereby prioritise resources, the following factors were investigated for their correlation with the intensity of cormorant presence per turbine at Burbo Bank:

1. Geology & Habitat: Burbo Bank lies in a region of infralittoral sand habitat, with sand, slightly gravelly sand, and gravelly muddy sand overlapping. The most populated areas lie at intersections of these habitats, near the large expanse of sand.
2. Fishing & Prey Availability: Burbo Bank lies near to Cefas harvest areas for bivalves and shellfish, which may attract some fish species which cormorants hunt. Fishing activity near the wind farm is relatively low, though this is not necessarily indicative of prey availability for seabirds.
3. Vessels & Disturbance: The more populated side of the wind farm coincides with a region of lower vessel density, compared to the north side where there is a major shipping lane nearby. Though cormorants are not easily disturbed, they may avoid areas of high vessel density due to reduced visibility or prey availability, noise pollution, or risk of collision.
4. Designated Areas: Burbo Banks sits within Liverpool Bay SPA, and many of the surrounding estuaries are also protected areas for birds or fish species. The population intensity in BBW01 correlates with proximity to these estuaries, however as the protected areas cover most of the coastline, it is unclear if this is a causal factor, or if the indicative factor is proximity to shore.

Development of Mitigation Measures

To assist development of mitigation measures, design workshops were carried out with key stakeholders at Burbo Bank, and with Ørsted's "Concept Line" team. The following solutions were discussed and proposed for trial:

1. Physical exclusion using mesh and wiring: the simplest method to prevent cormorant roosting is to remove the locations where the birds are able to perch, by putting wire mesh around the vertical railings and ladder cages, and high-tension wires along the top of the railings to make perching uncomfortable or impossible.
2. Alternative perches: for physical exclusion methods to work, alternative roosting must be available for the full population of cormorants using the site, as close as possible to the previous roost, e.g. on the same turbine, but jutting out to sea. The more attractive roosting options available, the less likely the birds are to work around the exclusion measures.
3. Laser deterrents around ladder and crane: when pointed at the ground and restricted to a small area, lasers could provide a safe and effective deterrent method, though offshore trials are limited and for the measure to work it must be very localised, with alternative perches nearby.
4. Further development of TP Clean Assist: The automated cleaning system designed by Ørsted's James Almond could also work as an effective deterrent method, as cormorants roost primarily to dry their wings, and so spraying water would make a roost less attractive. However, there are concerns around corrosion impacts on the turbine, so trials should be monitored closely.

Opportunities for Net Gain

Recommendations are made to enable developers to address cormorant roosting at the turbine design stage, through minimisation of potential roosts and improved monitoring methods.

Glossary of Abbreviations

BBW01	Burbo Bank Offshore Wind Farm	TP	Transition Piece
BBW02	Burbo Bank Extension		
MDE	The Crown Estate's Marine Data Exchange		
SPA	Special Protection Area		

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1 Introduction

Over recent years, Ørsted has received increasing reports of great cormorants (*Phalacrocorax carbo*) roosting at Burbo Bank Offshore Wind Farm (BBW01), located in Liverpool Bay. This has caused conflicts with operational activities, due to the accumulation of guano on turbine structures, and the associated health, safety, and welfare concerns for maintenance personnel. Various deterrents and guano mitigation measures have been trialed at the site; however, none have been effective at reducing conflicts in the long-term. This project was commissioned as part of the Marine Futures Internship, to understand the extent of the issue and identify possible solutions.

Cormorants roost in wind farms for a number of reasons, however it is considered that the primary influencing factors are the ability to extend their foraging range, and therefore reach more attractive feeding locations than they could from their onshore roosts, and to avoid disturbance from human activities and predators onshore, who pose a significant risk to their energy balance and survival. (Clifford and Mather 2021a, pages 24-27).

Discussions with cormorant experts during phase 1 of the present project indicated that cormorants preference for certain roost locations could be influenced by a number of factors, including water depth, as their dives are typically I the range 7-15m, seabed habitat, as though they are highly generalist hunters they do show preference for bottom-dwelling fish, and weather patterns; depending on the location and temperature, cormorants may wish to be exposed to more wind, in order to help their feathers to dry, or less wind, in order to conserve more body heat. (Clifford and Mather 2021a, pages 24-27).

Finally, as cormorants are anecdotally noted to be slightly “clumsy” fliers, requiring space to take off and preferring to use the effects of wind shear close to the water to conserve energy. It is therefore thought that they may show preference for the edges and corners of the wind farm, as they then have a “clear path” out, and the wind patterns are less complex than the region between turbines. (Clifford and Mather 2021a, pages 24-27). However, as with their hunting behaviour, cormorant roosting behaviour is greatly understudied, and little is known for sure about the reasons for choosing certain roosts.

The present report details the second phase of this project, comprising spatial analysis of various environmental factors to attempt to explain why some areas of the wind farm are more heavily used than others, and development of mitigation solutions to assist operational teams in excluding cormorants from some areas of the turbine, in order to better manage the guano accumulation. Recommendations are also made for future wind farm developers, to allow positive co-existence with cormorants and other seabirds to be considered at the design stage.

