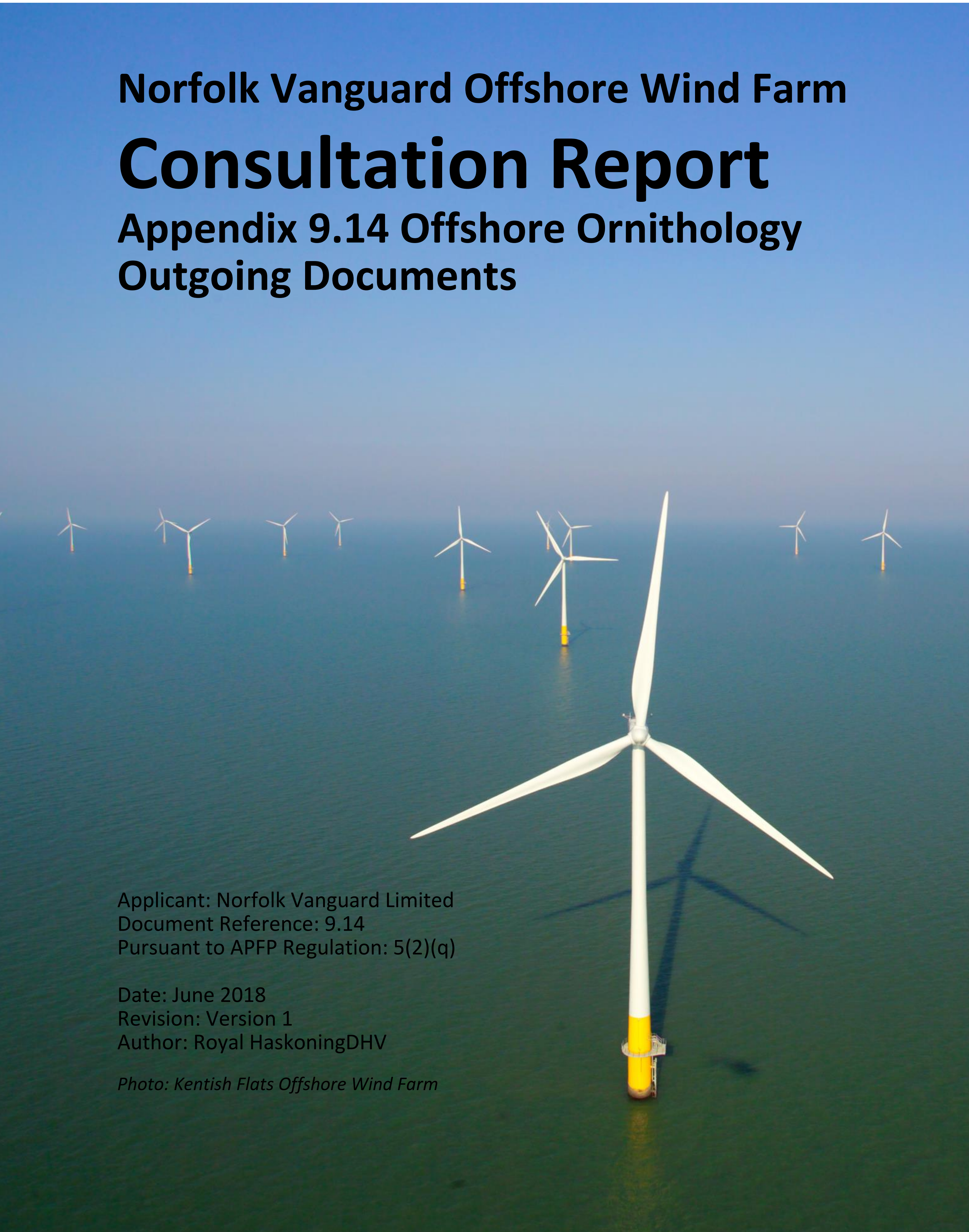
Norfolk Vanguard Offshore Wind Farm

Consultation Report

Appendix 9.14 Offshore Ornithology Outgoing Documents



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Data Analysis and Survey Strategy for East Anglia (North) Tranche 1 East

P293

Issued March 2016

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Appendix I Time Elapsing Between Ornithological Surveys, Development Applications and Consent decisions for Round 3 (and a selection of Round 2) OWF Projects

Project Name (Round No.)	Survey Dates (Boat)	Survey dates (Aerial)	Period over which surveyed (Months)	Period between first survey and Application (Months)	Period between first survey and Consent Decision (Months)
East Anglia THREE	n/a	September 2011 – August 2013	24 months	50 months	Pending (Minimum 56 months)
Hornsea Project 2	March 2010-Feb 2013	n/a	35 months	58 months	Pending (Minimum 64 months)
Dogger Bank Teeside	Jan 2010 – June 2012	Spring 2010 – December 2011	30 months	51 months	68 months
Navitus Bay	Nov 2009 – Nov 2011	Not stated	24 months	53 months	70 months (Declined)
Dogger Bank Cryke Beck	Jan 2010 – June 2012	Spring 2010 – December 2011	30 months	43 months	61 months
Hornsea Project 1	March 2010-Feb 2013	n/a	36 months	39 months	57 months
Rampion	March 2010 – Feb 2012	August 2010 – August 2011	24 months	36 months	51 months
East Anglia ONE	May 2010 – April 2011	November 2009 – October 2011	24 months	37 months	45 months
Triton Knoll	January 2008 – December 2009	Winter 2004 to summer 2005	24 months	48 months	66 months
Galloper	June 2008 – May 2010	n/a	24months	42 months	60 months

NORFOLK VANGUARD OFFSHORE WIND FARM

Environmental Impact Assessment

Offshore Ornithology Method Statement

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This method statement has been prepared by MacArthur Green on behalf of Vattenfall Wind Power Limited (VWPL) in order to build upon the information provided within the Norfolk Vanguard Environmental Impact Assessment (EIA) Scoping Report. It has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate. All content and material within this document is draft for stakeholder consultation purposes, within the Evidence Plan Process.

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LIST OF TABLES

1 INTRODUCTION

1. The purpose of this document is to provide background rationale for the Environmental Impact Assessment (EIA) approach to offshore ornithology for the Norfolk Vanguard project. The data sources which will be used to establish the current baseline environment and inform the subsequent assessment of impacts are described and key ecological receptors and potential impacts for assessment identified. The methodology which will be used to undertake the assessment and the associated guidance are also outlined.

2. This method statement has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate.

3. The approach outlined in this method statement also takes account of previous correspondence with Natural England, including:

- Vattenfall introduction meeting with the MMO in January 2016;
- Email and telephone correspondence with Natural England in 2016 regarding offshore ornithological survey requirements.

1.1 Background

4. A Scoping Report for the Norfolk Vanguard Environmental Impact Assessment (EIA) was submitted to the Planning Inspectorate on the 3rd October 2016. Further background information on the project can be found in the Scoping Report which is available at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010079/EN010079-000022-Scoping%20Report.pdf

5. The Scoping Opinion was received on the 11th November 2016 and can be found at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010079/EN010079-000018-Scoping%20Opinion.pdf.

1.2 Norfolk Vanguard Programme

1.2.1 DCO Programme

- Scoping Request submission - 03/10/2016 (complete)
- Preliminary Environmental Information submission - Q4 2017
- Environmental Statement and DCO submission - Q2 2018

1.2.2 Evidence Plan Process Programme

6. The Evidence Plan Terms of Reference provides an overview of the Evidence Plan Process and expected logistics, below is a summary of anticipated meetings:

- Steering Group meeting 21/03/16

(complete)

- Steering Group meeting — 20/09/16 (complete)
- Post-scoping Expert Topic Group meetings — Q1 2017
  - Discuss method statements and Project Design Statement
- Expert Topic Group and Steering Group meetings as required — 2017
  - To be determined by the relevant groups based on issues raised
- PEIR Expert Topic Group and Steering Group meetings — Q4 2017 - Q1 2018
  - To discuss the findings of the PEI (before or after submission)
- Pre-submission Expert Topic Group and Steering Group meetings — - Q1 - Q2 2018
  - To discuss updates to the PEIR prior to submission of the ES.

1.2.3 Survey Programme

7. The 2012-2014 East Anglia FOUR survey data, the September 2015 to April 2016 NV East data and the ongoing data collection since September 2015 for NV West will be the key data sources for the ornithology site characterisation and quantification of parameters for the impact assessment (e.g. Collision Risk Modelling, CRM). Tables 1.1 and 1.2 set out the data available for the two NV areas.

Table 1.1 Ornithology aerial survey coverage to be used in the assessment for Norfolk Vanguard East.

Site	EA4 & 4km buffer			NV East & 4km buffer	
	2012	2013	2014	2015	2016
Jan					
Feb					
Mar					
Apr					
May					
Jun					
Jul					
Aug					
Sep					
Oct					
Nov					
Dec					

Table 1.2. Ornithology aerial survey coverage to be used in the assessment for Norfolk Vanguard West.

Site	NV West & 4km buffer		
	2015	**2016**	**2017**
Jan			
Feb			
Mar			
Apr			
May			
Jun			
Jul			
Aug			
Sep			
Oct			
Nov			
Dec			

8. Additional survey data for the East Anglia zone which may be used to provide context include:

- East Anglia Zone November 2009 – April 2011 (HiDef and APEM)
- East Anglia THREE September 2011 – August 2013 (APEM)
- East Anglia ONE November 2009 – October 2011 (APEM)

9. For Norfolk Vanguard East there will be 32 months of site specific survey data available. This comprises 24 months of surveys of the originally planned East Anglia FOUR site which incorporates the current Norfolk Vanguard East site, plus an additional eight surveys of the Norfolk Vanguard East site. These were conducted over the nonbreeding season as this has been demonstrated to be the period of highest seabird abundance in the East Anglia Zone (from previous wind farm assessments). Natural England agreed that these survey data would be sufficient for the impact assessment (correspondence from Alex Thompson on 21st March 2016).

10. For Norfolk Vanguard West there will be 20 months of site specific survey data available, covering two nonbreeding seasons and the intervening breeding season. While it has become customary to conduct surveys for two complete years, seabird activity in the East Anglia zone has been found to be very low during the breeding season months (May to August). The ornithological baseline for these months will include the 2016 Norfolk Vanguard survey data, supplemented by the additional datasets for the region (see above), thereby ensuring a robust baseline for the breeding season.

11. A preliminary review of the baseline bird densities for key species expected to be assessed in the Norfolk Vanguard ES and HRA is presented in Appendix 1: Norfolk Vanguard Baseline Seabird Data.

12. The ornithological survey results obtained to date for the Norfolk Vanguard sites have found very similar temporal patterns and overall abundances of the species recorded on other wind farms in the region. In summary, seabird activity is at its highest during the nonbreeding season, with passage migrants (e.g. gannet) and overwintering species (e.g. red-throated diver, guillemot, razorbill, etc.). The only species which has been found to be present in similar or higher numbers in the breeding season is lesser black-backed gull. This is likely to be connected to that fact that this species has breeding colonies in the region, in contrast to the other species.

13. It should be noted that while the baseline review presented in Appendix 1 focuses on known key species which have been assessed for the other East Anglia zone wind farms, the Norfolk Vanguard assessment will include data on all species observed, with analysis and assessment presented for all the predicted sensitive receptors identified by this process (i.e. the final list will be dictated by the survey records).

2 PROJECT DESCRIPTION

2.1 Site Selection Update

14. Further to the site selection information provided within the Norfolk Vanguard Scoping Report (Royal HaskoningDHV, 2016), additional site selection work has been undertaken to refine the locations of the onshore infrastructure. Offshore, the boundaries of the site and offshore cable corridor are the same as those already presented in the Scoping Report. The Norfolk Vanguard EIA Scoping Report identified search areas for the onshore infrastructure, including a landfall search area. Further data review has been undertaken to understand the engineering and environmental constraints within this search areas identified. Public drop-in-exhibitions in October 2016 and the Scoping Opinion have also contributed to our broader understanding of local constraints and opportunities.

