Marine Futures
In partnership with

Cormorant Roosting in Offshore Wind Farms

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

Report 1: Initial Scoping Investigation
11th February 2021

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Project Details

Foreword

This report details the first 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 acts as the prelude to a second report titled “Report 2: Environmental Distribution & Solutin Design”*,* which details the environmental factors which could be influencing cormorant distribution within the wind farm, the steps taken to develop potential solutions, which have been handed over to Ørsted’s Concept Line team for trial in 2021, and recommendations for future developments to minimise conflicts with cormorants and other seabirds.

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 2 can be found under the following reference:

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Farms – An Investigation into Bird Behaviour, Conflicts and Mitigation Measures at Burbo Bank*, Internal Ørsted report, Unpublished.

This report should be cited as:

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Farms – An Investigation into Bird Behaviour, Conflicts and Mitigation Measures at Burbo Bank*, Internal Ørsted report, Unpublished.

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Acknowledgements

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

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 trialled 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. The following report details the outcomes of an initial scoping phase, in which interviews were conducted with the Burbo Bank site team, and research was undertaken into cormorant behaviour, seabird interactions with offshore wind farms, cormorant deterrents, artificial roost provisioning and guano mitigation measures.

Interviews with the BBW01 site team found that guano accumulation has been steadily increasing since the cormorants colonised the site, regularly reaching unacceptable levels. The accumulation is most significant during winter, with September to March quoted as the worst period, during which time the cormorants are thought to be present on site 24 hours per day. Various deterrent methods have been trialled, including bird spikes, ultrasonic sounders, and mobile rollers, however the birds habituated to these measures quickly, and none had a lasting impact. Turbine cleaning is carried out by an external contractor every 1-2 months during the winter season, however discussions indicated that at peak times, the guano accumulation returns to unacceptable levels within a couple of weeks.

Literature reviews and expert consultation indicated that cormorants in particular are attracted to offshore wind farms, with key reasons quoted as lack of disturbance, proximity to food sources and the provision of platforms for wing drying, thus extending their foraging range and providing energetic benefits. Cormorants were described as pursuit-diving piscivorous species, with highly generalist feeding patterns, though plaice, flounder, and other bottom-dwelling fish were noted as key prey species. Expert consultees quoted a foraging range of 7-40km, and typical dive depth around 10m, which supported literature estimations. Liverpool Bay is a Special Protection Area with cormorants included within the site's waterbird assemblage feature. The site is noted to be important for great cormorants, highlighting the need for any mitigation measures to consider the welfare of the cormorant population.

Literature reviews of deterrents, alternative roost site provision and guano removal mitigation measures were conducted. "Scarer" deterrents were found to be ineffective long-term for cormorants, due to habituation, however water jets may be more effective. It was concluded that permanently removing birds from a site should be regarded as an unrealistic objective. Floating and platform artificial roost sites are used by cormorants, with the availability of other roosts and factors such as the height and material influencing use. A review of guano mitigation methods on offshore helidecks indicated unattended sites were affected by guano more than attended sites. A washing system and the use of tarpaulin were the most effective methods to manage guano accumulation on these structures.

Research goals are proposed for the next phase of this project, covering three key areas: (1) environmental factors affecting cormorant distribution, to be investigated using ArcGIS Pro software and The Crown Estate's Marine Data Exchange; (2) novel mitigation measures, to be investigated through a divergent design process, using functional criteria derived from the initial scoping phase; and (3) opportunities for net gain, resulting in recommendations for future offshore developments to encourage co-location in a way which benefits cormorants and minimises conflicts with on-site maintenance teams.

Glossary of Abbreviations

BBW01	Burbo Bank Offshore Wind Farm	PPE	Personal Protective Equipment
BBW02	Burbo Bank Extension	SPA	Special Protection Area
NUI	Normally Unattended Installations	TP	Transition Piece
OWF	Offshore Wind Farm	WeBS	Wetland Bird Survey

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1 Introduction and Site Context

1.1 Burbo Bank Offshore Wind Farm

Burbo Bank Offshore Wind Farm 1 (BBW01) is located on Burbo Flats in Liverpool Bay at the mouth of the River Mersey in the UK (Figure 1). BBW01 occupies approximately 10km^2 of seabed. It's closest points to land are 6.4km from the Sefton coast and 7.2km from the north Wirral coast. BBW01 consists of 25 x 3.6MW wind turbine generators (hereafter, 'turbines') with a total generating capacity of 90MW.
The turbine arrays are connected to one another by sub-sea cables, and the electricity generated is exported to a conversion station on land at Mockbeggar Wharf, Wirral, via three export cables from turbines BB12, BB22, and BB31 at the southern end of the wind farm.

Burbo Bank was part of The Crown Estate's "Round 1" development lease; the first large scale leasing of the seabed in the UK for the development of offshore wind farms in the UK. An Environmental Statement for BBW01 was compiled between 2001 and 2002 and the wind farm received consent in July 2003, under the Food and Environment Protection Act 1985 (FEPA). Construction began in 2006 with the installation of monopile foundations, followed by cable works in 2006-2007, and the placement of the wind turbine generators in spring 2007. The site became fully operational in August 2007.

Burbo Bank Extension Offshore Wind Farm (BBW02), which lies adjacent to BBW01 to the west, became operational in 2017. Both sites were constructed and are operated by Ørsted (formerly DONG Energy Limited).

Operation and maintenance activities within the sites include guano and algae removal and re-painting of turbines, anode replacement, ladder repair or replacement, major component exchanges and cable repair.

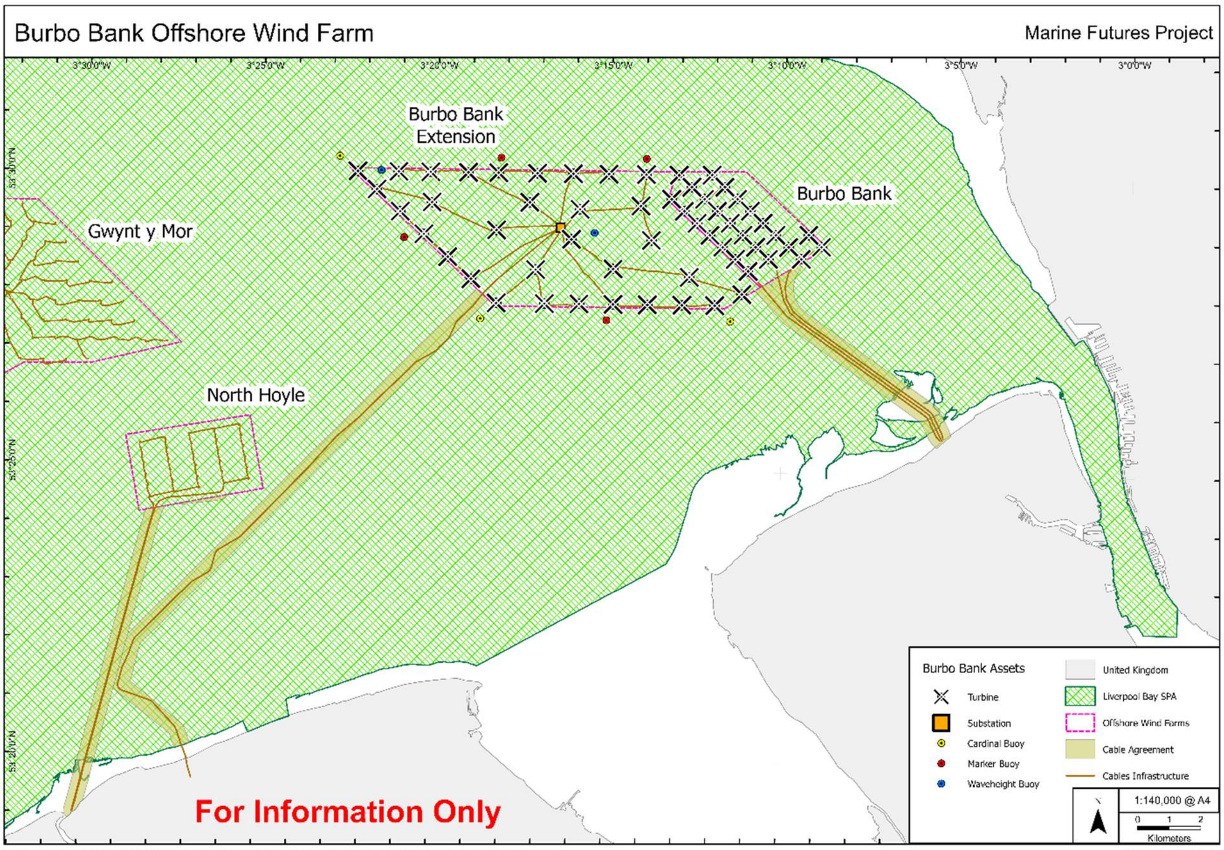

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Figure 1: Burbo Bank and Bubro Bank Extension Offshore Wind Farms.

1.2 Liverpool Bay SPA

Liverpool Bay Special Protection Area (SPA) is an internationally important area for marine birds, designated under the European Union Directive 79/409 on the Conservation of Wild Birds, also known as the ‘Birds Directive’. It covers an area of around 2,528km^2 in the east of the Irish Sea, bordering the coastlines of north-west England and north Wales, running as a broad arc from Morecambe Bay in the north to the east coast of Anglesey (Figure 2).

The site is classified for the protection of red-throated diver (*Gavia stellata*), common scoter (*Melanitta nigra*), and little gull (*Hydrocoloeus minutus*) in the non-breeding season; as well as common tern (*Sterna hirundo*) and little tern (*Sterna albifrons*) in the breeding season, and an internationally important waterbird assemblage (including great cormorants (*Phalacrocorax carbo*, hereafter ‘cormorants’ unless stated otherwise).

The site was classified as a SPA in August 2010. In November 2016, formal consultation on the addition of three new features and associated boundary amendments began, before the site was reclassified to include these in October 2017 (JNCC, 2020).