2 Environmental Distribution Factors

In order to prioritise resources and enable developers to predict which areas of their wind farm may be most affected by guano accumulation, analysis was carried out into the environmental factors correlating with the intensity of cormorant roosting. Based on the findings of Report 1 (Clifford and Mather, 2021a), the following factors were investigated for the area surrounding Burbo Bank, using third party data from The Crown Estate's Marine Data Exchange (Hereafter, MDE), and anecdotal evidence of the cormorant distribution within the wind farm (Clifford and Mather 2021a, pages 12-13).

1. Geology & Habitat
2. Fishing & Prey Availability
3. Vessels & Disturbance
4. Other Factors

A further high-level analysis of these factors was carried out using the findings of a survey investigation across Ørsted's European OWFs (NIRAS, 2021), for which a qualitative summary is provided.

2.1 Geology & Habitat

Figure 1 (page 9) shows the combined marine habitats in the area surrounding BBW01 (JNCC, 2007) compared to the cormorant distribution. The seabed sediment, bedrock type, and predicted habitat were also assessed; however, it was considered that this data set was most representative of the benthic habitats in this area.

BBW01 lies in a region of infralittoral sand habitat, with sand, slightly gravelly sand, and gravelly muddy sand overlapping. The most populated areas lie at intersections, near the large expanse of sand.

2.2 Fishing & Prey Availability

In order to predict the abundance of piscine prey in the area which the cormorants are likely to be foraging, the fishing intensity (MMO, (2017a): Fishing Activity in 2015 and MMO, (2018): Fishing Activity in 2016) and designated shellfish waters (CEFAS, (1990a): Bivalve Harvest Areas and CEFAS, (1990b): Shellfish Waters) were compared. Figure 2 (page 10) shows the location of BBW01 compared to the 2016 fishing intensity and the Cefas harvest areas.

BBW01 lies near to harvest areas for bivalves and shellfish, which may attract some fish species which cormorants hunt. Fishing activity near the wind farm is relatively low, though this is not necessarily indicative of prey availability for seabirds.

2.3 Vessels & Disturbance

Though cormorants are not highly sensitive to disturbance, vessel intensity in the areas surrounding the windfarm may impact where cormorants choose to roost and dive, due to factors such as visibility, noise, and collision risk. Figure 3 (page 11) shows the 2015 vessel density in the area surrounding BBW01 (MMO (2017b): Vessel Density Grid 2015).

There was found to be a major shipping lane into the Mersey estuary. The more populated side of the wind farm coincides with a region of lower vessel density, compared to higher vessel density on the north side. However, two of three highly populated turbines are within the high intensity shipping area, so this does not seem to be a strong exclusion factor.

The recreational sailing intensity (RYA, 2015) was also compared for this area, however this showed no significant correlation.

2.4 Designated Areas

As discussed in Report 1 (Clifford and Mather 2021a, pages 7-8 & 22-24), Burbo Bank sits with Liverpool Bay SPA, which is known to be an internationally important area for cormorants. Many of the surrounding estuaries are also designated as SPAs and SACs for various bird or fish species. Figure 4 shows the designated areas surrounding BBW01 (JNCC, 2020) as well as the Cefas Disposal Sites (Cefas, 2012) which have the potential to smother benthic habitats and thus reduce foraging attractiveness.

Based on this spatial analysis, the disposal sites seem to have no impact on cormorant distribution. The estuarine protected areas do correlate with the population intensity in BBW01, however as these regions cover most of the surrounding coastline, this may not be a causal factor.

2.5 Discussion of Environmental Factors

Based on the analysis carried out this section, it seems that the most populated areas are those with sandy infralittoral (or near-shore) habitat, with low vessel intensity in the surrounding waters, and proximity to coastlines or estuaries.

However, as the distribution data is based only on anecdotal evidence from a small sample size, it is difficult to draw meaningful conclusions at such a small scale.

A study carried out into the presence of cormorants across all of Ørsted's OWFs found that the sites with the most guano accumulation from Cormorants were Barrow, Burbo Bank, and Anholt (NIRAS, 2021). An analysis and comparison of the environmental factors at each of these sites was not within the scope of this project. However, based on the findings of this project (Clifford and Mather, 2021a; 2021b) it is thought the following conditions may occur at these sites and may contrast to conditions at less populated wind farms. This requires further investigation to prove:

- Shallow surrounding water, less than 15m deep
- Sandy benthic habitats, which would support common cormorant prey species
- Known onshore roosts nearby, and a historic increase in onshore disturbance
- Less than 10km from the shore