15. Information provided in this Method Statement is a draft for stakeholder consultation only and is provided in confidence. Equivalent information will be presented during open drop-in-exhibitions in March 2017, providing an opportunity for local people and the wider public to understand the way in which their feedback, as well as the Scoping Opinion, has influenced our design. Given the broad range and complexity of the factors influencing onshore site selection, including landfall, and the scale of the area under discussion, it is our intention that local people and interested parties view the map for the first time, with Vattenfall and suitably qualified experts on hand. This enables a meaningful discussion of the proposed

options and enables participants to refer directly to points of reference they may wish to discuss. During the March drop-in exhibitions, participants will also be invited to provide feedback on the latest design.

2.1.1 *Landfall Zones*

16. The landfall search area was presented in the Scoping Report as Figure 1.3. Following studies on the engineering feasibility of horizontal directional drilling (HDD), this has been refined to three landfalls options; Bacton Green, Walcott Gap and Happisburgh South (Figure 1).

17. Ongoing public and stakeholder consultation as well as initial EIA data collection will be used to inform selection of final locations for the EIA and DCO application, with the aim to further avoid sensitive areas. Impacts that cannot be avoided through site selection will aim to be reduced through sensitive siting, alternative engineering solutions (mitigation by design) and additional mitigation measures, where possible. Mitigation options will be developed in consultation with stakeholders.

2.1.2 *Offshore Project Area*

18. The offshore project area remains unchanged from that presented in the Norfolk Vanguard EIA Scoping Report (Royal HaskoningDHV, 2016a) and consists of:

- The offshore cable corridor;
- Norfolk Vanguard West (NV West); and
- Norfolk Vanguard East (NV East).

2.2 Indicative Worst Case Scenarios

19. From a seabird perspective, determination of the Worst Case Scenario (WCS) relates primarily to collision risk, for which the relevant design aspects relate to the total rotor frontal area at potential collision height.

20. The other potential effects on seabirds which would be predicted during the operational phase (displacement and barrier risk), are less affected by the different project designs (which mostly relate to alternative turbine and foundation options) as they are primarily assessed in relation to the overall wind farm footprint, which it is assumed will be largely consistent across turbine options. Some species may be subject to disturbance during construction. The magnitude of this impact is primarily related to the foundation type used.

2.2.1 *Wind Turbines and Foundations*

21. The WCS turbine parameters currently under consideration are for a design with 120 15MW turbines with a rotor diameter of 303m. This option has the highest total rotor swept area and therefore would be expected to generate the highest collision risk.

22. A range of foundation options; jacket, gravity base, suction caisson, monopile and floating foundations will be included in the Rochdale Envelope.

23. Further to the information provided in the Scoping Report, floating foundations will be included in the Norfolk Vanguard Rochdale Envelope. Ongoing review by the VWPL engineering team has identified that this is necessary in order to future proof the EIA and DCO to include the types of foundations that are likely to be available by the time of Norfolk Vanguard construction, potentially starting in 2023. Parameters of the floating foundations are currently being reviewed by the VWPL engineering team and will be available for the EIA and DCO application.

24. From an ornithological perspective it is difficult to predict the potential impacts of floating foundations compared with static foundations. If floating bases provide larger areas for seabirds to roost then there may be the potential for increased activity in the vicinity of turbines which could elevate the collision risk. Further consideration of floating foundations is provided in the relevant sub-sections below.

2.2.2 Layout

25. The layout of wind turbines will be determined pre-construction based on post consent site investigation works and detailed design works. The minimum spacing will be four times the turbine diameter (616m based on the minimum diameter of 154m) and the maximum spacing will be 15 times the turbine diameter (4.5km based on the maximum diameter of 303m).

26. The maximum capacity that may be located in NV West is estimated to be 1800MW (i.e. 100% of the turbines, with none located in NV East) and the maximum capacity in NV East is estimated to be 1200MW (i.e. 67% of the turbines) with the remaining 600MW in NV West. Consideration will be given to the worst case location for seabirds, which will be partly dependent on survey results, and is likely to correspond to the maximum number of turbines in the site which has the greatest seabird activity (subject to the available density estimates, Section 3.1.1).

2.2.3 Offshore Cabling

27. Two electrical solutions are being considered for Norfolk Vanguard, a High Voltage Alternating Current (HVAC) and a High Voltage Direct Current (HVDC) scheme. The decision as to which option will be used for the project will be agreed post consent and will depend on availability, technical considerations and cost. Both electrical solutions will have implications on the required offshore infrastructure. The key indicative offshore cabling parameters are as follows:

- Number of cables;
  - 6 subsea HVAC export cables or 4 subsea HVDC export cables;

  - 2 subsea HVAC interconnector systems linking the three offshore substations or 1 HVDC subsea interconnector system linking the two offshore converter stations;
  - Inter-array cabling - subject to number of turbines and layout;
- Export cable length per cable;
  - NV East - approximately 110km for HVAC and HVDC;
  - NV West - approximately 100km for HVAC and HVDC;
- Maximum export cable length;
  - 640km based on six HVAC cables;
- Interconnector cable length up to 50km per system for HVDC option only
- Inter-array cable length up to 515km.

28. The preferred construction technique and depth of burial for the offshore electrical infrastructure will be decided pre-construction based on ground investigation. Possible installation techniques include:

- Ploughing;
- Jetting;
- Dredging;
- Mass flow excavation[1]; and
- Trenching.

29. In some cases, cable burial cannot be undertaken and surface laying with cable protection will be required. In addition to this, it is estimated that up to 50m of cable may be surface laid on approach to the wind turbines or substation/convertor station platforms.

2.2.4 Ancillary Infrastructure

2.2.4.1 Offshore substation/convertor station platforms

30. Up to three substation platforms (HVAC) or two convertor station platforms (HVDC) will be required. Foundation options are:

- Piled monopile (10m diameter);
- Suction caisson monopile (20m diameter);
- Piled tripod (3m diameter pile x 3);
- Suction caisson tripod (3m diameter caisson x 3);
- Piled quadropod (3m diameter pile x 4);
- Suction caisson quadropod (3m diameter caisson x 4).

31. The seabed footprint of ancillary infrastructure will be considered in relation to potential changes to prey resource and water quality. The worst case scenarios

[1] An example of a mass flow excavator is available at http://www.rotech.co.uk/subsea/

associated with these are provided in the Fish and Shellfish Ecology Method Statement and the Marine Water and Sediment Quality Method Statement.

2.2.4.2 Accommodation platforms

32. A single accommodation platform may be required. Foundation options are as described in Section 2.2.4.1).

2.2.4.3 Met Masts

33. Up to 2 operational meteorological masts (met masts) may be installed within Norfolk Vanguard. Foundation options are:

- Jacket with pin piles;
- Jacket with suction caissons;
- Gravity Base;
- Suction caisson monopile; and
- Piled Monopile.

34. In addition two LiDAR buoys and two wave buoys may be required.

2.2.5 Construction Vessels

35. Indicative vessel numbers that may be on site at one time for construction of a 600MW Phase or for 1800MW installed in one phase (further information on Phasing in Section 2.2.7.1) are provided in Table 2.1. These numbers are based on all activities occurring concurrently which is unlikely but provides a conservative worst case scenario. The PEIR/ES will also provide estimated vessel movements.

36. There may be up to two piling vessels operating concurrently in NV East and NV West, resulting in up to four vessels operating concurrently across the whole of Norfolk Vanguard.

Table 2.1 Indicative Vessel numbers on site at one time

Vessel Type	Maximum for single 600MW Phase	Maximum for 1800MW installed in 1 phase	Average for single 600MW Phase	Average for 1800MW installed in 1 phase
Seabed preparation vessels	5	9	2	5
Transition piece installation vessels	1	3	1	3
Scour Installation Vessels	5	9	3	5
Number of vessels engaged in foundations	10	30	10	15
WTG installation vessels	6	18	4	6
Commissioning vessels	6	15	4	6
Accommodation vessels	1	2	1	2

Vessel Type	Maximum for single 600MW Phase	Maximum for 1800MW installed in 1 phase	Average for single 600MW Phase	Average for 1800MW installed in 1 phase
Inter-array cable laying vessels	3	7	2	3
Export cable laying vessels	4	12	4	12
Landfall cable installation vessels	2	2	2	2
Substation / collector station installation vessels	2	6	2	6
Other vessels	2	6	2	6
Total	47	119	37	71

2.2.6 Landfall

37. As discussed in Section 2.1.1, there are three potential landfall locations for Norfolk Vanguard:

- Bacton Green;
- Walcott Gap; and
- Happisburgh South.

38. Initial survey and data collection for the EIA, including survey of the MCZ, will enable the selection of the landfall location for Norfolk Vanguard. The PEIR and ES will present a single landfall option.

2.2.7 Construction Programme

2.2.7.1 Phasing

39. Norfolk Vanguard may be constructed in the following options and phases:

- A single phase of up to 1800MW;
  - The indicative construction period for a single phase approach is 3 to 5 years.
- Three 600MW phases (HVAC option);
  - A single 600MW phase construction may be 1 to 3 years.
  - The construction periods of each phase may partially overlap, be consecutive, or have a break in between phased construction.
  - The total programme for 1800MW is 3 to 10 years.
- Two 900MW phases (HVDC option)
  - A single 900MW phase construction may be 1 to 3 years.
  - The construction periods of each phase may partially overlap, be consecutive, or have a break in between phased construction.
  - The total programme for 1800MW is 3 to 10 years.

2.2.8 Foundation installation duration

40. It is expected that installation of all foundations would take up to a total of 12 months of activity over the whole construction period. There may be up to four piling vessels operating concurrently.

41. The worst case scenario for pile driving duration is based on the quadropod option due to this having the greatest number of piles. The piling duration is estimated to be 6 hours per foundation for a 7MW turbine and 12 hours for a 15 to 20MW turbine, allowing contingency for issues such as refusal. The duration of active piling is estimated to be 3 hours per foundation for a 7MW turbine and 6 hours for a 15 to 20MW turbine. The longest overall duration is associated with the maximum number of turbines (i.e. 257 x 7MW).

2.2.8.1 Offshore cable laying

42. Cable laying may take up to a total of 12 months of activity over the whole construction period, with up to two cable laying vessels used simultaneously.

2.2.8.2 Landfall

43. It is expected that landfall HDD works would take up to 30 weeks for HVAC or 10 weeks for HVDC. Cable pull-through will be undertaken subsequent to the duct installation.

2.2.9 Operation and Maintenance (O&M) Strategy

44. Once commissioned, the wind farm would operate for up to 25 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substations would be monitored and maintained during this period in order to maximise efficiency.

45. An estimate of the amount of potential maintenance work required, including vessel numbers and movements, will be provided in the PEIR/ES and included in the impact assessment. This will be based on anticipated planned maintenance as well as an estimated number of unplanned maintenance activities based on experience from other offshore wind farms. Maintenance work may be required to all elements of the offshore project described in Sections 2.2.1 to 2.2.3.

46. As discussed in Section 2.2.1, parameters of the floating foundation options are currently being reviewed by the VWPL engineering team and will be available for the EIA. The following operational parameters will be considered in order to assess the impact of floating foundations on ornithology during operation:

- Mooring line options;
    - Tension;
    - Catenary (with slack to allow the turbine to rise and fall with the tide);

- Mooring line material and diameter.

2.2.10 Decommissioning

47. Decommissioning would most likely involve the accessible installed components comprising: all of the wind turbine components; part of the foundations (those above sea bed level); and the sections of the inter-array cables close to the offshore structures, as well as sections of the export cables. The process for removal of foundations is generally the reverse of the installation process. Possible impacts to seabirds associated with the decommissioning stage(s) will be further considered as part of the EIA.

48. It is anticipated that a full EIA will be carried out ahead of any decommissioning works to be undertaken.

Table 2.3 Summary of worst case scenario impacts during each phase of the proposed development.