Cormorants are thought to be present in internationally significant numbers within the SPA. Several organistions have campaigned for their protection as a separate feature of the site, rather than being included in the “waterbird assemblage”, in order to reflect the importance of the site. However, as cormorants spend little time on the sea surface, aerial surveys often underrepresent their true numbers, and there is limited data available from alternative survey methodologies to determine the true population for SPA assessments. This topic is discussed further in section **Error! Reference source not found.**.

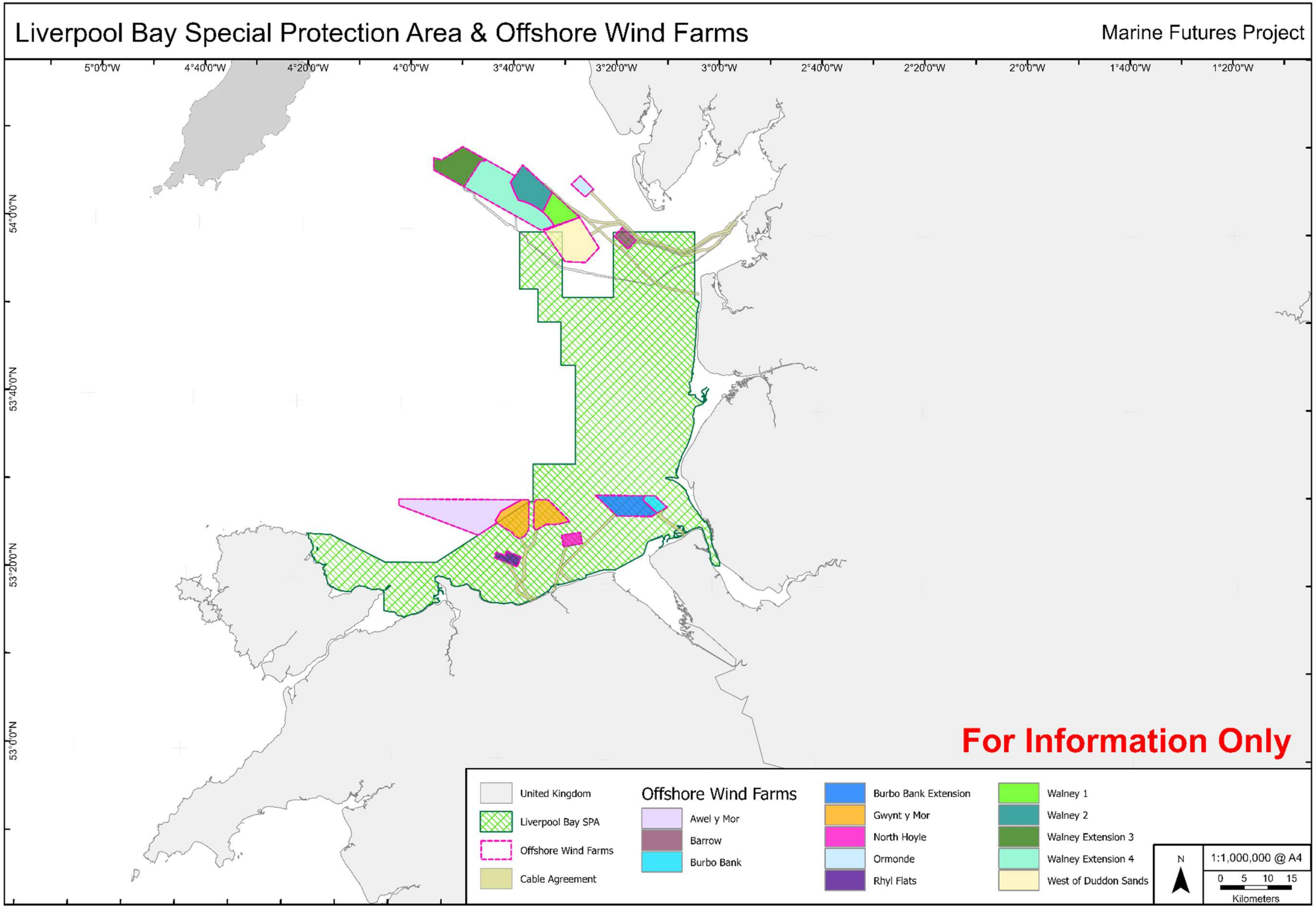

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Figure 2: Liverpool Bay Special Protection Area and Offshore Wind Farms.

1.3 Project Plan/Scope

In November 2020, following reports and growing concerns about the operational impacts of seabird guano at Burbo Bank Offshore Windfarm, Ørsted commissioned a project to investigate the cormorant population of Liverpool Bay, conflicts with Burbo Bank Offshore Wind Farm and mitigation measures for guano accumulation problems.

The overarching aims of this project are to investigate;

1. Can green infrastructure for preferential roosting be used to encourage cormorants to roost elsewhere?
2. What other methods may be effective in deterring the cormorants or mitigating the effects of guano accumulation?
3. What environmental factors are determining the distribution of this issue, and how could this knowledge be used to tackle it?

This report documents the findings from the first stage of this project. The aims of this research phase were:

1) To conduct initial research to understand and document the operational conflicts and guano mitigation measures trailed at Burbo Bank to date.
2) To review cormorant behaviour and interactions with offshore structures.
3) To review possible mitigation measures, and their success in managing guano accumulation on other offshore structures.
4) To identify possible novel solutions to minimise conflicts.

The research was conducted primarily by semi-formal interviews with the operational teams at Burbo Bank Offshore Wind Farm, as well as informal interviews with external cormorant experts, and a review of the available published literature on the topics of cormorant behaviour, seabirds and offshore wind farms, cormorant deterrent methods, and novel guano mitigation measures.

2 Scoping Interviews

In order to understand the interactions between Burbo Bank Offshore Wind Farm and cormorants, semi-structured interviews were conducted between December 2020 and January 2021 with six staff who work at BBW01/BBW02. The aim of these interviews was to gather information on any conflicts between the birds and site operations, cormorant behavior and mitigation measures trialled to date within the site. The following sections outline the main findings from these discussions.

The questions used for these interviews are detailed in Appendix A.

2.1 Conflicts with Operational Activities

The interviewees discussed the conflicts between the cormorants and operations of the site, primarily the issue of guano build on the turbine platforms. The following section details the extent of this issue.

2.1.1 Overview of the Problem

All interviewees stated that the birds within Burbo Bank are causing a problem due to the accumulation of guano (and some dead/regurgitated fish). All interviewees stated that great cormorants (*Phalacrocorax carbo*) were the main species causing this problem, however gulls were also recognised as using the turbine structures. Specific gull species were not identified.

Interviewees rated the severity of the problem between one, meaning no impact, and five, meaning a severe impact. The mean score of these responses is 4.5 (0.83 standard deviation) with some interviewees also giving a lower score of 2 during the summertime or solely for the impact on operations. The main concerns of the interviewees are noted in the following sections.

The figure below (Figure 3) shows the accumulation of guano on the transition piece platform, and intermediate ladder platform. It was reported by several interviewees that guano builds up to an intolerable level in these locations as little as two weeks after cleaning.

Figure 3: Guano Accumulation on Turbine Platforms, kindly provided by Lee Rolleston, Ørsted.

2.1.2 Employee Welfare Considerations

All the interviewees mentioned the negative impact of guano on the working environment for staff, with technicians getting guano on their clothes and tools, as well as taking contaminated items home or off site with them. This presents a welfare issue for the employees, with reduced team morale and a feeling of neglect by management, leading to refusal or unwillingness to work in conditions where there are large accumulations of guano.

Staff are currently encouraged to wear Personal Protective Equipment (PPE) in the form of disposable overshoes, gloves and overalls, however it was noted that staff are not keen to wear these as it inhibits their climbing ability.

2.1.3 Employee Health and Safety Considerations

The guano has reportedly been tested for toxicity, with one interviewee stating the guano is of a lower toxicity than pigeon guano. However, on dry days the guano becomes airborne as a solid powder, which can be breathed in and is treated by the site as a serious respiratory risk.

The actual severity of the inhalation risk reported varied between interviewees. An increased risk of slips and trips were referenced by all interviewees, particularly after rain. One interviewee quoted that 12 cases of slips, trips, and falls reported in 2018 were related to bird guano, including some resulting in injury. Some reports of sickness were mentioned, however these were thought to be rare and it is almost impossible to link these directly to the bird guano. A health risk to the technicians families and/or housemates was also mentioned due to the transfer of guano on the technicians and their possessions.

2.1.4 Other Operational Impacts

None of the interviewees thought the birds had any other negative impacts on the site other than guano accumulation.

None of the interviewees thought the guano had any effect on equipment except simply covering surfaces. The guano was not thought to be having a corrosive effect on the wind turbine structures, and one interviewee even noted that it may be providing some protection from ultraviolet rays.

While the Burbo Bank technicians were not aware of any corrosion issues arising from the guano, several studies have shown that bird guano can degrade the coating systems via chemical mechanisms, mainly due to hydrolytic reactions from a catalytic effect of the enzymatic structure of guano or pancreatin. Such degradation can lead to conditions that allow corrosion to initiate earlier than expected (Price and Figueira, 2017). Appendix C shows corrosion occurring at Burbo Bank, thus, it cannot be ruled out that guano is not causing enhanced corrosion, however as none of the interviewees reported this, it’s unlikely to be occurring to an extent that warrants any major concerns.

2.1.5 Turbine Design Factors

BBW01 has solid transition piece platforms, which was mentioned as contributing to the problem of guano build up. Transition pieces are generally designed with a grated base at newer wind farms, which should help reduce the problem at other sites. BBW02 has a grated intermediate platform (but a solid concrete TP level platform), which may partially explain why guano accumulation is reported as less of an issue compared to BBW01.

Birds roosting on turbines should be considered in the design, planning and consents stages of wind farm developments, as well as the decommissioning stage.

2.2 Roosting at Burbo Bank

The six interviewees were also asked questions about the abundance and distribution of cormorants/guano accumulation, as well as behavioral observations of the birds (questions detailed in Appendix A). The following section outlines the main findings from these discussions.