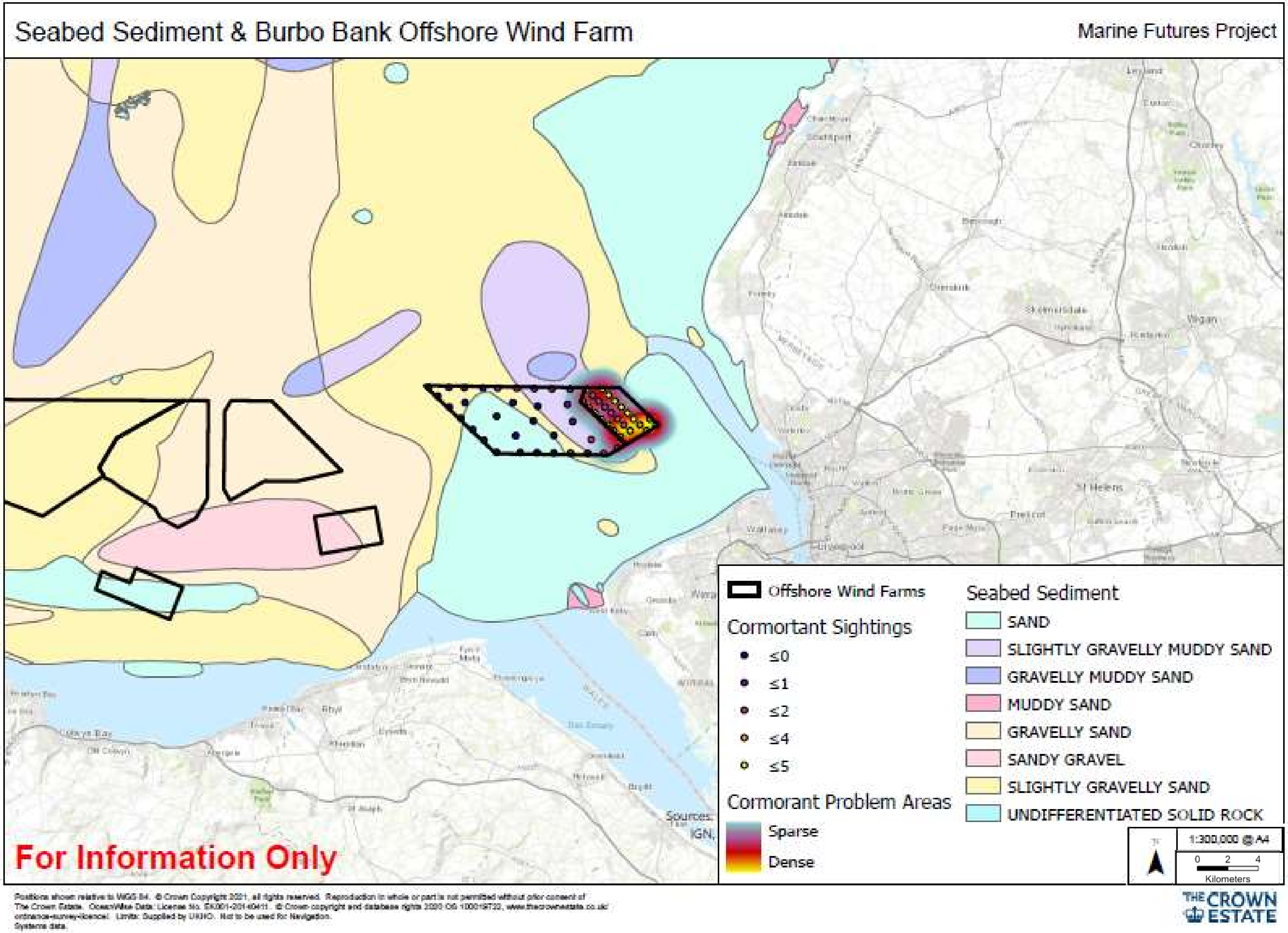

Figure 1 – Seabed Sediment in and around Burbo Bank Offshore Wind Farm.