Impact	Parameter	Maximum worst case	
		HVAC	HVDC
Construction			
Disturbance from Vessels	Maximum number of vessels on site at any one time during construction	Maximum = 119 Average = 71 These numbers are based on all activities occurring concurrently which is unlikely but provides a conservative worst case scenario.	
	Indicative number of movements	TBC	
	Port locations	TBC	
Changes to prey resource	Impacts upon prey species	See Fish and Shellfish Ecology Method Statement	
Changes to water quality	Impacts on water quality which may impact prey species	See Marine Water and Sediment Quality Method Statement	
Operation and maintenance			
Collision Risk	Number of wind turbines	The worst case scenario in relation to collision risk will derive from the largest total rotor swept area, which relates to the largest number of turbines, i.e. 257 x 7MW turbines.	
Displacement / Barrier effects	Total wind farm footprint	TBC. This will depend on seabird distributions (from survey data) and turbine split between the East and West sites.	

Impact	Parameter	Maximum worst case	
		HVAC	HVDC
Disturbance from Vessels	Number of wind farm support vessel trips to site	TBC	
Impacts upon prey species	Impacts upon prey species	See Fish and Shellfish Ecology Method Statement	
Changes to water quality	Impacts on water quality which may impact prey species	See Marine Water and Sediment Quality Method Statement	
Decommissioning			
Disturbance from Vessels	Assumed to be similar vessel types, numbers and movements to construction phase (or less).		
Changes to prey resource	Impacts upon prey species	See Fish and Shellfish Ecology Method Statement	
Changes to water quality	Impacts on water quality which may impact prey species	See Marine Water and Sediment Quality Method Statement	

2.2.11 Cumulative Impact Scenarios

49. In addition to Norfolk Vanguard, Vattenfall is also developing the Norfolk Boreas offshore wind farm to the north of NV East, with the EIA following approximately a year behind the Norfolk Vanguard EIA.

50. The development of Norfolk Boreas will use the same offshore cable corridor as Norfolk Vanguard with the addition of a spur to the Norfolk Boreas site.

51. The full implications of the Norfolk Vanguard and Norfolk Boreas cumulative impact scenarios, as well as cumulative impacts with respect to other existing and planned projects (including, but not limited to, East Anglia One, East Anglia Three, East Anglia One North and East Anglia Two), will be fully considered as part of the EIA process.

52. The CIA will include any projects with any potential impacts occurring from the end of the project baseline, as detailed in the ES chapter, until the end of the project. Types of plans or projects to be taken into consideration are:

- Other wind farms;
- Aggregate extraction and dredging;
- Licensed disposal sites;
- Navigation and shipping;

- Planned construction sub-sea cables and pipelines;
- Potential port/harbour development; and
- Oil and gas operations.

53. Screening of specific plans and projects will follow a stepwise process defined below as:

a) Definition of a study area based on receptor ecology and/or footprint of impact (temporal and spatial).
    i. Spatial boundaries will take account both of the relevant spatial scales for individual receptors (foraging distances, migratory routes) and the spatial extent of environmental changes introduced by developments. These spatial boundaries will be analogous to the extent of the reference populations considered in the impact assessment.
    ii. Temporal boundaries will take account of the project life cycle and the receptor life cycles and recovery times.

b) Establish a source-pathway-receptor rationale. Projects will be screened out where no pathway exists, with clear justification to be provided. This screening process will be species specific.

54. These steps will lead to an initial list of potential projects which could have a cumulative impact with Norfolk Vanguard. The next stage of screening considers the plans or projects where sufficient information exists to undertake an assessment.

55. The CIA will consider projects, plans and activities which have sufficient information available in order to undertake the assessment. Insufficient information will preclude a meaningful quantitative assessment, and it is not appropriate to make assumptions about the detail of future projects in such circumstances. The focus of the assessment will therefore be on those projects or activities where sufficient relevant information exists. Whilst other projects may be acknowledged within the assessment, in the case of inadequate information it is up to the regulator to judge how to take these into account. It is likely that plans or projects with sufficient information to include in the CIA include wind farms at various stages of development. A second screening process will follow a tiered approach analogous to that outlined by Joint Nature Conservation Committee (JNCC) and Natural England (undated) in the document 'Suggested Tiers for Cumulative Impact Assessment'.

Table 2.2 Suggested tiers for undertaking a staged cumulative impact assessment (JNCC and Natural England)

Tier Description	Consenting or Construction Phase	Data Availability
Tier 1	Built and operational projects should be included within the cumulative assessment where they have not been included within the environmental characterisation survey, i.e. they were not operational when baseline surveys were undertaken, and/or any residual impact may not have yet fed through to and been captured in estimates of "baseline" conditions e.g. "background" distribution or mortality rate for birds.	Pre-construction (and possibly post-construction) survey data from the built project(s) and environmental characterisation survey data from proposed project (including data analysis and interpretation within the ES for the project).
Tier 2	Projects under construction	As Tier 1 but not including post-construction survey data
Tier 3	Projects that have been consented (but construction has not yet commenced)	Environmental characterisation survey data from proposed project (including data analysis and interpretation within the ES for the project) and possibly pre-construction
Tier 4	Projects that have an application submitted to the appropriate regulatory body that have not yet been determined	Environmental characterisation survey data from proposed project (including data analysis and interpretation within the ES for the project)
Tier 5	Projects that the regulatory body are expecting an application to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects)	Possibly environmental characterisation survey data (but strong likelihood that this data will not be publicly available at this stage).
Tier 6	Projects that have been identified in relevant strategic plans or programmes (e.g. projects identified in Round 3 wind farm zone appraisal and planning (ZAP) documents)	Historic survey data collected for other purposes/by other projects or industries or at a strategic level.

56. Each plan or project will be assigned to a tier. The CIA will include all projects classed in tiers 1 to 4 in the assessment as a realistic scenario. Consideration will also be given to projects assigned to tier 5, and this may include projects where there is additional uncertainty regarding their potential impacts. CIA screening will be undertaken in consultation with stakeholders.

57. Following submission of the PEIR, reviews will be undertaken to ensure that any new information is incorporated into the CIA. Once issues, plans or projects have been scoped out and agreed there must be a strong justification for scoping them back in again, and this will be agreed with statutory consultees.

58. Given the fast moving nature of offshore development and assessment methods, it is likely that new projects relevant to the assessment will arise throughout the pre-application period. In order to finalise an assessment, it will be necessary to have a cut-off period after which no more projects will be included. A reasonable cut-off point would be the date of receipt of comments upon the PEIR.

2.2.12 Transboundary Impact Scenarios

59. There is the potential for transboundary impacts on breeding seabirds from colonies outside the UK but within foraging range of the proposed developments, and also on passage migrants. These will be investigated in consultation with the relevant countries' agencies.

3 BASELINE ENVIRONMENT

3.1 Desk Based Review

60. A desk based review of the seabird populations of the southern North Sea will be included as background to the impact assessment. This will include consideration of various sources of ornithological data, including (but not limited to):

- The results of seabird tagging programmes conducted at Flamborough and Filey Coast pSPA (e.g. gannet and kittiwake tracking projects undertaken by the RPSB for the FAME and STAR projects), tagging of lesser black-backed gulls from the Alde-Ore Estuary SPA by the BTO;
- Seabird distribution information, such as SeaMAST, Stone et al. (1995), the UK Bird Atlas (http://app.bto.org/mapstore/StoreServlet);

3.1.1 Available Data

61. The primary source of data for characterising the baseline environment will be from digital aerial surveys of the wind farm sites and 4km buffers (see section 1.2.3 and Tables 1.1 and 1.2).

62. As well as data from large scale seabird surveys of the North Sea (e.g. Stone et al. 1995), the publicly available data for other East Anglia Zone wind farms (East Anglia ONE and East Anglia THREE) will be used to inform the impact assessment.

63. No dedicated surveys are planned for the offshore cable corridor, however as effects resulting from cable laying operations will be short term and localised, this aspect will be assessed on the basis of existing seabird data (as noted above).

3.1.2 Designated sites

64. The Habitats Regulations Assessment will consider the potential for connectivity between the wind farm sites and species recorded during surveys. An initial long list of SPAs will be screened for connectivity, Recent experience of wind farm assessments in this zone suggests that the following Special Protection Areas (SPAs)

and features will require assessment for the potential for Likely Significant Effects (LSE):

- Alde-Ore Estuary SPA (lesser black-backed gull)
- Outer Thames Estuary SPA (red-throated diver)
- Greater Wash pSPA (red-throated diver, little gull)
- Flamborough and Filey Coast pSPA (gannet, kittiwake)

3.2 Planned Data Collection

65. Monthly digital aerial surveys of the Norfolk Vanguard East and West sites commenced in September 2015. In agreement with Natural England, surveys of the Norfolk Vanguard East site were completed in April 2016. Surveys of the Norfolk Vanguard West site continued and are due to be completed in April 2017.

4 IMPACT ASSESSMENT METHODOLOGY

4.1 Defining Impact Significance

66. A matrix approach will be used to assess impacts following best practice, EIA guidance and the approach previously agreed with stakeholders for other recent offshore wind farms (e.g. East Anglia THREE). Receptor sensitivity for an individual from each species will be defined within the ES, following definition's set out in Table 4.1. The conservation value of each receptor species or population will be defined as per Table 4.2. The potential magnitude of effect will be described for permanent and temporary outcomes, as detailed in Table 4.3. The significance of impacts will be assessed using the matrix presented in Table 4.4.

4.1.1 Sensitivity

67. The sensitivity of a receptor is determined through its ability to accommodate change and reflects on its ability to recover if it is affected. The sensitivity level of marine mammals to each type of impact is justified within the impact assessment and is dependent on the following factors:

- Adaptability – The degree to which a receptor can avoid or adapt to an effect;
- Tolerance – The ability of a receptor to accommodate temporary or permanent change without a significant adverse effect;
- Recoverability – The temporal scale over and extent to which a receptor will recover following an effect; and
- Value – A measure of the receptors importance, rarity and worth (see below).

Table 4.1 Definitions of the sensitivity levels for offshore ornithology

Sensitivity	Definition
High	Bird species has very limited tolerance of sources of disturbance such as noise, light, vessel movements and the sight of people
Medium	Bird species has limited tolerance of sources of disturbance such as noise, light, vessel movements and the sight of people
Low	Bird species has some tolerance of sources of disturbance such as noise, light, vessel movements and the sight of people
Negligible	Bird species is generally tolerant of sources of disturbance such as noise, light, vessel movements and the sight of people

4.1.2 Conservation Value

68. In addition, the 'value' of the receptor forms an important element within the assessment, for instance, if the receptor is a protected species or judge to be part of a protected population. It is important to understand that high conservation value and high sensitivity are not necessarily linked within a particular impact. A receptor could be of high conservation value (e.g. a component of an SPA) but have a low or negligible physical/ecological sensitivity to an effect and vice versa. Similarly, low value does not equate to low sensitivity and is judged on a receptor by receptor basis. The potential significance of an impact is not simply increased because a feature has a higher value, just as impact significance will not be decreased for species judged to be of lower value. Obviously, the basis for these determinations is important, and will be included in the assessment.

69. The conservation value of ornithological receptors is based on the population from which the individuals are drawn. This reflects the current understanding of the movements of species, with site based protection (e.g. SPAs) generally limited to specific periods of the year (e.g. the breeding season). Therefore, conservation value can vary through the year depending on the relative sizes of the number predicted to be at risk of impact and the population from which they are estimated to be drawn. Ranking therefore corresponds to the degree of connectivity which is predicted between the wind farm site and protected populations. Using this approach the conservation importance of a species seen at different times of year may fall into any of the defined categories (Table 4.2).

Table 4.2 Definitions of the conservation value levels for offshore ornithology

Value	Definition
High	A species for which individuals at risk can be clearly connected to a particular SPA.
Medium	A species for which individuals at risk are probably drawn from particular SPA populations, although other colonies (both SPA and non-SPA) may also contribute to individuals observed on the wind farm.
Low	A species for which it is not possible to identify the SPAs from which individuals on the wind farm have been drawn, or for which no SPAs have been designated.