2.2.1 Colonisation of BBW01

No guano issues were reported during the construction phase of BBW01. Whilst some of the interviewees were not working at the site when the cormorants first started roosting there, those who were present reported that cormorants started using the site following a four-week power outage, during which all the turbines were stationary. The date cited for this outage varied between 2008 and 2009 (two respondents).

It's an interesting thought that the cormorants colonised Burbo Bank when all the turbines were stationary during a power outage. Smallwood et al., (2009) found that 22% of bird (various species, not including cormorants) perching time was spent on turbines that were not operational (compared to 1% on working turbines) at Altamont Pass Wind Resource Area, suggesting birds may be more likely to colonise a site if all the turbines are stationary. Similarly, findings from offshore helidecks have shown that Normally Unattended Installations (NUI) are affected by guano accumulation more than manned installations, suggesting human presence may be a factor influencing colonisation.

Interestingly, Liverpool Bay was highlighted as an area where guano accumulation was a problem for NUI, with one helicopter operator serving Liverpool Bay and Morecambe Bay reporting the guano problem arises when the interval between visits is extended to about 4 weeks. BHP Petroleum, operating three manned and three unmanned assets in Liverpool Bay highlighted that the manned installations are 'trouble free' however the three NUI were particularly effected, reporting a coverage of 90% of the helidecks at times (Health and Safety Executive, 2001). Cormorants are known to be attracted to wind turbines (see 3.3) and bird surveys at other Offshore Wind Farm (OWF) sites have shown an increase in cormorant and large gull species abundance (e.g. within one operational year at Robin Rigg; MMO, 2014).

One interviewee stated that before the outage, the cormorants fished from a large sand bank near the site and avoided the wind farm. A few interviewees mentioned the artificial reef effect of turbines may be attracting the birds to the site. One interviewee also mentioned that the site is not very busy compared to other wind farms, so there is less disturbance by boats meaning the birds have time to congregate.

Several interviewees noted that cormorant numbers/guano accumulation has increased over the years since the birds colonised the site. However there is significant variation in the number of birds reported by the interviewees, ranging from 7 to 40 per turbine, as shown in Table 1.

Table 1 – Number of cormorants reported by interviewees, per turbine.

Interviewee	1	2	3	4	5	6
Number of cormorants reported per turbine	15 – 20	20 – 30	10 – 15	7 -10	Up to 40	Initially 6-12. Now up to 40

2.2.2 Seasonal and Temporal Variation

While it is recognised that staff do not work in the wind farm at night (typically arriving at 7:00 and leaving around 17:00), the cormorants were thought to occupy the wind farm 24 hours a day, seven days a week, as they are present at both the start and end of the working day.

While one interviewee stated that the cormorants are more common in summer than winter, all other interviewees stated the cormorants are present and the guano accumulation was worst in BBW01 between September to March each year. One interviewee stated October to January as the period during which problems with guano accumulation are most severe, noting that some cormorants are present all year round.

The same turbines are thought to be the most commonly used every year. No nests were reported within the wind farm by any interviewees.

These reports mirror known seasonal peaks of the population from bird surveys (see section 3.1).

2.2.3 Distribution within BBW01 and BBW02

The interviewees mainly reported cormorants roosting on the turbines around the edges of BBW01, with the south-east and north-west corners being cited as particular hotspots for guano accumulation. Although all of the turbines are thought to be used by the birds, the centre of the site is thought to be used less frequently by the cormorants as this area is impacted by guano much less than the turbines around the edges of the site.

Following the construction of BBW02, the cormorants are reported spreading into BBW02, using the turbines adjacent to BBW01, however, the consensus was that they have not spread much into this area. BBW02 has a grated intermediate platform (but a solid concrete TP level platform), which may partially explain why guano is reported as less of an issue here.

Figure 4 shows where cormorants were most commonly reported within BBW01 and BBW02 by the interviewees. Details of the methodology for producing this map can be found in Appendix B. It should be noted that this map is made from solely from anecdotal evidence.
The interviewees stated that these locations were not thought to be subject to any temporal changes.

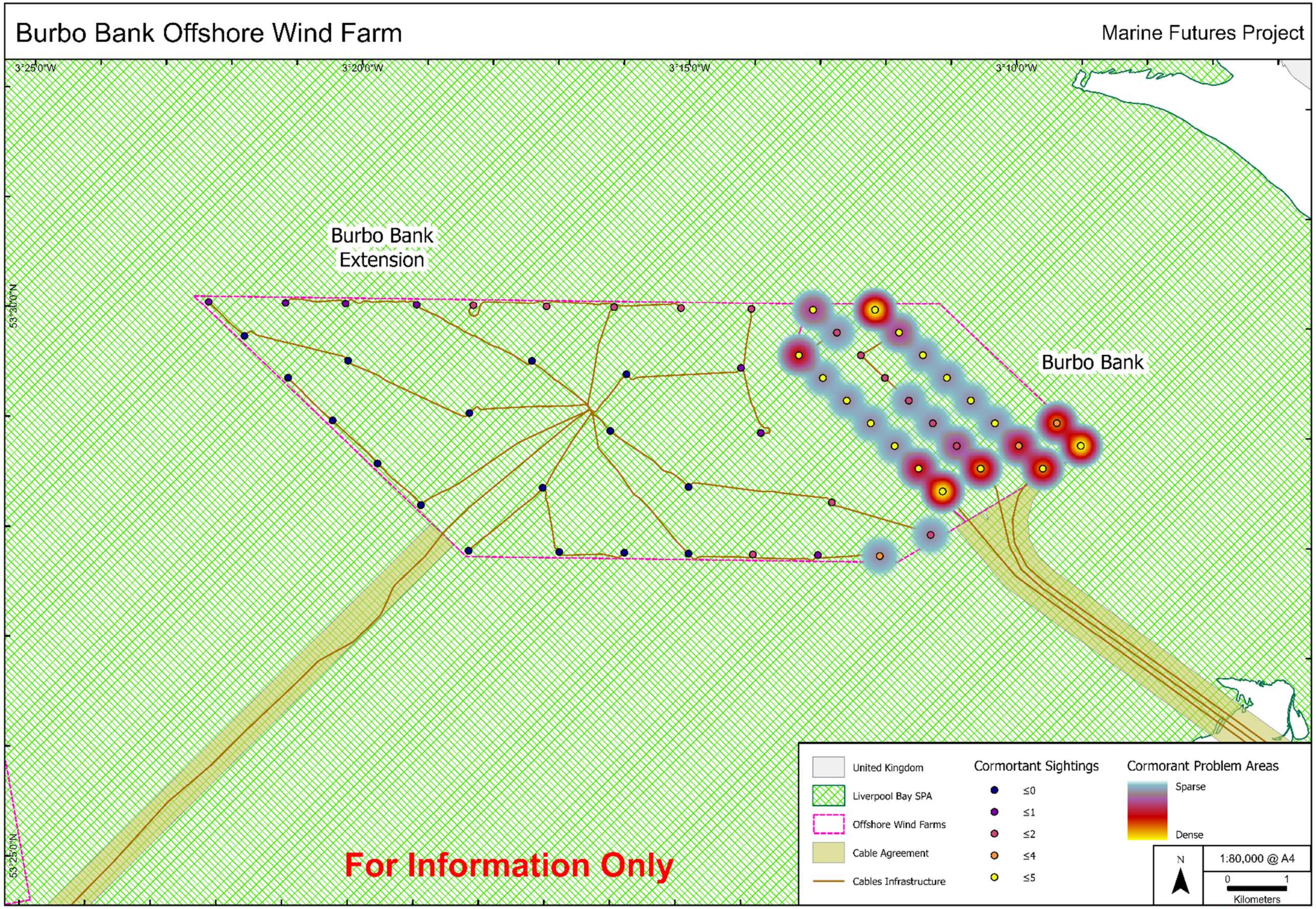

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Figure 4: BBW01 and BBW02 Site Staff Cormorant Observations (5 staff). Circles indicate turbine locations, colour coded by the number of interviewees who stated they have seen cormorants on that particular turbine, while the heatmap indicates the number of interviewees who stated the particular turbine was a problem area for guano accumulation.

2.2.4 Available Roosting Sites on the Turbine Structure

There are many locations on the turbines for cormorants to roost. The list of locations stated by interviewees included the climbing section of the transition piece, the rails, and the crane case.

The cormorants were thought to roost 360 degrees around the turbine, with no area more often used than any other. However, it was noted that technicians only need to access one side of the turbine, so roosting behaviour may be more noticeable here.

Figure 5 shows a the transition piece, with commonly reported roosting locations marked.

Figure 5: Turbine Transition Piece with observed roost locations labelled, picture kindly provided by John Vernon, Ørsted.

2.2.5 Behavioural Observations

Interviewees reported that the cormorants typically fly away when the boat vessel arrives. Discussions indicated that the cormorants may be becoming more habituated to human presence, with reports of the birds taking longer to move off when the boat arrives, sometimes staying on the turbines as staff climb up to the transition piece until people are as close as 6ft (1.83m) away.

When displaced by human presence, the birds were reported moving to nearby turbines. One interviewee reported the cormorants stay in pairs and follow each other, flying in a large sweeping circle before landing on a turbine. The cormorants were reported as returning to their original roost site following disturbance.

Cormorants have been observed foraging, sitting, diving and wing spreading within the wind farm, a common behaviour used for drying their wings following a dive (Figure 6). Many interviewees stated that the cormorants eat mussels from base of the turbine, and reported finding shells on the turbine transition piece platform, however, given cormorant's bill morphology and ecology it is thought these are more likely to be from gull species. There is a possibility cormorants could be catching plaice and flounder, who may in turn have eaten mussels and hence these may be regurgitated by the cormorants, although this is unlikely (Booth, C., 2020).

It was clear from discussions, that although some key behavioural characteristics were noted, further investigation would be needed to build up a clear picture. As the technicians are working, they have limited time to observe the birds.

Figure 6: Cormorant displaying wing spreading behaviour, Photograph © John Bridges.