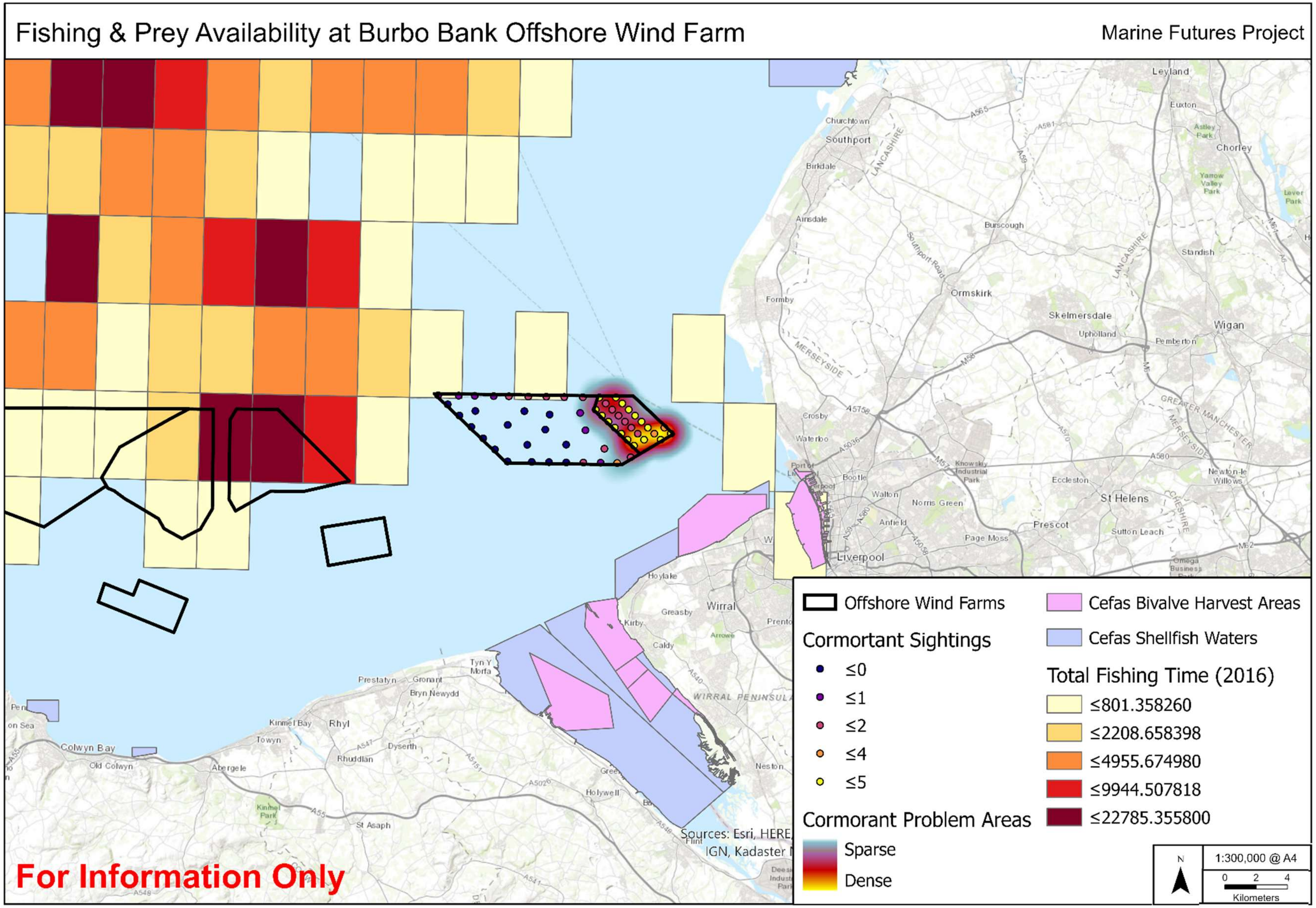

Figure 2 – Fishing Intensity and Prey Availability at Burbo Bank Offshore Wind Farm.