4.1.3 Magnitude

70. The definitions of the magnitude levels for ornithology receptors are set out in Table 4.3. This set of definitions has been determined on the basis of changes to bird populations.

Table 4.3 Definitions of magnitude levels for offshore ornithology

Magnitude	Definition
High	A change in the size or extent of distribution of the relevant biogeographic population or the population that is the interest feature of a specific protected site that is predicted to irreversibly alter the population in the short-to-long term and to alter the long-term viability of the population and / or the integrity of the protected site. Recovery from that change predicted to be achieved in the long-term (i.e. more than 5 years) following cessation of the development activity.
Medium	A change in the size or extent of distribution of the relevant biogeographic population or the population that is the interest feature of a specific protected site that occurs in the short and long-term, but which is not predicted to alter the long-term viability of the population and / or the integrity of the protected site. Recovery from that change predicted to be achieved in the medium-term (i.e. no more than five years) following cessation of the development activity.
Low	A change in the size or extent of distribution of the relevant biogeographic population or the population that is the interest feature of a specific protected site that is sufficiently small-scale or of short duration to cause no long-term harm to the feature / population. Recovery from that change predicted to be achieved in the short-term (i.e. no more than one year) following cessation of the development activity.
Negligible	Very slight change from the size or extent of distribution of the relevant biogeographic population or the population that is the interest feature of a specific protected site. Recovery from that change predicted to be rapid (i.e. no more than circa 6 months) following cessation of the development related activity.
No change	No loss of, or gain in, size or extent of distribution of the relevant biogeographic population or the population that is the interest features of a specific protected site.

4.1.4 Significance

71. Following the identification of receptor sensitivity and value and the determination of the magnitude of the effect, the impact significance will be determined using expert judgement. The matrix (provided in **Error! Reference source not found.**) will be used as a framework to aid determination of the impact assessment. Definitions of impact significance are provided in **Error! Reference source not found.**

Table 4.4 Impact Significance Matrix

Sensitivity	Magnitude				
	High	**Medium**	**Low**	**Negligible**	**No change**
High	Major	Major	Moderate	Minor	No change
Medium	Major	Moderate	Minor	Minor	No change
Low	Moderate	Minor	Minor	Negligible	No change
Negligible	Minor	Negligible	Negligible	Negligible	No change

Table 4.5 Impact Significance Definitions

Impact Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or, could result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issues but are unlikely to be important in the decision-making process.
Negligible	No discernible change in receptor condition.
No change	No impact, therefore no change in receptor condition.

72. Note that for the purposes of the EIA, major and moderate impacts are deemed to be significant. In addition, whilst minor impacts are not significant in their own right, it is important to distinguish these from other non-significant impacts as they may contribute to significant impacts cumulatively or through interactions.

4.2 Potential Impacts

73. For each potential impact described below, a screening exercise will be conducted to identify those species most likely to be at risk. Species with low sensitivity to the impact, or recorded in very low numbers will be screened out of further assessment.

74. For all impacts, consideration will be given to:

- The most appropriate population scale for assessment (drawing on a review of alternative population scales, Appendix 2);
- The appropriate seasonal definitions for assessment of impacts at the Norfolk Vanguard site, allowing for migratory movements (Appendix 3); and
- The most appropriate means to estimate population impacts using population models which incorporate density dependence (Appendix 4; NB only ornithological impacts for which additional assessment is necessary will be assessed using population models).

75. The methods for establishing the baseline site characterisation and for conducting the impact assessment will be discussed with statutory consultees during the Evidence Plan process.

4.2.1 Potential Impacts during Construction

4.2.1.1 Impact: Direct Disturbance and Displacement

76. The construction phase of the proposed project has the potential to affect bird populations in the marine environment through disturbance due to construction activity leading to displacement of birds from construction sites. This would effectively result in temporary habitat loss through reduction in the area available for feeding, loafing and moulting.

77. Construction activity to be assessed will include that for the wind farm itself and also for the offshore cable (as noted in the Norfolk Vanguard Scoping Opinion, PINS ref: EN010079).

4.2.1.1.1 Approach to assessment

78. There are a number of different measures used to assess bird disturbance and displacement from areas of sea in response to activities associated with an offshore wind farm. Garthe and Hüppop (2004) developed a scoring system for such disturbance factors, which is used widely in offshore wind farm EIAs. Furness and Wade (2012) developed disturbance ratings for particular species, alongside scores for habitat flexibility and conservation importance. These factors were used to define an index value that highlights the sensitivity of a species to disturbance and displacement. As many of these references relate to disturbance from helicopter and vessel activities, these are considered relevant to this assessment.

79. For species at risk of displacement during the nonbreeding season, consideration will be given to a proposed approach for standardising assessments (i.e. to account for different numbers of nonbreeding seasons; Appendix 5).

80. Assessment of disturbance and displacement during offshore cable installation activity will be focussed on the potential effects on sensitivity species (such as red-throated diver) resulting from temporary displacement around the vessels involved. Data sources for this assessment will include the surveys used to underpin the proposed Greater Wash pSPA.

4.2.1.2 Impact: Indirect impacts through effects on habitats and prey species

81. Indirect disturbance and displacement of birds may occur during the construction phase if there are impacts on prey species and the habitats of prey species. These indirect effects include those resulting from the production of underwater noise (e.g. during piling) and the generation of suspended sediments (e.g. during preparation of the seabed for foundations) that may alter the behaviour or availability of bird prey species. Underwater noise may cause fish and mobile invertebrates to avoid the construction area and also affect their physiology and behaviour. Suspended sediments may cause fish and mobile invertebrates to avoid the construction area and may smother and hide immobile benthic prey. These mechanisms result in less prey being available within the construction area to foraging seabirds.

4.2.1.2.1 Approach to assessment

82. This aspect will be informed by the Benthic Ecology assessment and Fish and Shellfish assessment, with any significant impacts on prey species used to inform the potential for knock-on effects on seabirds.

4.2.2 Potential Impacts during O&M

4.2.2.1 Impact: Direct Disturbance and Displacement

83. The presence of wind turbines has the potential to directly disturb and displace birds from within and around the Norfolk Vanguard sites. This is assessed as an indirect habitat loss, as it has the potential to reduce the area available to birds for feeding, loafing and moulting. Vessel activity and the lighting of wind turbines and associated ancillary structures could also attract (or repel) certain species of birds and affect migratory behaviour on a local scale.

84. Seabird species vary in their reactions to the presence of operational infrastructure (e.g. wind turbines, substations and met mast) and to the maintenance activities that are associated with it (particularly ship and helicopter traffic), with Garthe and Hüppop (2004) presenting a scoring system for such disturbance factors, which is used widely in offshore wind farm EIAs. As offshore wind farms are a new feature in the marine environment, there is limited evidence as to the disturbance and displacement effects of the operational infrastructure in the long term.

4.2.2.1.1 Approach to assessment

85. Natural England and JNCC issued a joint Interim Displacement Guidance Note (Natural England and JNCC 2012), which provides recommendations for presenting information to enable the assessment of displacement effects in relation to offshore wind farm developments. This guidance note will be used to shape the assessment.

86. There are a number of different measures used to determine bird displacement from areas of sea in response to activities associated with an offshore wind farm. Furness and Wade (2012), for example, use disturbance ratings for particular species, alongside scores for habitat flexibility and conservation importance to define an index value that highlights the sensitivity to disturbance and displacement. These authors also recognise that displacement may contribute to individual birds experiencing fitness consequences, which at an extreme level could lead to the mortality of individuals.

87. A matrix approach will be used to calculate a range of predicted impact magnitudes. This method is the same as that used in recent offshore wind farm assessments (e.g. East Anglia THREE) and which Natural England advise should be used.

88. For species at risk of displacement during the nonbreeding season, consideration will be given to a proposed approach for standardising assessments (i.e. to account for different numbers of nonbreeding seasons; Appendix 5).

4.2.2.2 Impact: Indirect Impacts Through Effects on Habitats and Prey Species

89. Indirect disturbance and displacement of birds may occur during the operational phase if there are impacts on prey species and the habitats of prey species. These indirect effects include those resulting from the production of underwater noise (e.g. the turning of the wind turbines), electro-magnetic fields (EMF) and the generation of suspended sediments (e.g. due to scour or maintenance activities) that may alter the behaviour or availability of bird prey species. Underwater noise and EMF may cause fish and mobile invertebrates to avoid the operational area and also affect their physiology and behaviour. Suspended sediments may cause fish and mobile invertebrates to avoid the operational area and may smother and hide immobile benthic prey. These mechanisms could result in less prey being available within the operational area to foraging seabirds. Changes in fish and invertebrate communities due to changes in presence of hard substrate (resulting in colonisation by epifauna) may also occur, and changes in fishing activity could influence the communities present.

4.2.2.2.1 Approach to assessment

90. This aspect will be informed by the Benthic Ecology assessment and Fish and Shellfish assessment, with any significant impacts on prey species used to inform the potential for knock-on effects on seabirds.

4.2.2.3 Impact: Collision Risk

91. There is a potential risk of collision with the wind turbine rotors and associated infrastructure resulting in injury or fatality to birds which fly through the Norfolk Vanguard site whilst foraging for food and commuting between breeding sites and foraging areas.

4.2.2.3.1 Approach to assessment

92. Collision Risk Modelling (CRM) using the Band Model Options 1 or 2 (Band 2012) will be used in this assessment to estimate the risk to birds associated with the proposed project (the choice of which option, 1 or 2, will be dependent on the species-specific sample sizes of flight heights obtained from the surveys). Full details of the data used and the modelling methods will be provided in the ES and supporting technical reports.

4.2.2.4 Impact: Barrier Effect

93. The presence of the proposed Norfolk Vanguard project could potentially create a barrier to bird migratory and foraging routes, and as a consequence, the proposed project has the potential to result in long-term changes to bird movements. It has been shown that some species (divers and scoters) avoid wind farms by making detours around wind turbine arrays which potentially increases their energy expenditure (Petersen et al. 2006; Petersen and Fox 2007) and potentially decreases survival chances. Such effects may have a greater impact on birds that regularly commute around a wind farm (e.g. birds heading to / from foraging grounds and roosting / nesting sites) than migrants that would only have to negotiate around a wind farm once per migratory period, or twice per annum, if flying the same return route (Speakman et al. 2009).

4.2.2.4.1 Approach to assessment

94. The potential for the wind farm to act as a barrier will be assessed for all potential sensitive receptors.

4.2.3 Potential Impacts during Decommissioning

4.2.3.1 Impact: Direct Disturbance and Displacement

95. Disturbance and displacement is likely to occur due to the presence of working vessels and crews and the movement and noise associated with these.

4.2.3.1.1 Approach to assessment

96. Such activities will be expected to have similar or lower magnitudes as for this effect during construction. Therefore, the same approach will be adopted.

4.2.3.2 Impact: Indirect Impacts Through Effects on Habitats and Prey Species

97. Indirect effects such as displacement of seabird prey species is likely to occur as structures are removed.

4.2.3.2.1 Approach to assessment

98. Such activities will be expected to have similar or lower magnitudes as for this effect during construction. Therefore, the same approach will be adopted.

4.2.4 Potential Cumulative Impacts

99. The impacts identified above for the Norfolk Vanguard project alone will be assessed for the potential to create cumulative impacts. At this stage it is anticipated that the most likely cumulative impacts will be operational disturbance and displacement and collision risk.

4.2.4.1 Impact: Operational Disturbance and Displacement

100. There is a potential that the Norfolk Vanguard wind farm to contribute to a cumulative displacement impact.

4.2.4.1.1 Approach to assessment

101. Cumulative displacement will be assessed taking into account the relevant biological scales for those species screened in for this impact. Relevant impact magnitude data from other wind farms which are considered likely to contribute to effects on the same population will be included in the assessment.

4.2.4.2 Impact: Collision Risk

102. There is a potential that the Norfolk Vanguard wind farm to contribute to a cumulative collision risk impact.

4.2.4.2.1 Approach to assessment

103. Cumulative collision risk will be assessed taking into account the relevant biological scales for those species screened in for this impact. Relevant impact magnitude data from other wind farms which are considered likely to contribute to effects on the same population will be included in the assessment.