2.3 Current Mitigation Measures

The interviewees were also asked about mitigation measures that have been trialled at BBW01 to reduce the negative impact of guano accumulation on operations and staff. The following section outlines the measures trialled and the reported effectivity of such measures.

2.3.1 Turbine Cleaning Regime

When the guano initially became a problem, the turbines were cleaned by the site technicians using a seawater jet wash and full PPE, including a sealed mask. However, this was not deemed a sustainable mitigation measure in the long term, as it does not fall within the accepted scope of the maintenance technician's role.

Cleaning was then taken over by the crew on one of the site's two crew transfer vessels, who would clean the affected turbines between their other work and received an additional payment for providing this service. This worked well, as they were able to react quickly to cleaning requests, and the guano did not build up over long periods. One interviewee reported that this method had a positive impact on morale, as staff could see that their concerns were being dealt with.

However, after about one year, Burbo Bank reduced to one boat for crew transfers for whole site and thus the contract with this particular vessel was terminated. As there is now only one boat there is no time for turbine cleaning between crew transfers and cleaning services are not included in the contract for this vessel.

At present, a specialist marine cleaning contractor (Wildcat Marine) is recruited from Barrow-in-Furness, Cumbria, to wash the turbine access points when requested by the site. This involves two crew on a boat and two on the turbine using a pressure washer and scrubbing brush to remove the guano. Cleaners wear a head mask and overalls. It takes between one to two hours to clean one turbine, meaning the contractors can wash around seven or eight turbines per day.

The services of Wildcat Marine are requested around four times per year, approximately once per month through winter. It was noted however that it only takes a few weeks for the turbines to go from clean to an unacceptable level of guano accumulation. The first clean after summer was quoted as being the most difficult.

The Site Manager stated that the cost of cleaning the turbines at this rate is around £100,000 per year, and over £500,000 has been spent to date, as of December 2020. Table 1 details a breakdown of these costs. The cost to washing 25 turbines (totalling £54,870.00), three times a year, amounts to a total of £164,610.00 per year.

Cleaning activities are licenced by the Marine Management Organisation (current case ref: MLA/2016/00148). Due to the cost of this cleaning method, Ørsted are looking to move away from this cleaning programme.

Table 1: Cost of the Current Cleaning Strategy at BBW01 and BBW02 (kindly provided by James Almond, Ørsted).

Cost for Cleaning 35 WTGs at BBW01 & BBW02	
Vessel	Cost
Hire Costs (28 days)	£ 41,720.00
Harbour Dues	£ 1,078.00
Lodging	£ 2,800.00
Fuel	£ 7,700.00
Overall cost (28 days)	£ 53,298.00
OPS	Cost
Overall cost (28 days)	£ 23,520.00
Cost Per Turbine	**£ 2,194.80**
Total	**£ 76,818.00**

2.3.2 Mitigation Methods Trialled

As of December 2020, around £200,000 had been spent on mitigation measures in an attempt to prevent the birds from excreting on the turbines. Details of the mitigation measures trialled are outlined in Table 2.

Figure 7 shows the plastic tubing/wire and rollers trialled. The interviewee who designed these suggested that factors such as the size of rollers, the exact positioning of the wire and the wire tension may have an influence of the effectivity of this measure. Changing the configuration of the conduit piping so it’s threaded on the wire vertically, standing up right was also suggested as a method to make it impossible for the birds to stand on it.

An automated cleaning device, named ‘TP Clean Assist’ or ‘Clean Assist’ for short, has been partially designed and trialled by one of the technicians on site. This involves a pump and spray nozzles which are timed to spray sea water over the transition piece for approximately one hour per day. Figure 8 and Figure 9 show the design of this system, with the key components labelled.

A control system has been developed for this TP Clean Assist, which will allow for cleaning every night during the high tide, however some assistance is needed with mechanical design, due to concerns about mounting, stability, pump capacity and the number of potentially breakable parts. This is an area for which wider support may be needed, as the technician in question has very limited time to spend on this project.

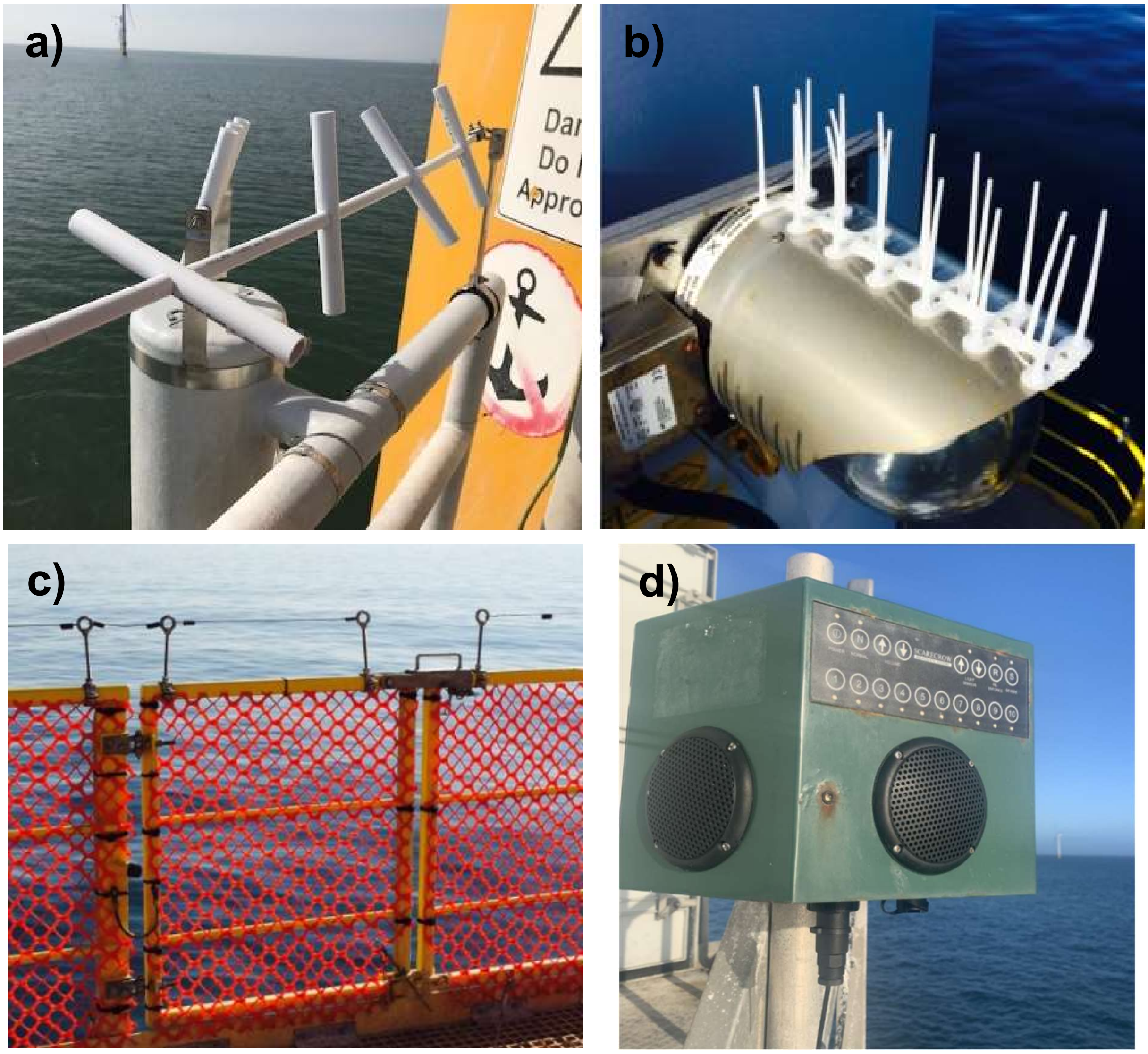
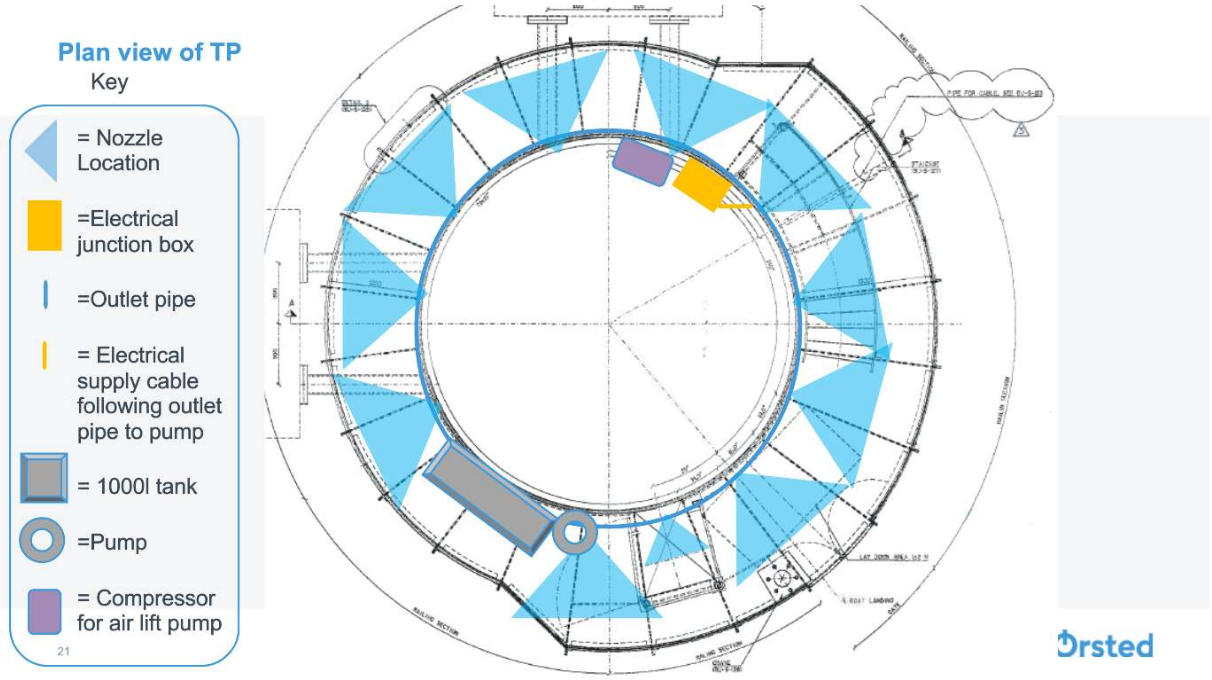


Figure 7: Examples of previous mitigation measures trialled at Ørsted's wind farms; left to right a) wire rollers, b) bird spikes, c) snow fencing (photos kindly provided by Environment & Consents team) and d) ultrasonic sounder device (photo kindly provided by James Almond, Ørsted).