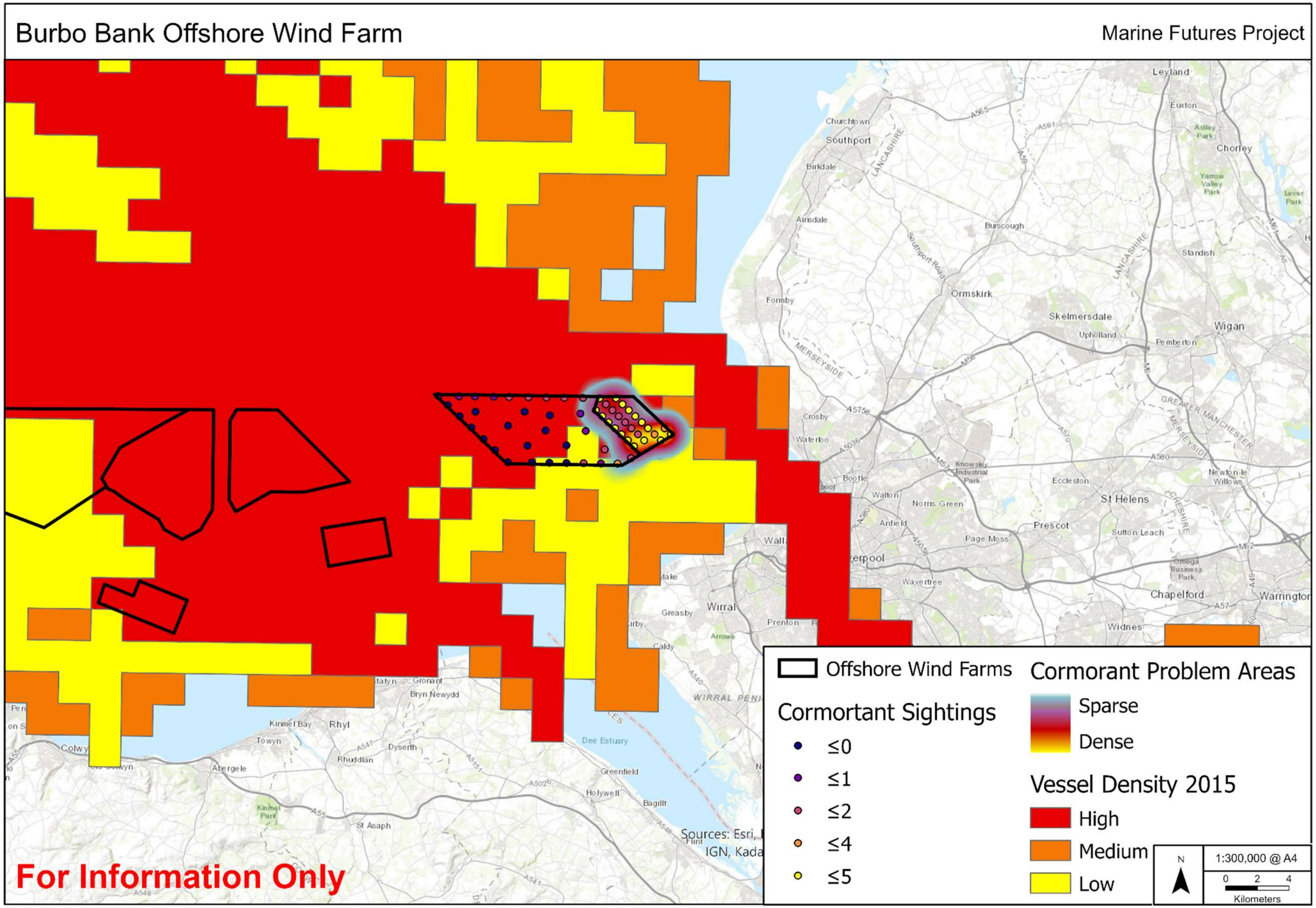

Figure 3 – Vessels and disturbance at Burbo Bank Offshore Wind Farm.

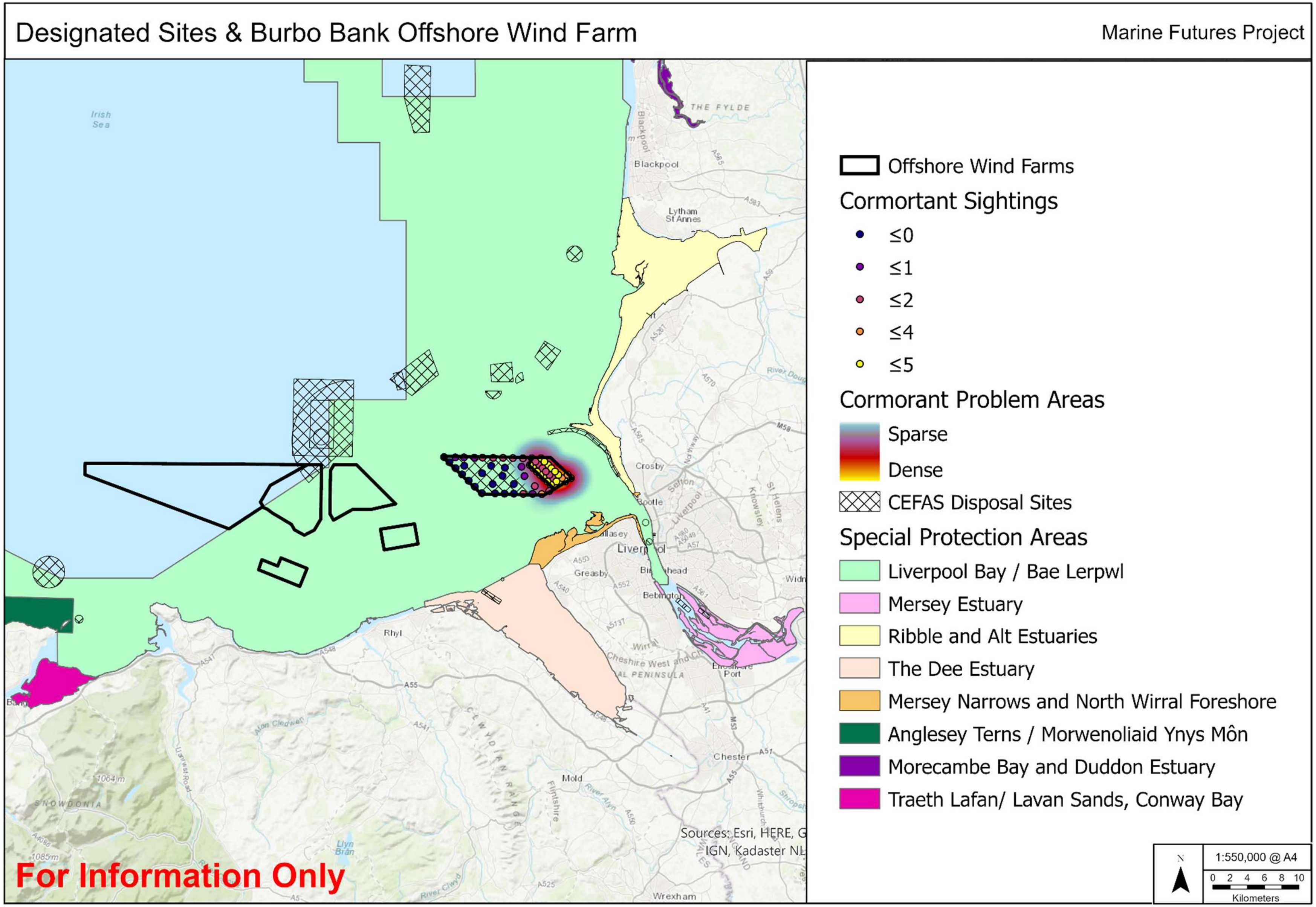

Figure 4 – Designated sites near Burbo Bank Offshore Wind Farm.