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Petersen, I.K. & Fox, A.D. (2007). Changes in bird habitat utilisation around the Horns Rev 1 offshore windfarm, with particular emphasis on Common Scoter Report Commissioned by Vattenfall

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APPENDIX 1. BASELINE SEABIRD DATA FOR NORFOLK VANGUARD

This note provides an overview of the seabird abundance data collected to date for the Norfolk Vanguard East and West wind farm sites. To provide context, the data are presented alongside the survey data collected for the East Anglia ONE, THREE and FOUR sites (the last of which was almost identical in extent to the current Norfolk Vanguard East site).

Only the species expected to be the primary focus for the wind farm assessments have been selected for presentation here: red-throated diver, gannet, kittiwake, lesser black-backed gull, great black-backed gull, herring gull, guillemot and razorbill. For each species, a figure is presented of the average abundance on each of the five wind farms (plus 4km buffer) in each month, without correction for area (although note the wind farms are comparable in size). It should be noted that for the Norfolk Vanguard sites only one nonbreeding season was available at the time this note was prepared. In summary, the data used were:

- East Anglia ONE: Nov 2009 – Oct 2011
- East Anglia THREE: Sep 2011 – Aug 2013
- East Anglia FOUR: Mar 2012 – Feb 2014
- Norfolk Vanguard East: Sep 2015 – Apr 2016
- Norfolk Vanguard West: Sep 2015 – Apr 2016

As agreed with Natural England (21st March 2016), no further surveys are required for Norfolk Vanguard East. Surveys for Norfolk Vanguard West continued after April 2016 and are due to be completed in April 2017 (see further discussion on this below). A map illustrating the relative locations of the five wind farm sites is provided in Figure A1.1.

Monthly abundance estimates for East Anglia Zone wind farms

The following figures provide the estimated monthly abundance (i.e. following extrapolation from the surveyed area to the total area) for the key species, estimated across the wind farm sites and their respective 4k buffers, and includes birds on the water and in flight (note that no correction has been applied for diving species being underwater during the surveys).

For all species, similar patterns of abundance can be seen across the five wind farm sites, with abundance peaking in the nonbreeding seasons. For most species, this reflects either passage movements (e.g. gannet) or over-wintering (e.g. red-throated diver). Species-specific features are noted below each figure. Note that unidentified guillemots and razorbills have been added to each species totals using the average proportion of known individuals present on the site in question.

It should also be noted that the abundance estimates for the two Norfolk Vanguard sites and the East Anglia FOUR data which will be used in the impact assessment will be calculated using spatial modelling and therefore the final abundance estimates may change slightly from the preliminary values provided here. Records for all species observed will be provided in the final assessment.

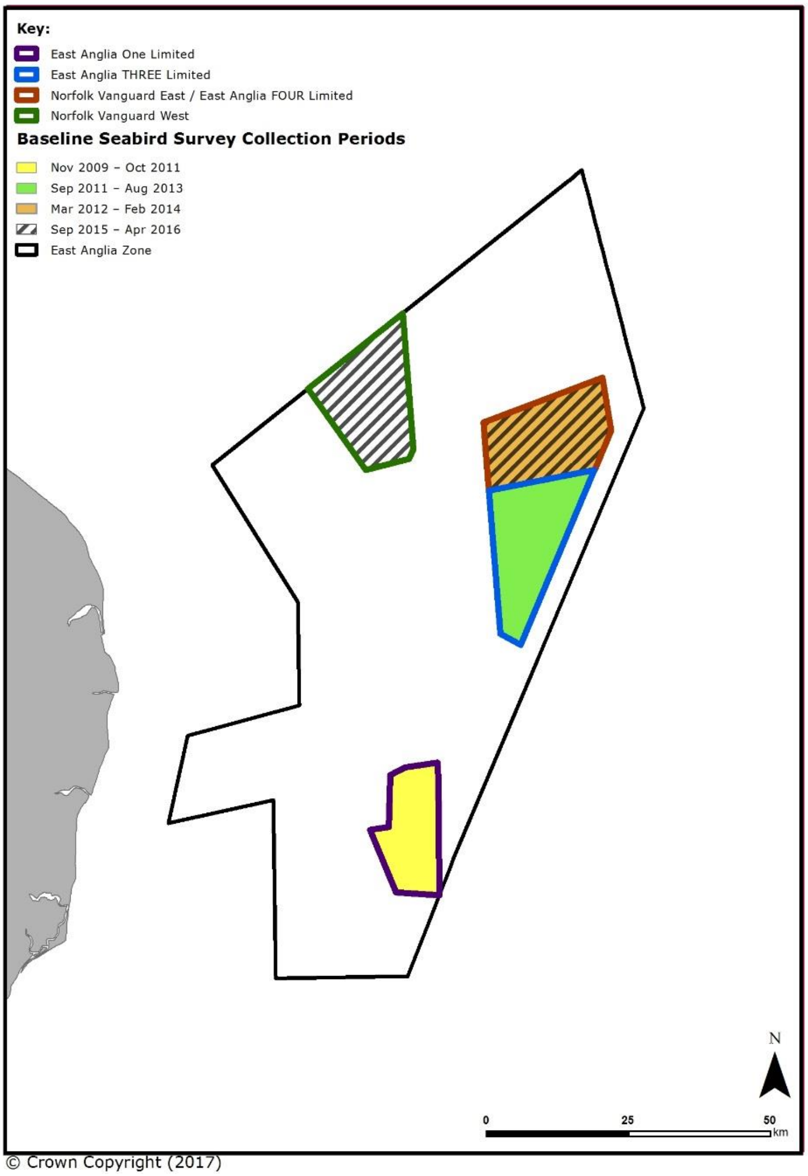
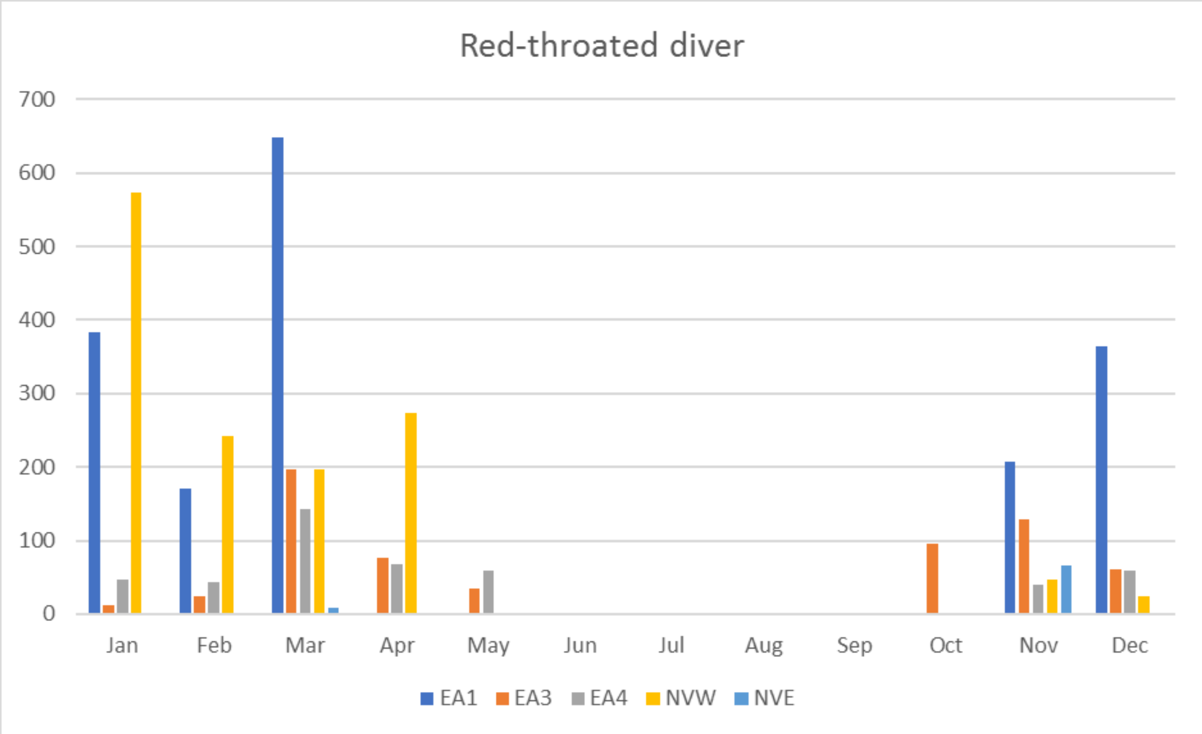


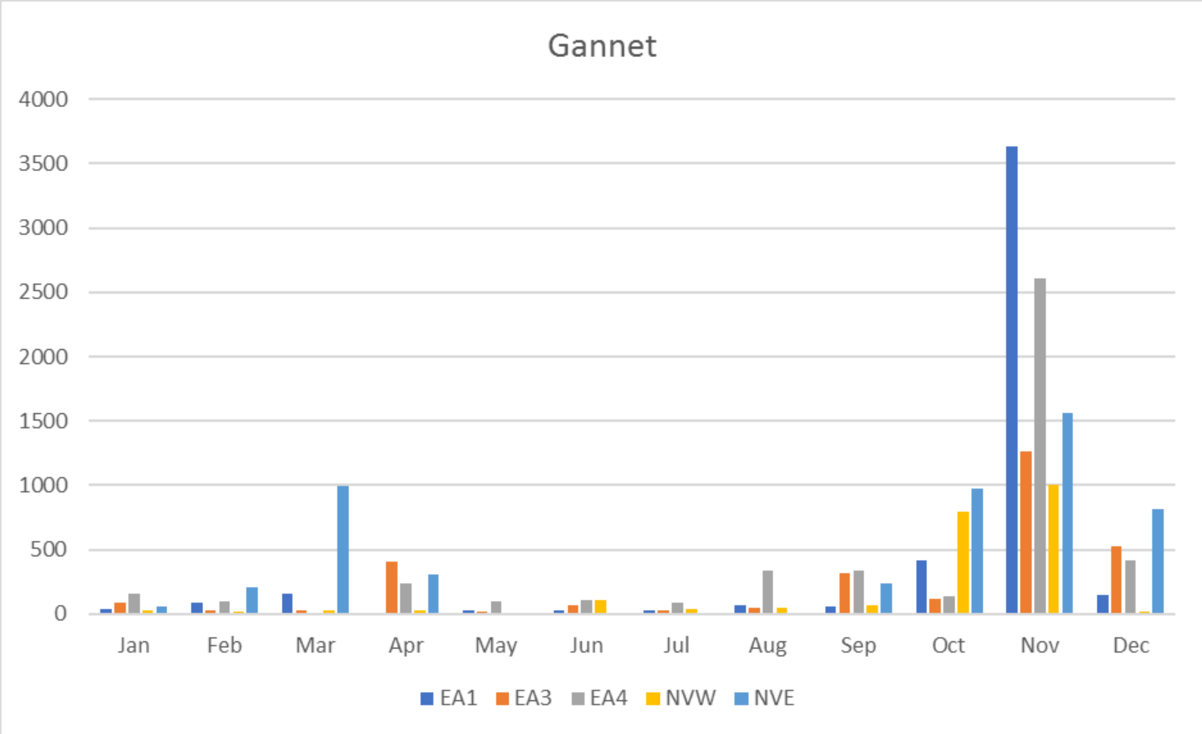
Figure A1.1. Map of East Anglia zone wind farm survey data to be used to define the Norfolk Vanguard seabird baseline.