2.4 Aspirational Mitigation Goals

The majority of interviewees stated that the ideal situation would be to have no cormorants utilising the wind farm, so the turbines remain clean. Other preferred solutions included an improved cleaning method and retrofitting the turbines, deterrents were mainly cited, however alternative roost sites were also suggested to draw the cormorants away from the areas which need to be accessed.

All interviewees stated the need to reduce the levels guano on the wind turbines.



Plan view of TP

Key

◀ = Nozzle Location

🟨 =Electrical junction box

| =Outlet pipe

| = Electrical supply cable following outlet pipe to pump

▣ = 1000l tank

◎ =Pump

🟪 = Compressor for air lift pump

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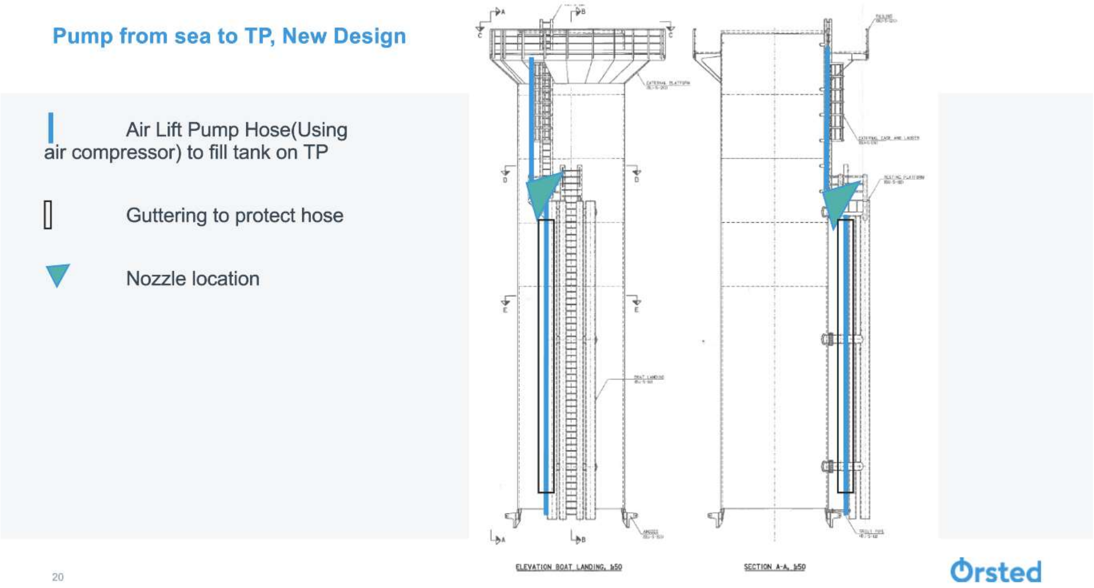
Figure 8: Diagram of TP Clean Assist design, shown in plan view with key components and spray area marked. Kindly provided by James Almond, Ørsted.



Pump from sea to TP, New Design

| Air Lift Pump Hose(Using air compressor) to fill tank on TP

▯ Guttering to protect hose

▼ Nozzle location

20

Figure 9: Diagram of TP Assist design, showing pump system from sea to platform, to be operated at high tide. Kindly provided by James Almond, Ørsted.

Table 2: Mitigation Measures Trialled at Burbo Bank Offshore Wind Farm (up to December 2020), effectivity and bird's reaction as reported during interviews of staff at Burbo Bank Offshore Wind Farm.

Mitigation Measure	Description	Location and Installation Details	Date Installed	Effect	Bird's Reaction	Marine Licence Case Reference
Bird Spikes	Plastic or silicone bird spikes attached with adhesive strips, designed to deter birds from landing.	Placed on one location only.	July 2011	None	These were ripped off by the cormorants within a few days.	MLA/2016/ 00110/3
Plastic Tubing/Wire & Rollers	A thin wire with free spinning conduit tubes threaded horizontally, installed above the handrails to physically prevent the birds from roosting. This was initially trialled with cheap metal that would corrode, without conduit rollers. After some effect, this was upgraded to stronger supports and conduit pipe rollers. The final upgrade made these out of stainless steel.	All turbines in BBW01 Since installation the equipment has not been maintained so is probably not in a good condition now.	Initial trial March 2012 on 1 turbine Full role out Jan 2017	Limited	The cormorants have not been seen sitting directly on these, but they can fit under/around. The birds often find other locations to sit. This measure reduced the guano but did not prevent it.	MLA/2017/ 00182/2
Snow Fencing	Orange plastic fence fixed around the platform to make it more difficult for birds to take off from the turbine and thereby deter them from resting on the turbines.		Trial in Nov 2016 Full role out not implemented	None		MLA/2016/ 00110/3
Ultrasonic Sounder	An ultrasonic sounder set to one frequency.		Trail in Jan 2017	Temporary	This worked as a deterrent method for a few weeks, after which the birds became habituated to the sound.	Not applicable.
Alternative Bird Perches	Bird perches for birds to rest on which extend out over the water. Each perch is 2m in length and comprises of a "hinge" and "arm".	2 perches per turbine installed on all 25 turbines in BBW01.	Jan 2018	Limited	These are used by the cormorants however due to the number of birds in the site there is not enough of these and they have had little effect, seemingly providing the birds with some additional space.	MLA/2017/ 00086/1

3 Consultation and Literature Review

3.1 Summary of the Cormorant Population

The local population of cormorants has steadily increased, mainly throughout the second half of the twentieth century. Liverpool Bay is a stronghold for the species, particularly off the Merseyside, Wirral and North Wales coasts. Prior to the construction of Burbo Bank OWF, during calm conditions, cormorants were observed roosting on buoys that mark the Mersey Channel and offshore sandbanks. Onshore winds often concentrated the birds at favoured roost sites along the coast.

The earliest large roost counts reported were 105 on the Mersey Estuary in 1967 and 108 at Formby Point in January 1973, but since the mid-1980s the largest land roosts have almost always been at Seaforth. The number of individuals at Seaforth sharply increased during the late 1980s and again at the end of the 1990s. Roost counts of cormorants in Morecambe Bay are far surpassed by those within the English sections of Liverpool Bay on the Dee, Alt and Ribble Estuaries. Roost sites inland at lakes and reservoirs have increased in line with those of the coast (White, McCarthy and Jones, 2008). Such increases reflect national trends of increasing numbers of wintering cormorants in England and Wales (Chamberlain *et al*., 2013).

While estimates of the local population are extremely difficult, it has been estimated that Liverpool Bay supports internationally important numbers of cormorants (White, McCarthy and Jones, 2008). This means that the birds using the site represent over 1% of a particular migratory flyway or population (JNCC 2001). The local bird recorder group estimates the cormorant population using Liverpool Bay (using onshore roost counts) is >5% of the global population. A coordinated Wetland Bird Count (WeBs) in November 2005 counted 1,356 individuals on the Alt and Ribble Estuaries (White, McCarthy and Jones, 2008). The five-year mean winter peak count (2009/10-2013/14) was 4,273 individuals on the Ribble Estuary, the Dee Estuary and the Alt Estuary (The Wildlife Trust for Lancashire, Manchester and North Merseyside, 2017). WebS counts from Ribble Esturay and Alt Estuary between 2011 and 2019 are included in Table 3, indicating a minimum number of individuals likely to forage in Liverpool Bay, as these do not include additional known roosts. Further roost sites have been observed in the Mersey Estuary, the southern section of Morecambe Bay and Wales. The most recent five-year mean winter peak (2015 to 2019) for the Ribble and Alt Estuaries combined is 1,872 individuals. The highest count within this data recorded 3,623 individuals in 2012.

Table 3 – Wetland Bird Survey counts of cormorants on the Ribble Estuary and Alt Estuary between 2011 and 2019 (data kindly provided by White, 2020). The Alt Estuary survey covers the stretch of coast from Seaforth Nature Reserve in Liverpool Docks to Formby Point. The Ribble Estuary survey covers from Formby Point north to Southport and across the marshes as far as Lytham.

Date	Ribble Estuary	Alt Estuary	Total
11/01/2011	1197	188	1385
03/01/2012	1848	268	2116
11/01/2012	1757	629	2386
12/01/2012	3297	326	3623
01/01/2013	1782	470	2252
09/01/2013	1545	393	1938
12/01/2013	2586	213	2799
01/01/2014	2572	668	3240
11/01/2014	730	975	1705
01/01/2015	1022	155	1177
10/01/2015	575	1676	2251
11/01/2015	1248	397	1645
01/01/2016	381	233	614
10/01/2016	250	1915	2165
10/01/2017	937	867	1804
11/01/2018	695	824	1519
10/01/2019	398	1224	1622

While cormorants are present on the coast throughout the year, data from 1990 to 2005 indicates a clear peak often occurs during October and early November (Figure 10; White, McCarthy and Jones, 2008). This trend is still thought to occur.