3 Development of Mitigation Measures

In order to ensure that appropriate, cost-effective, and environmentally sensitive solutions could be developed to address the issue of guano accumulation, a design and evaluation phase was carried out, exploring all of the possible options for cormorant exclusion and guano mitigation, and selecting solutions which could be worthy of trial. The following chapter details the work carried out in this phase, and the outcomes of collaborative workshops with key internal stakeholders.

3.1 The Brainstorming Stage

Prior to discussion and evaluation, a brainstorming stage was carried out, exploring solutions to address three key approaches to the issue: Physical Exclusion, Cormorant Deterrents, and Guano Mitigation. A sample of the solutions discussed in each is given below:

1. Physical Exclusion: this approach covers any solutions which aim to reduce cormorant presence by making it physically impossible or difficult for cormorants to roost thus reducing the number of available roosting locations in the target area, for example installing thin wires above railings to make it difficult for cormorants to hold on, netting around vertical structures such as the ladder cage to reduce the number of gaps in which a cormorant could sit, and solid obstacles above or in front of the roost locations which would obstruct the flight path, and thus make the roost less attractive.

2. Cormorant Deterrents: this approach covers any solutions which aim to scare the birds away and thus reduce the cormorant presence on the turbine. Cormorants are highly adaptable and will habituate to most deterrents based on this method, especially sound-based deterrents, and those based on flapping objects or predator-imitators, as the cormorants will quickly learn that they do not present a real threat. However, there are some possible to exceptions to this; moving lasers pointed at the ground were recommended by two consultees in Report 1 (Clifford and Mather, 2021a), though the evidence for their effectiveness was only anecdotal. Water sprays also have the potential to act as effective deterrents, as cormorants primarily roost to dry their wings, so if there is water spraying on the perches, they are likely to choose to roost somewhere else.

3. Guano Mitigation: this approach covers any solution which aims to remove the guano, or prevent the initial accumulation, rather than removing the cormorants. This approach has the highest likelihood of success, as the risk of cormorant habituation is removed, however it also has potential to be labour intensive or expensive to implement. Solutions discussed included the automated spray system “TP Clean Assist” developed by James Almond (Clifford and Mather 2021a, page 20) automated rotating brushes to sweep away the guano, and tarpaulin-style coverings of the TP structure to the guano from gathering. It was also discussed that prior to the reduction in Ørsted’s crew transfer fleet, cleaning was carried out by the vessel crew in between pick-ups and drop-offs, and this was observed to be highly effective at controlling the guano (Clifford and Mather 2021a, page 17)

The success of approaches 1 and 2 rely heavily on the provision of attractive alternative roost locations, as near as possible to the previous roost. For example, if additional perches are fixed onto the turbine at the same time as deterrents are implemented, there is much less chance of habituation, as the cormorants have less incentive to “work around” the measures.

Placing the alternative roosts as near as possible to the previous roost is important as cormorants return to the same roost location every year. In order to ensure there are no adverse effects on the cormorant population, the number of alternative roosts should be sufficient to support the current number of cormorants using the turbines (i.e. as many as possible). Consideration is needed for roost features which offer the same level of shelter, ease of escape (i.e. clear flight path out of the wind farm), and access to foraging grounds.

3.2 Stakeholder Workshops

Two stakeholder workshops were carried out to discuss potential issues and decide the best route forwards:

The first was an informal discussion with Ørsted's "Concept Line" team to summarise the findings of the initial phase of this study and compare to the findings of a separate study by NIRAS, commissioned to investigate the issue across all of Ørsted's OWFs (NIRAS, 2021):

- It was agreed by both parties that scarer deterrents are unlikely to work in the long-term, and a multi-pronged approach based on physical exclusion, deterrent, and mitigation was likely to be the most effective.
- Concept Line proposed a laser deterrent, which had been found to be effective by one of the papers investigated in the NIRAS study.
- Concerns were raised around the cost of installation and maintenance for TP Clean Assist, and the risk of additional corrosion to the turbine structures due to added presence of salt water.
- Concerns were also raised around the health and safety implications of a laser deterrent system, as well as the issue of interference with navigation lights and the possible implications for marine licensing.
- It was agreed that three solutions should be trialed; one based on physical exclusion using mesh and wiring, one using laser deterrents to trial their effectiveness, and one using TP Clean Assist to see if it could be economically and technically feasible. It was also proposed that the latter solutions are trialed in combination with the physical exclusion approach, to evaluate in-combination effects.