Red-throated diver



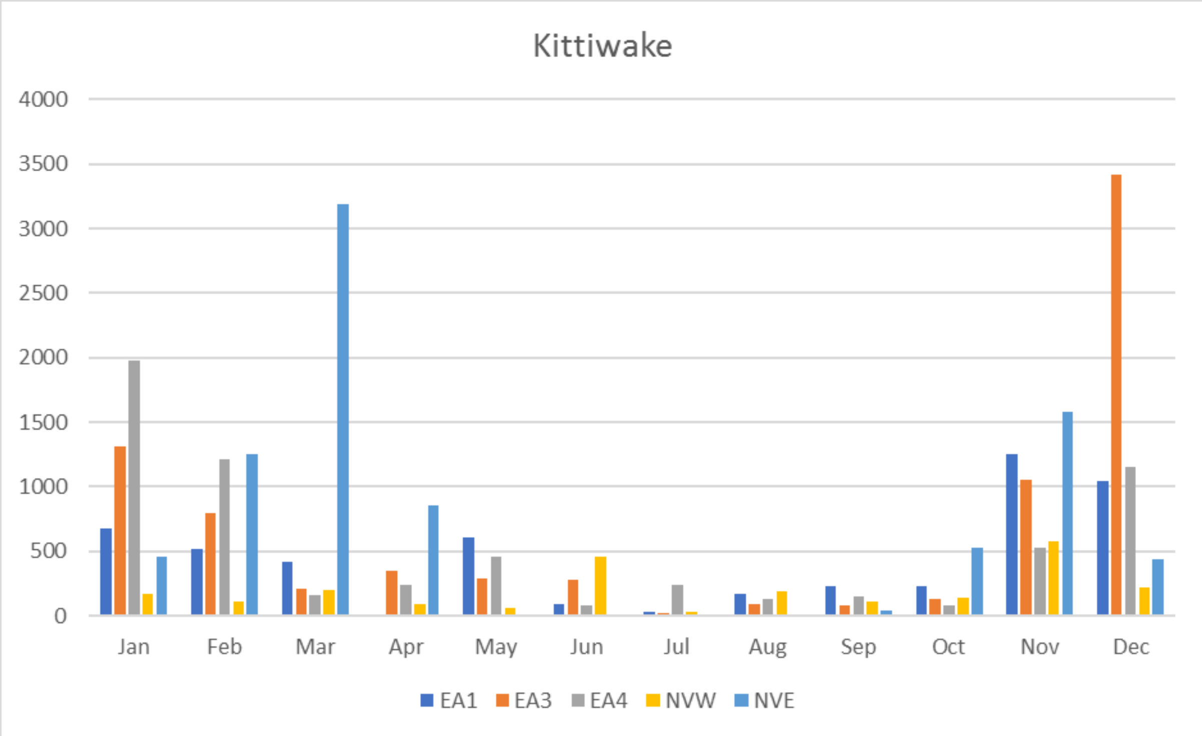
The seasonal pattern of red-throated diver abundance is consistent across all the sites, with no individuals observed between June and September. There is an indication of a difference between the sites within each month on the basis of proximity to the coast, with the sites closer to shore (EA1 and NVW) having higher numbers in most months. This is expected given the species' preference for shallower waters.

Gannet



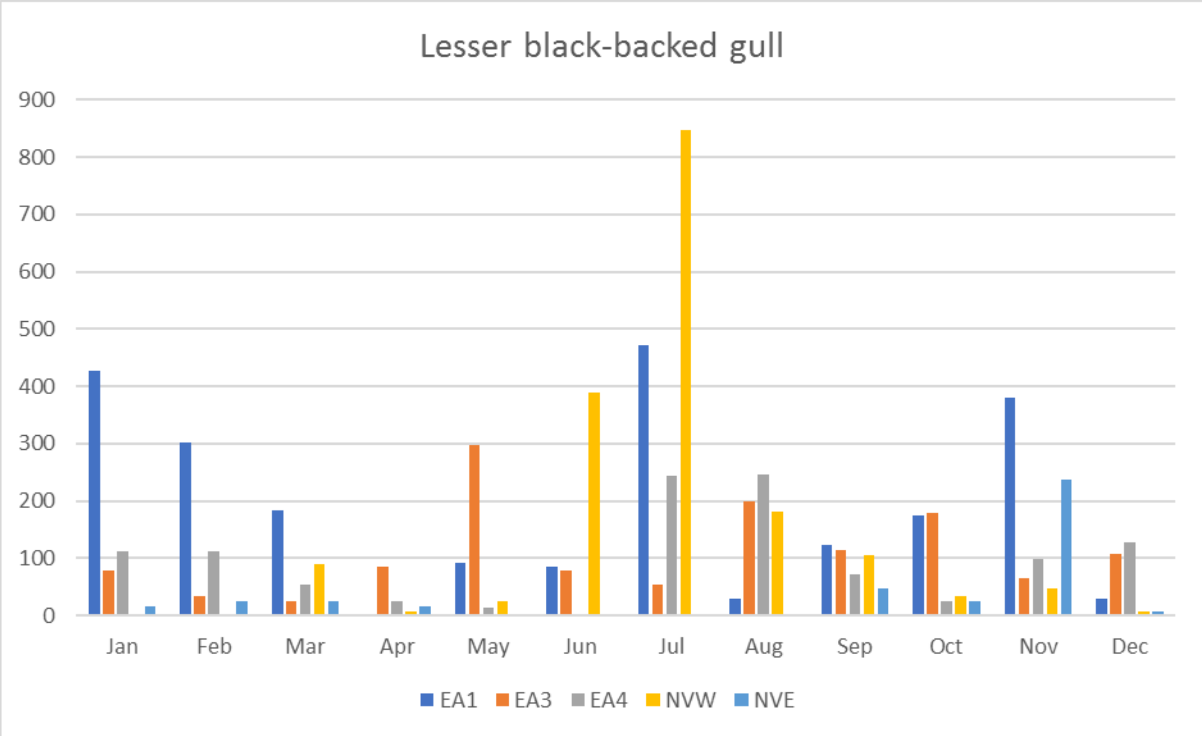
The pattern of gannet observations is very similar across all the sites, with the highest numbers seen in November, followed by October and December. There is a suggestion of a second peak in March and April, but otherwise gannets were recorded in low numbers during the remainder of the year. This is consistent with migratory movements through the southern North Sea, with birds travelling to and from breeding colonies to the north.

Kittiwake



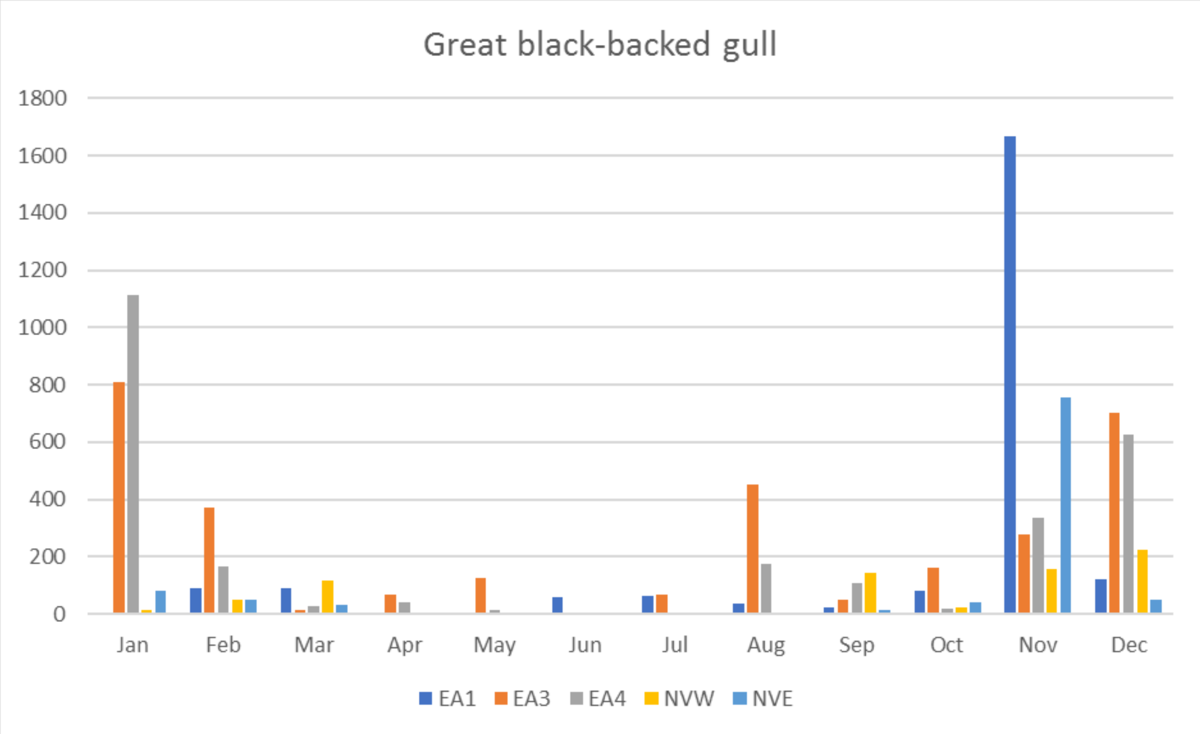
Kittiwake shows a similar pattern of migration movement to gannet, and the pattern across sites was also very similar. There is, however, a less pronounced difference between months, and a spring peak (Jan-May) that is similar in size to the autumn peak (Oct-Dec).

Lesser black-backed gull



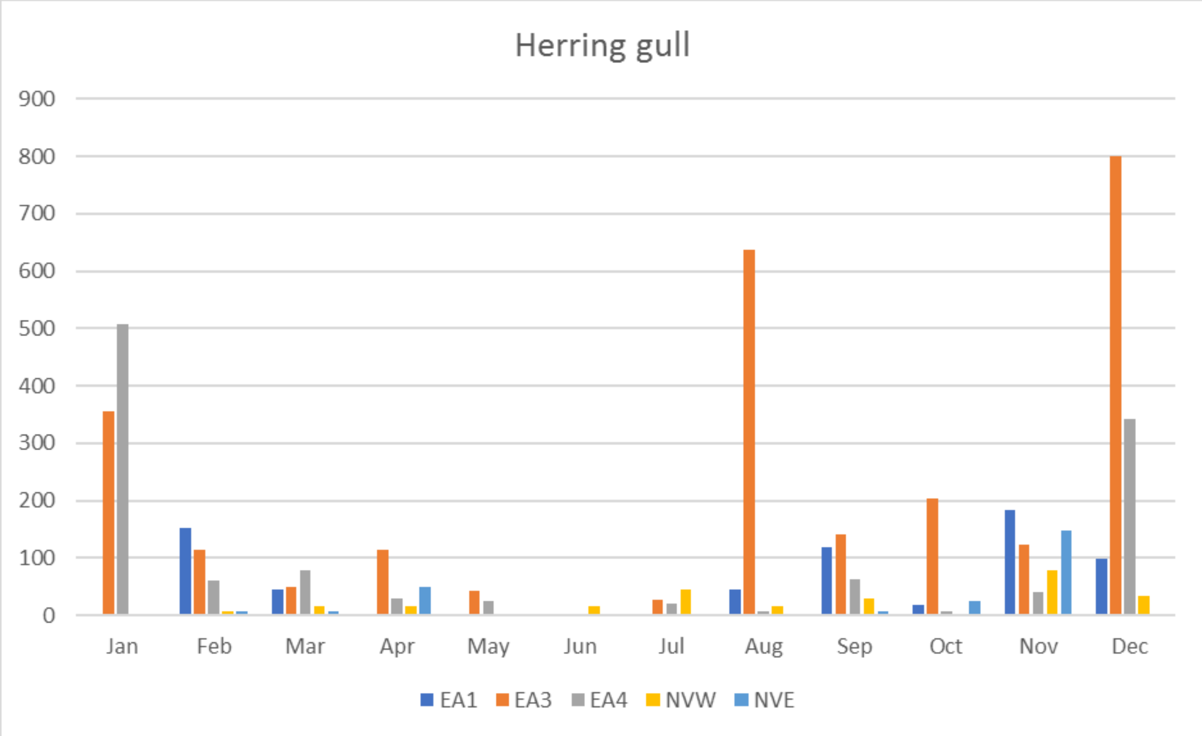
The pattern of lesser black-backed gull abundance shows the greatest variation across the wind farms of all the species presented here. East Anglia ONE had consistently high numbers in most months, which perhaps reflects its proximity to the Alde-Ore Estuary SPA. However, it is notable that numbers do not peak in the early and middle breeding season months (April – June), which suggests that connectivity with the SPA is not as clear-cut as might be assumed. Indeed, although the highest numbers were recorded in July, it is otherwise difficult to pick out an obvious peak period for this species. Occasional peak counts might possibly be related to levels of trawler fishing activity as this species tends to scavenge on discards behind fishing vessels.