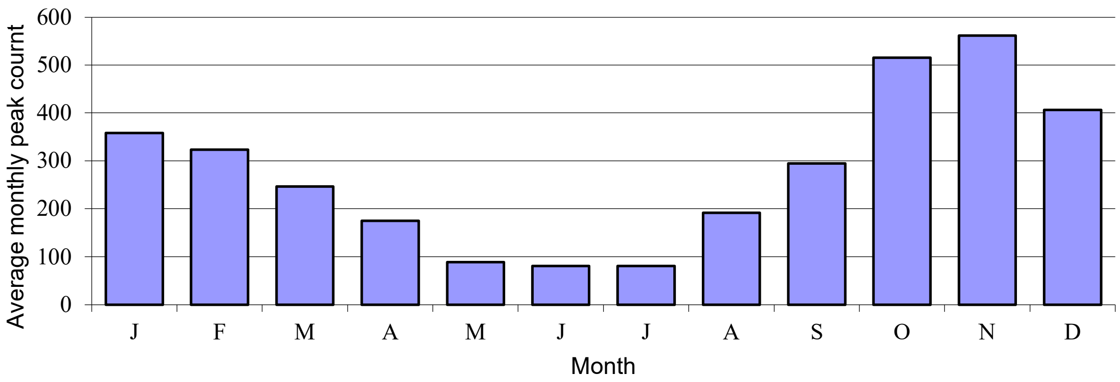


Figure 10: Average monthly peak counts of cormorants at Seaforth Nature Reserve, 1990-2005. (White, McCarthy and Jones, 2008).

Ring recoveries indicate that most of the cormorants in Liverpool Bay come from Irish Sea colonies, principally those in Pembrokeshire, the Solway Firth in Cumbria and Dumfries and Galloway, with small numbers also from County Dublin, the Isle of Man, Strathclyde and Anglesey (White, McCarthy and Jones, 2008). More recently, more birds are thought to originate from Puffin Island on Anglesey during the breeding seasons and wintering birds are known originate from all over Europe, although the majority come from British or Irish sites (White, 2020b). A few colour-ringed birds originating from inland sites to the south-east have been recorded inland or on the coast. These inland sites include Abberton Reservoir, Grafham and Rutland Waters, and Besthorpe in Nottinghamshire (White, McCarthy and Jones, 2008).

Disturbance on land has been noted as a factor impacting the distribution of the local cormorant population (Booth, 2020). This may make Offshore Wind Farms (OWFs) attractive roost sites as cormorants may be less disturbed here in comparison to sites on the coast or inland. The availability of roost sites in OWFs near to foraging areas may also save the birds a long flight back to alterative suitable roosts on the coast or inland, creating energetic benefits for the birds.

While cormorants are included within the waterbird assemblage feature of the SPA, there have been several objections by the Royal Society for the Protection of Birds (RSPB) and Lancashire, Manchester and North Merseyside Wildlife Trust, that the population of non-breeding cormorants exceeds the threshold to warrant the designation of this species as an individual feature (The Wildlife Trust for Lancashire, Manchester and North Merseyside, 2017). Discrepancies between the estimated cormorant population result as a review of the population was based upon data gathered by aerial surveys. Cormorants spend relatively little time on the sea surface, either diving or spending the majority of their time resting on land or offshore structures. They are thus unlikely to be detected during aerial or boat surveys and therefore the method was deemed inappropriate by these organisations. Evidence from WeBs counts (outlined above) suggest the cormorant population is substantially larger than the data from these aerial surveys and the SPA designation suggest.

It should be noted, additional data on the cormorant population may be available from other sources, such as Ørsted and the British Trust for Ornithology (BTO). Due to the limited scope of this research phase, these resources have not been explored. Studies of the local cormorant population are limited. A project attaching satellite tags to cormorants would be beneficial to increase knowledge of the species, local movements and behaviours (Booth, 2020).

3.2 Cormorant Behaviour

In order to understand the factors attracting the cormorants to the wind farm, an investigation was carried out into cormorant roosting and foraging behaviour. Informal consultations were also held with various ornithologists and cormorant experts, including representatives from the RSP, NIRAS, Aarhus University, Vattenfall, and the Lancashire and Cheshire Fauna Society.

Great cormorants (*Phalacrocorax carbo*) are the most common cormorant species in the UK, protected as a “frequently occurring migrating bird” under the European Commission Directive on the Conservation of Wild Birds (the ‘Birds Directive). They typically grow to 80-95cm tall and have an average lifespan of 11 years (Natural England, 2012; Cook *et al.*, 2011). Breeding locations are primarily coastal, with steep cliffs with sheltered ledges favoured as nesting sites, though inland habitats such as lakes and rivers are also commonly used.

The mean maximum foraging range of cormorants is 25±10km (Thaxter *et al*., 2012). Cormorants mainly forage by pursuit-diving, mostly in shallow waters, with typical dive depth of 12m, although they can dive as deep as 35m. They primarily hunt by disturbing their prey from muddy or sandy seabed, although they are also found over rocky substrate (Natural England, 2012). Communal feeding strategies are adopted by cormorants at some sites, working together to 'herd' shoals of fish and improve prey capture rates. This hunting method is thought to have particular benefits in more turbid water, but is used at a variety of sites. They are generalist feeders, primarily predating fish. The consumption of other animals (e.g. crabs, shrimps and crayfish) is rare except at some localities. Fish are digested entirely, with larger and thicker bones regurgitated in the form of discrete oral pellets. This usually occurs on a daily basis, typically at first light before the birds leave the roost to feed (European Commission, 2020). Cormorants are highly versatile and adapt to a wide range of habitats both coastal and inland (Dorfman and Kingsford, 2001; Worden, Hall and Cranswick, 2004).

These findings were confirmed by the expert consultations, with all expert consultees stating that cormorants were highly generalist and ate many different fish species depending on availability. It was noted that bottom-dwelling fish such as plaice, flounder, and eels, are particularly common prey species for cormorants, and social hunting to predate schools of fish was mentioned by one consultee. When asked, all consultees stated that it is highly unlikely that cormorants would eat shellfish such as mussels, as their beaks are not suited to breaking open the shells. Typical foraging range was quoted by the consultees as between 7 and 40km, and the average dive depth described was around 10m. One consultee noted that during the breeding season, foraging habits are much more selective, as the cormorants will seek young fish from inland rivers, which their chicks are able to digest more easily. As the period of interest for this study lies outside of the breeding season however, this behaviour was not investigated further.

Close links have been observed in Australia between the presence of seagrass and foraging behaviour, suggesting vegetation may be used as a foraging cue (Dorfman and Kingsford, 2001). However little evidence was found to support this observation in Europe, and one consultee who has worked extensively with cormorants suggested that they tend to avoid dense vegetation, as it can limit their ability to predate bottom-dwelling fish. Other consultees simply stated that, to their knowledge, there is no particular substrate or sediment type which cormorants prefer, and that they are highly skilled at finding new foraging sites with the best prey opportunities.

All consultees noted that there is insufficient evidence on cormorant foraging behaviour to draw conclusive observations, as they are a reasonably common species so have not been the subject of extensive research. Two consultees however, noted that they have similar ecology to the European Shag (*Phalacrocorax aristotelis*), which is much rarer and so has been studied in more depth.

Cormorants require regular access to perches within their foraging range to dry their wings, especially after dives longer than 5 minutes. Before flying to perch, they are often observed to "bathe" by splashing water over themselves for around 30 seconds before flying to a suitable roost site to dry. They dry their plumage by spreading their wings, often facing into the wind

(Sellers, 1995). Several studies have noted the importance of suitable roosts within foraging range, and the negative energetic effects of disturbance from roost sites (Jackson, 2017).

Most consultees noted the importance of stable perches above the tide line, with safety from disturbance and proximity to foraging habitat as the most important features of preferred roost sites. Many consultees indicated that the colonisation of the wind farm is likely to be influenced by human disturbance at onshore roosts, especially from dogwalkers. Anecdotally, consultees suggested that depending on the ambient temperature, birds may be roosting on the lee side of the turbines in order to gain shelter, or on the wind side in order to better dry their wings. One consultee noted that cormorants had been observed roosting behind other birds in order to gain shelter from the wind.

In flight, cormorants are shown to use vortices and wind shear near the water surface, observed in 95% of upwind flight and 35% of downwind flight (Finn *et al*., 2012). Anecdotally, cormorants are also observed to use thermal wind patterns to aid flight.

Finally, discussions with the consultees indicated that site fidelity is a key factor to consider, as individual cormorants often return to the same roost site every year. This was supported by a study into roosting sites on Lake Geneva, which found that a high proportion of individuals returned to the same roost site each year, and indicated that this proportion increased with the age of the cormorants rather than the duration of stay at a particular site (Reymond and Zuchuat, 1995).

3.3 Seabirds and Offshore Wind

A variety of studies have been carried out into the interactions between seabirds and offshore wind farms (OWFs). A review was undertaken to determine if the behaviour observed at Burbo Bank is common, and whether other species have exhibited similar attraction.

Birdlife International (2003) highlighted the key risks to birds posed by offshore wind farms as displacement, collision mortality, and loss of habitat, though cormorants were classified as low collision risk and it was noted that habitat loss offshore is small-scale. Other studies however suggested cormorants may be at high risk of collision (Cook *et al*., 2011). Some concern was posed around habitat change in offshore wind farms, especially changes to the seabed and effect of localised electro-magnetic fields on benthic species.

Cormorants and shags were classified as the only bird species showing “strong attraction” to windfarms, and in several cases were found to use turbine structures to extend foraging range into areas previously not in use (Dierschke, Furness and Garthe, 2016). Reasoning for cormorant attraction was judged to be the availability of prey and drying sites. Great cormorants were noted to rest primarily at edges of wind farms, and were only found at the centre in one site, Horns Rev 1, when the turbines were inactive. In one study of European wind farms, four key sites were highlighted as showing significant new presence of cormorants post-construction: North Hoyle, Robin Rigg, Prinses Amalia, and Egmond Am Zee (Dierschke et al 2016). Egmond Am Zee showed 3% attraction for cormorants, compared to 13% for speckled gull and 34% by little gull (Krijgsveld, 2014). At three of these wind farms, wing-drying and diving behaviour was observed, supporting the assumption that cormorants were using the sites to extend their foraging range. In three independent studies, it was noted that gulls and cormorants showed attraction to windfarms whereas divers, alcets, gannets, and seaducks, all showed avoidance behaviour (Dierschke et al 2016; Krijgsveld, 2014, MMO 1139). One incident was recorded at Horns Rev 1 showing “panicking” as cormorants entered windfarm, however this was not seen at any other sites, and Horns Rev 1 showed higher avoidance from all birds than sites with wider turbine spacing, suggesting this is an important factor.