A second workshop was carried out in collaboration with Concept Line to propose these solutions to senior operations personnel for Burbo Bank, and discuss any potential issues:

- The physical exclusion method was considered a good low-cost solution, which would be worth independent trial to see if it could be effective without further measures.
- Concern was raised that alternative perches jutting out into the sea may get in the way of lifting operations to the sides of the TP.
- Pin-joint perches were proposed which could be folded down when near-turbine access was needed, then put up again when the operations were complete.
- More information was needed as to the maintenance and installation costs of the laser solution in order to evaluate it's potential.
- The concern of maintenance costs and corrosion risk for TP Clean Assist was discussed, and it was agreed that this would need approval from the Asset Integrity team.
- The recommended location for the trials was agreed to be 3-4 adjacent turbines along the south side of the wind farm, and this area is the most densely populated and, by implementing trials on several adjacent turbines, some insight should be gained into whether solutions will be as effective when they are applied across the whole OWF.

In additional to the recommended solutions, the potential for monitoring was discussed to both understand the effectiveness of the measures and to gather data for future studies into cormorant behaviour in OWFs. Though some filming options such as CCTV would be unfeasible in the offshore environment, solutions such as hard-wearing trail cameras or GoPro-style cameras (GoPro cameras in waterproof casings have been successfully used underwater in marine environments so are likely to be able to withstand the conditions on a turbine) fixed to the turbine were discussed as a possible monitoring approach.

3.3 Proposed Solutions

Based on the discussions above and the findings of Report 1, the following solutions are proposed for trial at Burbo Bank OWF:

3.3.1 Physical exclusion using mesh and wiring

Mesh wiring around the ladder cage and TP fencing, with anti-perching tension wires along the top and alternative perches (described below) to limit the number of cormorants roosting in areas which require regular access by technicians. This could mimic the effects of the “snow fencing” previously trialed with limited success (Clifford and Mather 2021a, page 19), but with a more durable material. Consideration should be made in the material choice for corrosion and durability. This solution should be designed and arranged to ensure that cormorants cannot get their feet under them or right next to them. A small mesh size (around 1.6cm) is thought to be advantageous to avoid large gaps which cormorants or smaller birds could become caught and entangled in and to prevent the birds putting their feet thought the mesh to perch. The mesh should be taught enough so that birds bounce off the netting unharmed.

3.3.2 Alternative perches

Alternative perches extending from the TP out over the water are recommended, as they will increase the effectiveness off the exclusion measures by reducing the incentive for the cormorants to find a way around them. Due to potential spatial conflicts with operational needs, for example boats needing to pull up close to the turbine, a pin-joint perch could be used to enable the perches to be folded down when needed and put back up when works are complete. To ensure success of this measure, it is essential the perches remain up and usable at any time when technicians are not on the TP, including overnight, even if works are to continue the next day.

The number of perches should be sufficient to support the current population of cormorants utilizing the TPs and thus reduce the incentive for birds to find alternative perches or ways around mitigation measures. Our literature review (Clifford and Mather, 2021a page 30) suggests that perches around 3cm thick may be preferentially used by the cormorants compared to wider perches.

3.3.3 Laser deterrents around ladder and crane

In addition to the physical deterrent proposed above, laser deterrents above the ladder to scare cormorants away from that specific area may be successful. This requires consideration of health and safety concerns for personnel approaching the turbine, as well as navigation concerns in terms of interference with other lights or lasers, but it has been recommended as a viable non-lethal solution to scare cormorants at several onshore locations and could be transferrable to the offshore environment.

Moving lasers are likely to be more successful than static ones; however, to increase the area in which the laser is shone should be confined to a small area, enabling cormorants to use nearby alternative perches. Enabling the use of alternative perches will enhance mitigation success but reducing the incentive to adapt to mitigation measures.

3.3.4 Further development of TP Clean Assist

In addition to the physical deterrent described above, a water spray system using pumped salt water is likely to be an effective mitigation measure. This could have the combined effect as a deterrent whilst turned on, as cormorants are primarily roosting to dry their wings, and as a cleaning method, as pressurised water could be used to regularly wash away guano and reduce accumulation.

If this system is used, it's important it is used appropriately, as not to negatively impact the cormorant population. This can easily be achieved by turning the system on in sections of the wind farm, rather than turning on every turbine at once, thus allowing the birds to move to an alternative perch site nearby.

There are concerns about the complexity of such system, implications of spraying pressurised salt water onto the structures for corrosion and structural integrity, and maintenance costs. A preliminary trial is proposed, where the corrosive impacts are monitored.

Opportunities for Net Gain

Bird's use of wind farms as a roosting site should be considered in the design, planning and consents stages of wind farm developments, as well as the decommissioning stage. It should be noted that the presence of cormorants utilizing a wind farm is not a problem for operations, however the accumulation of their guano on offshore wind farm structures can cause significant problems for operation and maintenance activities. The aim should therefore be to minimize guano accumulation.

It is not known exactly what determines whether a site will be used by cormorants, however close proximity to land is likely to be a factor. It is recommended that the industry adopts a standardized condition monitoring system in order to routinely frequently monitor and report the impact of guano accumulation and efficiency of mitigation measures. This would aid research of the guano accumulation over space and time, significantly aiding research to understand the factors influencing roost use and guano accumulation and the effectivity of mitigation measures implemented. While useful for individual developers, sharing knowledge of the above between different developers would significantly aid research and solution identification for the industry as a whole.