Great black-backed gull



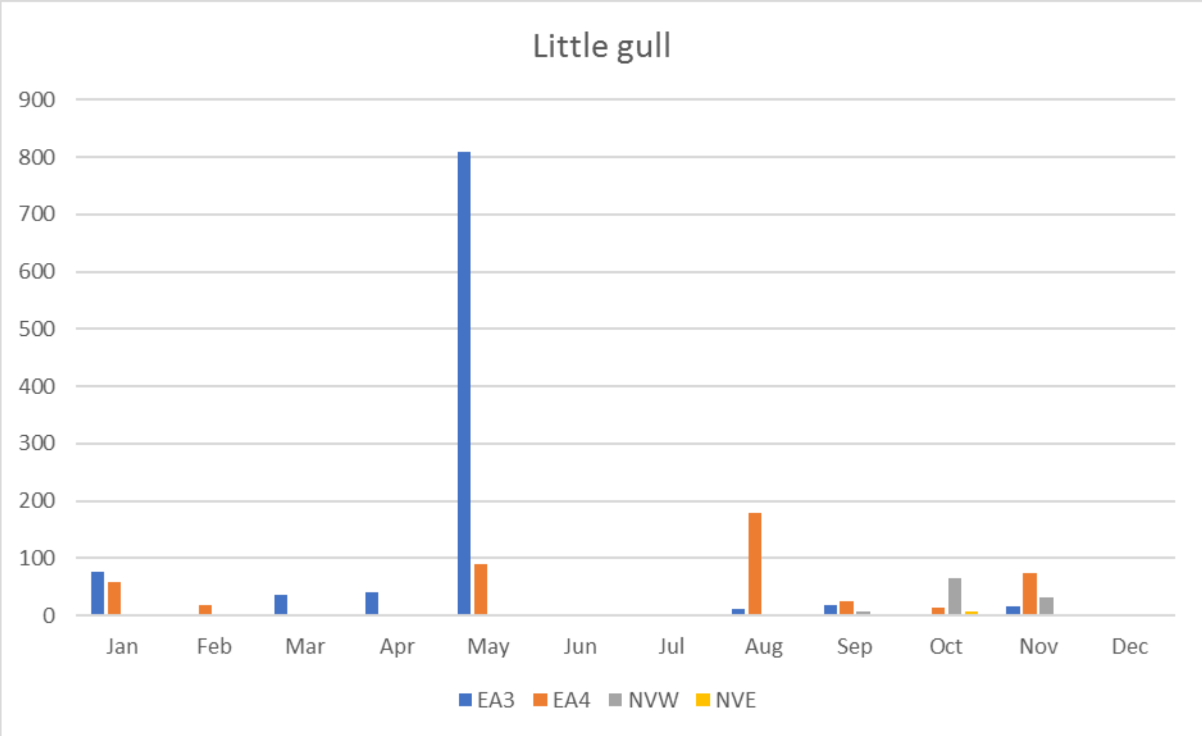
The seasonal patterns of great black-backed gull abundance are very similar across the sites, with numbers peaking between November and January. Outside of these months, numbers were mostly very low and the species was often absent on surveys between April and July. Occasional peak counts might possibly be related to levels of trawler fishing activity as this species tends to scavenge on discards behind fishing vessels.

Herring gull



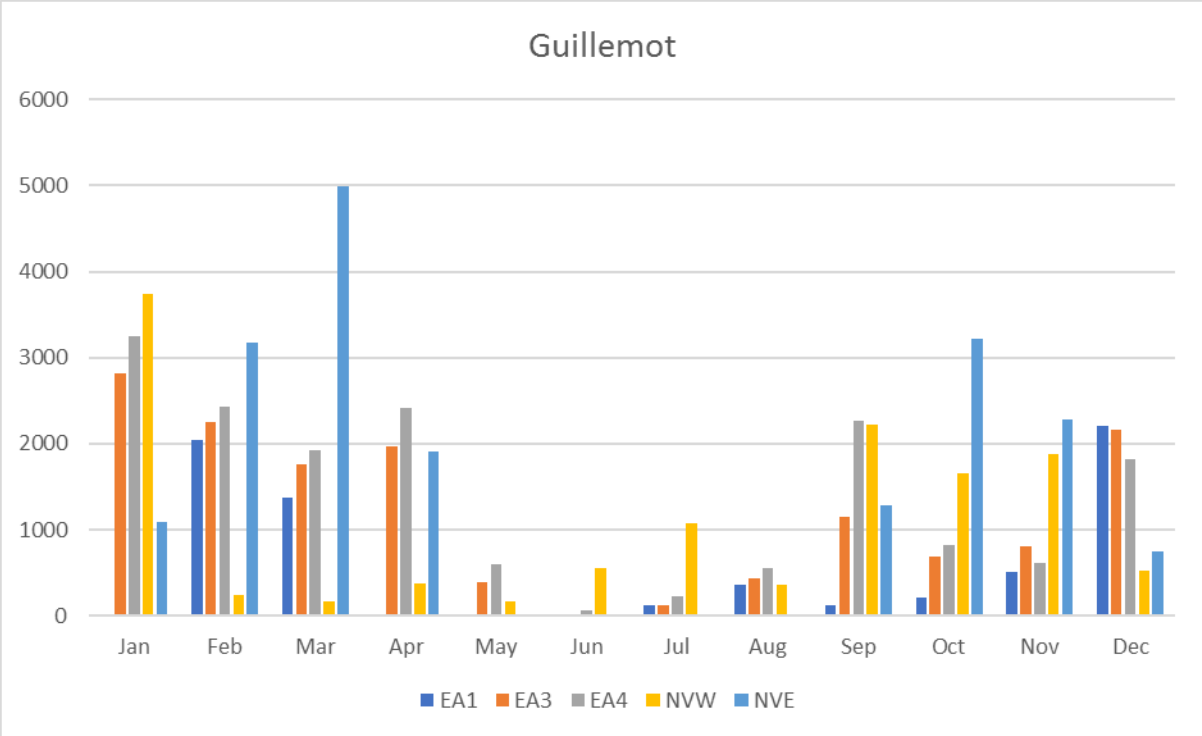
Herring gull shows a similar seasonal pattern to great black-backed gull, although overall numbers were generally around half that of the latter species. Occasional peaks were recorded, primarily on East Anglia THREE, but otherwise no clear patterns are present. Occasional peak counts might possibly be related to levels of trawler fishing activity as this species tends to scavenge on discards behind fishing vessels.

Little gull



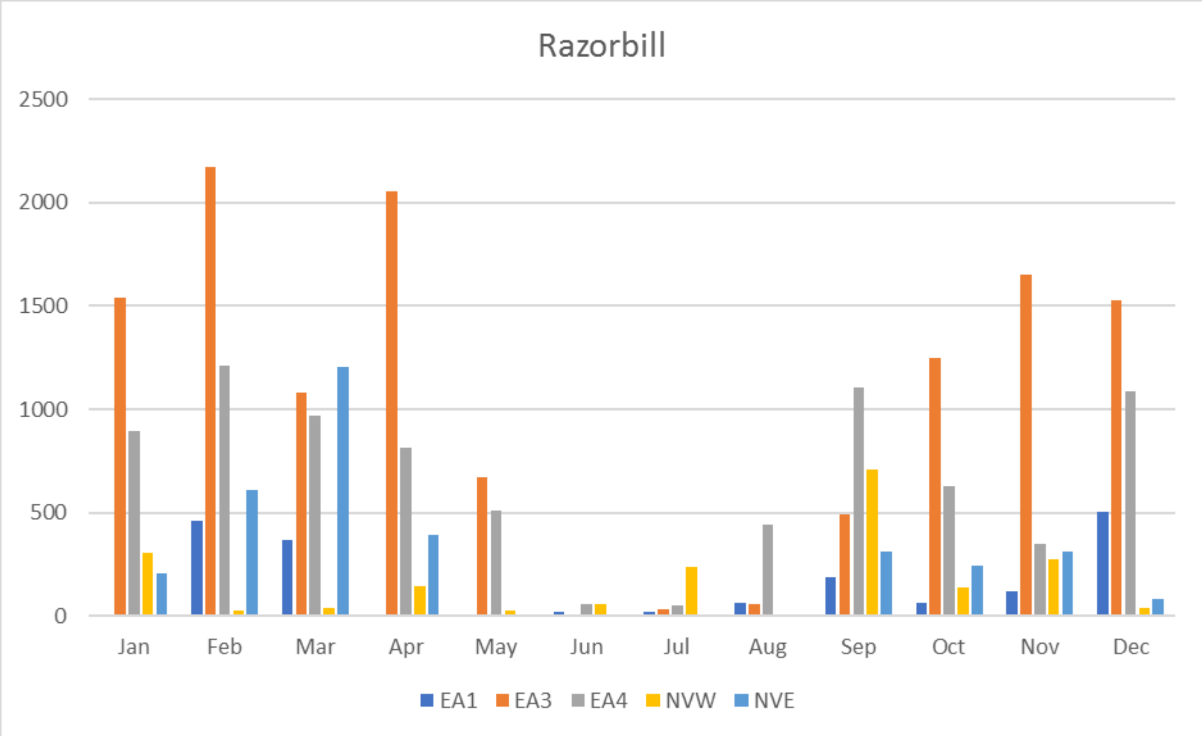
Little gull is a passage migrant in the UK North Sea. As such, with one exception, it was recorded occasionally and in small numbers (note little gull was not identified as a species for East Anglia ONE, but are likely to have been included in the 'small gull' category). A large number were estimated on East Anglia THREE in May 2013 (although this was based on an observation of 37 individuals).

Guillemot



Common guillemot is the most abundant species overall, and is present in perhaps the most similar numbers across the sites through the year. June had the lowest abundance, with numbers building from late summer to peaks in mid to late winter, before declining through the spring.

Razorbill



Razorbill shows a very similar seasonal pattern to common guillemot, which is to be expected given their similar life-histories. However, razorbill does show greater variation between the sites than guillemot. There is also a suggestion of complementary abundance of the two species on the East Anglia THREE and Norfolk Vanguard East sites, with razorbill peaking on the former and guillemot on the latter.

Baseline density estimation

It is proposed that the baseline site characterisation for use in the Norfolk Vanguard impact assessment will make use of as much of the data collected for the East Anglia Zone wind farms as possible. It is clear from the species-specific figures above that there is a considerable amount of seabird survey data available for assessing impacts in this zone. Using these data will ensure a very high level of robustness in the predicted impacts.

For Norfolk Vanguard East the primary data for use in the assessment will be :

- 24 months of East Anglia FOUR surveys (March 2012 – February 2014), and
- 8 months of Norfolk Vanguard East surveys (September 2015 – April 2016)

These will be complemented with the East Anglia ONE, East Anglia THREE and Norfolk Vanguard West data.

For Norfolk Vanguard West the primary data for use in the assessment will be:

- 20 months of Norfolk Vanguard West surveys (September 2015 – April 2017)

These will be complemented with the East Anglia ONE, East Anglia THREE and Norfolk Vanguard East data.