A further study by Cook *et al*., (2018), classified both cormorants and gulls as “moderately attracted” to OFWs and noted that conservation risk for cormorants due to windfarms was “Very Low” compared to “Moderate” risk for wave power and “Very High” risk for tidal power.

Foraging areas for cormorants were highlighted within Liverpool Bay in similar region to the OFWs of Gwynt-y-Mor, North Hoyle, Rhyl Flats, and Burbo Bank (Cook *et al*., 2011).

Offshore structures are known to create new opportunities for some animals. Marine life can settle on structures, creating artificial reefs (Langhamer, 2012; Claisse *et al*., 2014). Fish can seek refuge in their wake (Fraser *et al*., 2018) and seals use structures as foraging sites (Russell *et al*., 2014). Wakes generated downstream from anthropogenic structures can act like prey conveyer belts, attracting surface foraging seabirds (Lieber *et al*., 2019).

3.4 Cormorant Deterrent Methods

Many types of cormorant deterrent have been trialled to minimise conflicts in both onshore fisheries and offshore superstructures. A review was carried out to gauge the efficacy of different deterrents and determine their suitability for this project.

Cormorants will eventually habituate to most “scarer” deterrents, however the speed of habituation depends on the ability to vary the type and position of the deterrents as randomly as possible, and to use human interaction to reinforce the perceived threat. It is noted that it is harder to deter cormorants from an already established roost site, than to prevent them roosting in the first place, and that the success of all deterrent methods relies on having an alternative foraging site nearby to displace them to (Russell *et al.,* 2012).

Gas cannons, pyrotechnics, and shooting to scare were all relatively effective for onshore fisheries, however these would not be suitable within Liverpool Bay SPA. Bio-acoustic sounders were found to be more effective than generic sounders, with Orca calls noted as effective in scaring cormorants when diving for fish (Russell *et al.,* 2012). Ultrasonic sounds are likely to be outside cormorant’s range of hearing. No acoustic deterrents have ever proved effective over the long term (Dooling, 2002).

Streamers, mirrors, and loose clothing which flap in the wind can all be effective, however in all cases the birds will eventually habituate. It is noted that moving deterrents are always more effective than stationary deterrents (Russell *et al.,* 2012).

Water jets were found to be highly effective at protecting inshore fisheries, however it was not discussed whether this success was due to the removal of dry roost sites, or due to the screening of the water’s surface preventing the cormorants from spotting prey (Russell *et al.,* 2012).

By comparison, a study into bird deterrents used for offshore oil installations showed several "scarer" deterrents to be effective for gulls, with acoustic deterrents of species-specific distress calls, automated laser systems, and "bird-free gel" which emits UV light that the birds interpret as fire, all shown to be relatively effective over long time periods (Christensen-Dalsgaard *et al*., 2019).

Physical deterrents including vertical and horizontal metal spikes, fence grating, and moving wire constructions which flap in the wind were also shown to be effective at reducing the roosting space for gulls and therefore reducing the number of gulls using the structure (Christensen-Dalsgaard *et al*., 2019).

A report of guano mitigation on offshore helidecks concluded that permanently removing birds should be regarded as an unrealistic objective (Health and Safety Executive, 2001).

3.5 Artificial Roosts

A literature review was conducted to identify man-made ('artificial') roosts that have been created for cormorants or other seabirds. No resources were found detailing any use of artificial roosts in wind farms or other offshore structures, although it should be noted these may exist outside of public knowledge. A literature review identified one project which created artificial floating roosts and two projects which created artificial tree roosts. Information regarding local tern artificial floating roosts and cormorant interactions with these were also identified.

3.5.1 Artificial Floating Roosts

Recognising that waterbirds often roost and feed on oyster farms, in 2018-2019 BirdLife Australia trialled the use of floating, long-line oyster bags as a cheap, low-impact and adaptable alternative to traditional artificial roost construction for shorebirds (which often involves significant earthworks and hydrological alteration to create permanent, static structures). Trialling a system consisting of marine grade screw anchors, ropes, buoy, strong poly aqua storm line and oyster bags (made of High Density Polyethylene and Linea Low Density Polyethylene) with a float and thermologger.

Initial trials took place in November 2018 in Western Port Phillip Bay, Australia where coastal high-tide roosting sties have become jeopardized by sea-level rise and increased storm events. Following installation, birds were recorded using the floating roost, even when other roost options were available. Following this, the system as trialled in the Geum Estuary, on the Korean Peninsula in April 2019, filling the oyster bags with empty shells which both weighed the bags down (making them less prone to flipping on the lines) and which were subsequently colonised by invertebrates, providing a food source for shorebirds during the low tide. A lack of suitable roosting habitats in the Geum Estuary region is thought to be one of the main limiting factors to shorebird fitness. Following their installation, birds were observed using the artificial roosts within a few hours. At Geum Estuary roosts were used by a maximum abundance of >500 birds and 52 different species of waterbird (31 of which were shorebird species). Cormorants are cited as regularly using the artificial roosts here. The maximum tide and wind speed were found to be the most important factors influencing use. (BirdLife Australia, 2020a; BirdLife Australia, 2020b; BirdLife Australia, 2020d).

The artificial roosts were also installed in the Hunter Estuary, Australia in April 2019 as some roost sites are jeopardised by disturbance, mangrove incursion and altered hydrology. However, interestingly the floating artificial roosts were not used as a roosting site, although some birds were observed feeding around the oyster bags. It is thought the natural roosting habitat at this location is preferred and exists in a sufficient quantity, so the shorebirds don’t need supplementary artificial roosts. BirdLife concluded that this proves artificial habitats aren’t a substitute for natural roosts but offer a solution for places like the Geum Estuary where natural roosting habitat has undergone severe degradation (BirdLife Australia, 2020c).

Oyster bags are used commercially in high energy coastlines, including in Canada where they can be 3-4m swells. BirdLife monitored the floating roosts during the monsoon season, observing that they endured “blistering winds and wave action”. Thus, such structures may be able to withstand the conditions within wind farms. As the plastic design of the floating structures may contribute to marine plastic pollution. BirdLife are currently working with partners to develop and trial alternative materials (BirdLife Australia, 2020b; BirdLife Australia, 2020c).

Within Liverpool Bay, Lancashire Wildlife Trust annually place 8 to 10, approximately $3m^2$ square artificial floating rafts for terns at Seaforth Nature Reserve, each consisting of an anchor, around 8m of chains, blue barrels for floatation, wooden sides and a ledge surrounding a gravel pit for tern breeding. Cormorants are known to use these to roost and thus the artificial rafts are not put out until the first terns are observed (normally in April) and are removed as soon as possible post the tern breeding season (September/October). When occupied during the tern breeding season (with a high density of terns), cormorants are not observed using the artificial rafts. The rafts are deployed in an exposed area of the coast, however issues with anchoring have occurred in the past, thought to be due to an insufficient weight or number of anchors (Cripps, 2021).

3.5.2 Artificial Tree Roosts

Two papers were identified detailing the creation of tree roosts (Meier, 1981; Escutia *et al.,* 2020). Meier (1981) constructed platforms and perches in a degraded dead tree roost of double-crested cormorants (*Phalacrocorax auritus*) in Wisconsin, USA, in 1975. Three platform designs were trialled; (1) a wire platform with a wooden frame and one-inch mesh chicken wire stapled to the surface, (2) a lath platform with pieces of lath spaced across the surface and (3) a wooden box ontop of a perch. The lath platforms had by far the greatest uptake by cormorants. It is believed as this design allowed the birds to weave nesting material around the platform supports and provided good aeration, preventing waterlogging and rotting. This is unlikely to be relevant for the overwintering cormorant roost sites at Burbo Bank, however it was noted that the birds were reluctant to land or walk on the wire platforms. The use of perching structures was found to be proportional to the density of birds present.

The study noted that cormorants used platforms at heights ranging from 3 to 24 ft (0.91 to 7.32 m) above the water. However, platforms use increased with an increase in height. All nests built on artificial platforms occurred in the range of 9 to 24 ft (2.74 to 7.32 m), corresponding with the vertical range of natural roost sites of 8 to 27 ft (2.44 to 8.23 m). The vertical distance between platforms (3 vs 6 ft apart) had little effect on platform use, however vertical rotation was found to be important due to cormorants defecating on nearby nests. A consecutive 180° staggered vertical placement was used exclusively in the placement of platforms on all structures constructed in 1976. This resulted in platforms being back to back and oriented directly above each other. Since cormorants defecate sideways off the edge of the nest, this modification reduced defecation problems and facilitated use of lower platform levels.

The second artificial roost study was built for tree-roosting great cormorants (*Phalacrocorax carbo*) displaced by harbour developments in Barcelona, Spain, in order to prevent the birds moving to a roost site near the airport which would result in an increased risk to aeronautical safety. Escutia *et al.,* (2020) trialled artificial trees with 10m high masts and numerous horizontal crossbars at different levels, simulating branches. Through trial of several designs, they identified that artificial wooden branches, 3cm thick were preferentially used over 5cm thick or metallic branches, reflecting a preference for similarity to natural roost site characteristics (local eucalyptus with an average branch thickness of 2.3cm). The use of artificial roosts increased over time and were occupied by all age classes.

3.5.3 General Remarks

In most of circumstances, a lack of alternative available roosts was a factor influencing artificial roost use by birds. While floating roosts were used by cormorants in Australia, whether cormorants would use such roosts if alternative, more stable and dry sites are available is questionable. However, the occupation of tern artificial rafts in the local area (Seaforth) suggests an artificial floating raft may be used by the cormorants.

Experiments with different designs of artificial tree roosts indicate that the artificial roost material and height is an important factor. Replication of natural or existing roost site characteristics seems to be the most successful method for designing artificial roosts. Wood seems to be the most successful material, however this may not be suitable for marine/offshore wind farm sites. Orientation may be important in vertically designed roosts, in order to prevent guano accumulation on lower level platforms.