A simple system adapted from that recommended for normally unattended helideck pads (see Clifford and Mather, 2021a p.30) is recommended for condition monitoring (Table 1). This should be built into regular monitoring plans for the wind farms. Reports of birds roosting on turbines should also be recorded, with the number and species noted if possible.

Table 1

Score	Condition
1	Clean, no visible bird droppings.
2	Small, isolated bird droppings (<10% TP covered)
3	Noticeable, but not operationally problematic bird droppings (>10% TP covered)
4	Obvious frequent bird use, causing concern for operations (>20% TP covered)
5	Bird usage causing operational problems (>50% TP covered)
6	Totally obscured, operations not possible (>90% TP covered)

Designing wind farms with guano accumulation in mind can drastically help minimize conflicts between cormorants and operations and maintenance activities and allow opportunities for net gain. From our research, recommendations for TP design include:

1. Designing the TP base and intermediate platform (if required) to enable guano to fall though and into the sea. Grated TP bases are thought to significantly reduce problems of guano accumulation.
2. Use a hoist system as opposed to ladders and a ladder cage, to limit potential roost availability.
3. Remove/limit railings and use a clip in system for health and safety.
4. Limit flat surfaces as much as possible.
5. Where guano accumulation is suspected to be an issue (e.g. where nearby sites are affected), build mitigation measures into the TP design. This may include an automatic washing system.

4 Recommendations for Further Study

The following list summaries the recommendations from this research project (both report 1 (Clifford and Mather, 2021a) and this report):

4.1 Environmental Distribution Factors

Due to the availability and confidentiality of some third-party datasets, this study was unable to explore all the environmental factors which could influence cormorant distribution at Burbo Bank. Thus, the following factors are recommended for further investigation:

4.1.1 Water Depth: Cormorants are pursuit divers, and favour shallow coastal waters of 7-15m in depth (Clifford and Mather, 2021a).

4.1.2 Benthic and Fish Ecology: Though cormorants are highly generalist hunters, they favour bottom-dwelling fish such as plaice (Clifford and Mather, 2021a). Some analysis of this factor was carried out based on fishing activity, however a more reliable approach would be to use the data from benthic monitoring in post-construction surveys to compare the presence of fish species.

4.1.3 Indicator Species: As cormorants are reasonably common, they are not well-studied and there is insufficient data available on their distribution outside of the breeding season. As they spend significant portions of their time either hunting underwater or roosting on land, they are often missed by aerial seabird surveys. However the European Shag *(Phalacrocorax aristotelis)* is known to have a broadly similar ecology in coastal regions, and has also been shown to be attracted to offshore wind farms (Clifford and Mather, 2021a), so could be used to inform a high-level investigation of likely cormorant distribution in European OWFs. It is worth noting however, that *P. aristotelis* is not present in Liverpool Bay, so this approach cannot be adopted for investigations at Burbo Bank.

4.1.4 A study carried out into the presence of cormorants across all of Ørsted's OWFs found that the sites with the most guano accumulation from Cormorants were Barrow, Burbo Bank, and Anholt (NIRAS, 2021). An analysis and comparison of the environmental factors at each of these sites was not within the scope of this project. However, based on the findings of this project (Clifford and Mather, 2021a; 2021b) it is thought the following conditions may occur at these sites and may contrast to conditions at less populated wind farms. This requires further investigation to prove:

- Shallow surrounding water, less than 15m deep
- Sandy benthic habitats, which would support common cormorant prey species
- Known onshore roosts nearby, and a historic increase in onshore disturbance
- Less than 10km from the shore

4.2 Bird Use of Burbo Bank

4.2.1 Our data of the distribution of guano, and therefore birds, in Burbo Bank was based on anecdotal evidence from the site's technicians. While this provided useful data, a full monitoring survey to quantitatively determine how many birds are using the site and their distribution would be beneficial. This would also greatly benefit any further analysis of environmental factors which may influence wind farm use and cormorant distribution.

4.2.2 A telemetry tracking study, attaching satellite tags to cormorants would be beneficial to increase knowledge of the species, local movement and behaviours, including how the birds use the wind farm and whether they stay within the wind farm area or forage elsewhere. This would aid understanding of the bird's behaviour and interactions with the wind farm and wider environment.

4.2.3 Furthermore, there is limited data available on the number of cormorants utilising Liverpool Bay Special Protection Area, following a suitable methodology for cormorants (see report one section 2.5). Further data may be available from Ørsted and the British Trust for Ornithology (BTO), however, due to the limited scope of this research, these resources have not been explored. Further ornithological surveys of cormorants utilising the SPA would be beneficial.

4.3 Mitigation Measures

Limited data was available for the effectivity of mitigation measures on cormorants (with many studies focusing on gull species). Species-specific evaluations are important for determining the effectivity of mitigation measures and thus their success.

A monitoring study with cameras places on the TP to determine how the birds get around mitigation measures would aid mitigation measure design and placement.

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