3.6 Guano Mitigation Measures

While it is known other sites are affected, there is little information publicly available about the measures other OWF developers take to mitigate seabird guano accumulation. It should be noted, Ørsted have recently commissioned NIRAS to conduct a review of cormorant roosting and mitigation measures across all their sites, which is expected to be published imminently. This report will be complementary to this in-depth study of Bubo Bank and should be referenced for the wider picture.

However, a report by the Health and Safety Executive (2001) into guano accumulation and health and safety risks on the helidecks of Normally Unattended Installations (NUI) is publicly available. This report highlights similar problems to the offshore wind industry, with the accumulation of guano, feathers, fish/bones, dirt/debris and concerns regarding health and safety, unpleasant smells and the transfer of guano on footwear. About 30% of NUI helidecks were thought to have a consistent problem with guano accumulation, whereas instances on manned installations were found to be isolated and limited in their effect. One representative reported guano accumulation can build up to 0.5 to 1 inch thick after 4 or 5 weeks.

As highlighted above, deterrents were found to be in ineffective in the long-term on NUI helidecks and simply prompted the birds to move to another part of the same, or a different, platform. It was concluded that permanently removing birds from NUI should be regarded as an unrealistic objective (Health and Safety Executive, 2001) and that operators should accept that regular helideck cleaning and maintenance is required (UK Offshore Operators Association, 2005). Most operators dealt with the problem by jet or pressure washing the affected surfaces, some using chemicals to assist with guano removal. It should be noted, the use of chemicals is not an appropriate solution for Burbo Bank. The use of a tarpaulin over the helidecks was also suggested (Health and Safety Executive, 2001). This may be worth considering, although this measure would have some logistical issues due to the number of turbines affected.

Interestingly, in 1997 an operator fitted a system to spray sea water over the helideck. The system comprised of two industrial sprinkler heads fitted to the helideck guttering and fed from a sea water pump. The jets discharged water a distance of 19 meters at a height of 3 meters and was remotely activated when bird activity was observed by a remote camera relayed to a control room monitor. It was noted that the birds reacted immediately to this, moving off the helideck onto other parts of the installation. Although they returned to roost at sunset the water system reportedly quickly scared them off when switched on. The water jets were thus activated for one hour in the morning and evening, removing any guano build-up during the day. This water spray, used as a deterrent and cleaning device, combined with a sound device (‘Gull Scat’) was said to be prove very successful in minimising bird activity and ensuring the helideck remained fairly clean. It should be noted however, the ‘Gull Scat’ device was shown to be ineffective on its own in the long-term, thus the success may be related more to the water spray solution. Such a water spray system can be operated remotely or automatically by use of timing devices and motion sensors. At the time of the report (2001) no commercial systems were known to be available for this purpose (Health and Safety Executive, 2001).

A report by the UK Offshore Operators Association (2005), concluded that complete routine and frequent reporting of helideck condition is fundamental to efficiently managing guano accumulation. As such, a NUI helideck condition reporting matrix was formulated (Table 4), with any report of surface condition above level seven incurring flight restrictions and limiting operational helideck availability.

Table 4 – Helideck Condition Monitoring (UK Offshore Operations Association, 2005).

Level	Surface Condition/Restriction
1	Clean.
2	Small isolated bird droppings.
3	Noticeable, but no operationally significant bird droppings.
4	Markings beginning to be degraded.
5	Obvious bird usage.
6	Noticeable degradation of markings.
7	Bird usage causing operational problems.
8	Substantial degradation of markings.
9	No night operations.
10	Totally obscured – daylight cleaning operations only.

It was advised that cleaning should be a priority activity planned within the normal installation maintenance schedule, with detailed Control of Substances Hazardous to Health (COSHH) assessments being undertaken for any clean and repair work. A high-pressure pumping system was stated as being required for effective removal of guano accumulations.

A spray cleaning device for each wind turbine may be an appropriate mitigation measure for Burbo Bank. Given the water permeability of cormorant’s feathers and their needs to dry out, it would be reasonable to assume that water spray would both act as a deterrent and as a cleaning solution. Given the SPA status of the site and the importance of the turbines as roost sites, this should be done in a manner that minimises any impacts on the birds. For example, washing sections of the wind farm individually, as opposed to every turbine at once, would allow the birds to roost on nearby turbines during cleaning operations, minimising the energetic impact of this disturbance. Regular washing would help to address the guano accumulation problem, keeping on top of any excretions. Furthermore, a remotely controlled system could allow the turbines to be additionally cleaned prior to maintenance work visits by technicians.

4 Proposed Research Goals

Based on the findings of this initial scoping investigation, the following research goals were identified:

4.1 Environmental Distribution Factors

Primarily, an investigation should be carried out into the environmental factors affecting cormorant distribution within Burbo Bank wind farm. This will include a wide range of factors, including seabed characteristics, hydroclimatology (weather) patterns, and distribution of prey species in the surrounding area. It is hoped that the results from this investigation may be extrapolated to other areas, in order to predict the distribution of cormorants within a site and characteristics which may make an offshore wind farm attractive to cormorants in the first instance.

This will be carried out using the GIS software ArcGIS Pro, and a range of survey and climate data accessed through The Crown Estate's Marine Data Exchange and public datasets. Factors will be investigated individually and compared in order to identify trends and draw meaningful conclusions.

In order to improve the reliability of the anecdotal distribution data obtained in interview, it is recommended that a dedicated survey of the cormorant distribution within the wind farm is carried out. This could be achieved by boat survey, aerial survey, or a telemetry study; however, the scope of such surveys within this project is yet to be determined. This will be discussed with project partners in order to reach a suitable solution.

4.2 Novel Mitigation Measures

Thus far, investigation into novel mitigation measures has focused largely on measures trialled by other offshore industries. In this section, a divergent design analysis will be carried out, to gather a wide range of possible solutions and compare their suitability against key design criteria. Based on discussion with operational personnel, and restrictions due to the importance of cormorants within Liverpool Bay, the following criteria were determined as a functional specification for the design (Table 5):

Table 5 – Criteria as Functional Specifications for Mitigation Measure Design.

Compulsory Outcomes	Additional Outcomes
Guano accumulation is reduced to acceptable levels on all areas of the turbine which require regular access by technicians.	Number of cormorants roosting in turbine areas requiring regular access is reduced compared to current status.
Cost of guano mitigation to Ørsted is reduced compared to current status.	Recurring costs for guano mitigation are kept to a minimum, following initial implementation.
Benefits to cormorant population, in terms of extended foraging range and low disturbance roost sites, are maintained. No negative effects on the population are created.	Benefits of offshore wind farms to cormorants and other seabird populations are improved compared to pre-construction: net gain is achieved.

4.3 Opportunities for Net Gain

Finally, recommendations will be made for how offshore wind developers can incorporate green infrastructure or other suitable measures, in the design and planning phase, in order to achieve colocation in a way which benefits both cormorant populations and on-site maintenance teams.

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6 Appendices

Appendix A

Questions used for semi-structured interviews with staff at Burbo Bank Offshore Wind Farm are detailed in Table 6:

Table 6 – Questions for Interviews with Burbo Bank Offshore Wind Farm Staff.

Topic	Interview Structure/Questions
The problem	Tell us about the birds in the wind farm/describe the situation as a whole.
The problem	Can you describe the birds that use the wind turbines.
The problem	Are the birds causing a problem? Yes or no
The problem	On a scale of 1 to 5, how severe is the problem? (1 being no effect and 5 being severe impact)
The problem	Which birds are causing a problem?
The problem	What problems are they causing?
The problem	What problems does the bird poo cause?
The problem	What effect do the birds have on your work?
The problem	What effect does the bird poo have on the equipment?
The problem	How did it start? When did you first see the birds? How long has this been a problem?
The problem	What do you think the ideal situation/best solution would be? What does success look like to you?
Bird Behaviour	Where are the cormorants/problem birds?
Bird Behaviour	Tell us about their movements
Bird Behaviour	Are they seen more on some turbines or areas of the site than others or distributed evenly throughout the wind farm?
Bird Behaviour	Which turbines/areas of the wind farm are they on/in most? Ask them to mark it on a map both where they have seen cormorants (yellow), and on which turbines there's the greatest problem (red).
Bird Behaviour	Does this change? Do they move about within the wind farm?

Bird Behaviour	Are the cormorants present all year round? Are they there 24 hours a day?
Bird Behaviour	Have you seen any nests?
Bird Behaviour	How do they behave? - What do you see them doing?
Bird Behaviour	Do they ever stand with their wings held open?
Bird Behaviour	Do you see them in the water as well as stood on the turbines?
Bird Behaviour	How do they react to human presence?
Bird Behaviour	How do they react when you're working on the turbines?
Previous mitigation	Tell us about the mitigation measures trailed
Previous mitigation	Saw the costs on the marine licences, are these accurate?
Previous mitigation	What does the washing involve? - How many turbines are washed/how often/how many people etc.
Previous mitigation	How long does it take to wash the turbines?
Previous mitigation	What HS methods have to be put in place for washing the turbines?
Previous mitigation	How much does it cost to wash the guano?
Mitigation measures	Do you know of any other mitigation measures? Are you aware of other solutions?
Data	Do you have any photos or videos of the birds within the wind farm you would be willing to share with us please?
Data	Would you be willing to take some?
Interview Close	Is there anything else you would like to tell us?

Appendix B

The methodology for the producting Figure 4 is detailed below:

During interviews with five BBW01/BBW02 staff, the interviewees were asked to indicate on a map of Burbo Bank where cormorants have been seen (in yellow) and which turbines are particularly problematic (in red). Unfortunately, the interviewer was unable to share screen for this exercise (due to IT restrictions when communicating with external parties) and thus the interviewees were asked to direct the interviewer who marked the map. These maps were used to extract the number of interviewees which had cited each turbine. These results were mapped using ArcGIS Pro software to produce Figure 4 (on page 14).

Appendix C

Corrosion at Burbo Bank offshore wind farm:

Figure 11: Photos of corrosion at Burbo Bank offshore wind farm (kindly provided by James Almond, Ørsted).