Thus, density estimates will be derived from site based observations (i.e. data collected on the Norfolk Vanguard East and West sites), while other parameters used in the assessment (e.g. seasonal flight heights) will be estimated using as much relevant data as possible from across the sites. This will ensure that the predicted impacts are both robust (i.e. use as much available data as possible) but also retain the necessary focus on the sites of interest. Although the Norfolk Vanguard West site assessment will include only one site specific survey in each month between May to August, this is not considered to be a concern for the following reasons:

- The abundance of almost all species are consistently at their lowest across the sites during these months,
- There are robust data available for these months from four other nearby sites from which an average density will be calculated for use as a monthly density estimate.
- The only species which is not present in lower densities in these months is lesser black-backed gull. In addition to the above method (average density estimate from the other sites), a thorough review will be conducted of the GPS tracking data for this species (conducted by the BTO from breeding colonies on the adjacent coast e.g. Alde-Ore Estuary SPA). This will ensure that suitably precautionary assumptions are incorporated in the assessment for this species.

Discussion

As would be expected, given the close proximity of the wind farm sites, the patterns of seasonal abundance are very similar across sites for all the species presented here. Indeed, the survey data collected to date for the Norfolk Vanguard sites (inc. that for East Anglia FOUR) suggest that these wind farm sites are very similar in their importance for seabirds to the other sites which have already been assessed (i.e. East Anglia ONE and East Anglia THREE).

The East Anglia Zone is characterised for seabirds by the absence of notable breeding season activity. This is not surprising since there are very few seabird breeding colonies within the typical foraging ranges of most species. However, large numbers of seabirds do pass through the southern North Sea on migration (e.g. gannet and kittiwake), while others take advantage of the relatively calm conditions for over-wintering (e.g. red-throated diver, auks and large gulls). These periods of the year are very well represented in the survey data available for the assessment, thereby ensuring that robust impact assessment can be undertaken.

APPENDIX 2. SEABIRD REFERENCE POPULATIONS

Summary

- Two alternative population scales are considered for use as reference populations for impact assessment: BDMPS and biogeographic
- The pros and cons of each in terms of uncertainty and precaution are considered
- It is proposed that both scales are used on the basis that this will bracket impacts
- For species with multiple BDMPS in Furness (2015) (i.e. species with subdivision of the nonbreeding season) a single estimate is suggested to simplify assessments.

This note provides an overview of alternative reference population options for seabirds for wider (i.e. EIA) scale assessment, and briefly outlines advantages and disadvantages of these different options.

The most up to date published estimates of biogeographic populations of seabirds is the 3rd SPA review (Stroud et al. 2016). Estimates from that work are given in column 4 of Table A2.1. Stroud et al. (2016) converted numbers of breeding pairs into total numbers by multiplying by a factor of three. This is a simple, but crude, estimate accounting for deferred maturity and the resulting proportion of immature birds in seabird populations. A disadvantage of assessing against biogeographic populations is that for many species, a significant proportion of the biogeographic population never visits UK waters, so is not at risk from offshore wind farms in UK waters.

Because only a part of the biogeographic populations of many seabird species visits UK waters, Furness (2015) used evidence on migratory movements of seabirds from different countries to assess the proportion of the population with connectivity to UK waters at some time of year; these estimates are given in Table A2.1. Furness (2015) used a population model based on species-specific data on demographic parameter values to estimate the ratio of immatures to breeders. That approach results in slightly different numbers from using a simple 3 times multiplier, and is likely to be more accurate than the simple approach used by Stroud et al. (2016). However, the greatest uncertainty in biogeographic population estimates is in the sizes of populations in many more remote areas, where counts are often imprecise and out of date. Not only are biogeographic population estimates very uncertain, but in most of the biogeographic range of seabirds there are no offshore wind farms. As a result, assessing impacts concentrated in the North Sea against a population distributed across a much larger area is less precautionary, and probably less accurate, than assessing on a smaller spatial scale. Either the biogeographic population scale provided by Stroud et al. (2016) could be used or the biogeographic population scale that has connectivity with UK waters (Furness 2015) could be used. We tend to prefer the choice of the Stroud et al. (2016) given that these estimates have the confidence of JNCC.

Because assessing against biogeographic populations may be difficult and subject to high uncertainty, Natural England developed the concept of Biologically Defined Minimum Population Scale (BDMPS) population estimates for seabirds in the nonbreeding part of the year, focussed on UK waters. UK waters may be split into several separate units if there is little or no exchange of individuals between units. For example, in many cases exchange is infrequent between UK North Sea waters and areas to the west of the UK. Rationale for subdivision of UK waters for selected seabird species is presented in Furness (2015). Estimates of BDMPS population sizes for seabirds in the UK North Sea (representing the smallest area considered appropriate for Vanguard OWF assessments, whether alone or cumulatively) are listed in Table A2.1. Where the nonbreeding season has been split into two or more time periods, Table A2.1 also presents a suggested single nonbreeding BDMPS estimate that would be appropriate to use. The advantage of the BDMPS scale is that it considers a clearly defined spatial scale based on knowledge of seabird seasonal movements, and allows assessment against offshore wind farm impacts that have been assessed using consistent and SNCB-approved methods. A disadvantage of the BDMPS approach is that it does not account for turnover of individuals moving in and out of the BDMPS defined spatial area.

An intermediate between BDMPS and biogeographic scale could be the whole North Sea scale, but that would require a cumulative assessment that would include OWFs in Belgian, Dutch, German and Danish waters, and those assessments do not necessarily provide impact quantification consistent with UK methods. Cumulative impact estimates across the whole North Sea would therefore be much more difficult to attempt, with an associated increase in uncertainty.

We conclude that assessment of cumulative impact separately at both the BDMPS and also at the biogeographic scales may be the most informative approach. Estimation of cumulative impacts is more accurate at the BDMPS scale, but the population size may be underestimated (hence this is likely to be precautionary in relation to assessment of impacts of collision mortality at the population level). In contrast, estimation of cumulative impacts at the biogeographic scale will be less certain but relatively smaller (hence less precautionary). This is because while there is uncertainty in the biogeographic population sizes (population estimates in some overseas areas are only very approximate; Stroud et al. 2016), the populations will increase more than the impacts as spatial scale extends further into areas without offshore wind farms.

Table A2.1 Possible BDMPS and biogeographic reference populations suggested for key seabird species

Species	BDMPS (individuals), season and name of area of UK waters (from Furness 2015)[1]	Biogeographic with connectivity to UK waters (individuals) (from Furness 2015)[2]	Biogeographic total and name of area (from Stroud et al. 2016)[3]
Red-throated diver	UK SW North Sea (winter: Dec-Jan) 10,177	27,000	300,000 individuals (wintering in NW Europe)
	UK North Sea (migrations: Sep-Nov, Feb-Apr) 13,277		
	UK North Sea (nonbreeding: Sep-Apr) 13,000		
Northern fulmar	UK North Sea (winter: (Nov) 568,736	8,055,000	10,200,000 individuals (Atlantic *glacialis* subspecies) (=3,400,000 breeding pairs x3)
	UK North Sea (migrations: Sep-Oct, Dec-Mar) 957,502		
	UK North Sea (nonbreeding: Sep-Mar)		

MacArthur Green

Species	BDMPS (individuals), season and name of area of UK waters (from Furness 2015)[1]	Biogeographic with connectivity to UK waters (individuals) (from Furness 2015)[2]	Biogeographic total and name of area (from Stroud et al. 2016)[3]
	950,000		
Northern gannet	UK North Sea & Channel (autumn: Sep-Nov) 456,298 UK North Sea & Channel (spring: Dec-Mar) 248,385 *UK North Sea & Channel (nonbreeding: Sep-Mar) 450,000*	1,180,000	1,170,000 individuals (world) (=390,000 breeding pairs x3)
Great skua	UK North Sea & Channel (autumn: Aug-Oct) 19,566 UK North Sea & Channel (winter: Nov-Feb) 143 UK North Sea & Channel (spring: Mar-Apr) 8,485 *UK North Sea & Channel (nonbreeding: Aug-Apr) 19,000*	73,000	48,000 individuals (N Atlantic) (=16,000 breeding pairs x3)
Little gull	Not assessed	Not assessed	123,000 individuals (Europe)
Lesser black-backed gull	UK North Sea & Channel (autumn: Aug-Oct) 209,007 UK North Sea & Channel (winter: Nov-Feb) 39,314 UK North Sea & Channel (spring: Mar-Apr) 197,483 *UK North Sea & Channel (nonbreeding: Aug-Apr) 200,000*	864,000	550,000 individuals (western Europe – subspecies *graellsii*)
Herring gull	UK North Sea & Channel (nonbreeding: Sep-Feb) 466,511	1,098,000	3,030,000 individuals (Europe – subspecies *argentatus* and *argenteus*)
Great black-backed gull	UK North Sea (nonbreeding: Sep-Mar) 91,399	235,000	435,000 individuals (N & W Europe)
Black-legged kittiwake	UK North Sea (autumn: Aug-Dec) 829,937 UK North Sea (spring: Jan-Apr) 627,816 *UK North Sea (nonbreeding: Aug-Apr) 800,000*	5,100,000	8,250,000 individuals (N Atlantic – subspecies *tridactyla*) (=2,750,000 breeding pairs x3)
Sandwich tern	UK North Sea & Channel (migrations: Jul-Sep, Mar-May) 38,051	148,000	220,000 individuals (Europe – subspecies

Species	**BDMPS (individuals), season and name of area of UK waters (from Furness 2015)[1]**	**Biogeographic with connectivity to UK waters (individuals) (from Furness 2015)[2]**	**Biogeographic total and name of area (from Stroud et al. 2016)[3]**
			sandvicensis)
Common guillemot	UK North Sea & Channel (nonbreeding: Aug-Feb) 1,617,306	4,125,000	3,532,000 individuals (NE Atlantic)
Razorbill	UK North Sea & Channel (migrations: Aug-Oct, Jan-Mar) 591,874	1,707,000	1,590,000 individuals (NW Europe – subspecies *islandica*) (=530,000 breeding pairs x3)
	UK North Sea & Channel (winter: Nov-Dec) 218,622		
	UK North Sea & Channel (nonbreeding: Aug-Mar) 590,000		
Atlantic puffin	UK North Sea & Channel (nonbreeding: mid-Aug-Mar) 231,957	11,840,000	17,028,000 individuals (NE Atlantic – subspecies *arctica*) (=5,676,000 breeding pairs x3)

1 Values in the shaded boxes are suggested options that could be used if it is preferred to have a single BDMPS population scale for the entire non-breeding period. These values are not presented in Furness (2015) but are derived from the data in that report.

2 Numbers in column 3 are sometimes larger than numbers in column 4. Population size estimates in column 3 were from a model based on species-specific demographic parameters (Furness 2015), while the estimate in column 4 was based on 3 times the breeding population, and provides a slightly different result.

3 Stroud et al. (2016) advocate use of 3 times breeding pairs to obtain an approximate estimate of total population size of seabirds when converting from pairs to individuals.

References

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APPENDIX 3. SEASONAL DEFINITIONS

Summary

- The breeding, migration and nonbreeding seasons are detailed for species which may be observed at Norfolk Vanguard offshore wind farm.
- On the basis of these seasons and the foraging ecology of breeding adults, recommended seasonal definitions for assessing impacts at the wind farm are proposed. These put the emphasis on migration periods, reflecting the fact that the wind farm is beyond the foraging range of most seabird species.

It is an inconvenient truth, that for many species of seabirds the timing of the breeding season of the UK population, overlaps with the timing of the peak migration season through UK waters of populations from higher latitudes, where breeding starts at a later date. As a consequence, peak numbers of some species at offshore wind farm sites may occur during the breeding season of the UK population (when most adults are attending the colony), but the birds in question may be predominantly from higher latitude populations that are still 'wintering' in UK waters or are moving towards their higher latitude breeding areas.

For offshore wind farms that are close to colonies, and where moderate or high numbers are present during the part of the breeding season when migration movements through UK waters have finished (defined as the migration-free breeding season), it may be appropriate to assume that many or all of the birds of that species that are present during the period of overlap between UK breeding season and migration of high latitude birds are locally breeding birds.

For offshore wind farms that are distant from UK colonies (perhaps defined as beyond mean maximum foraging range of breeding adults of that species), it seems more appropriate to recognise that these birds are likely to be migrants passing through UK waters on their way back to high latitude colonies, or are immatures or nonbreeders, remaining in wintering areas.

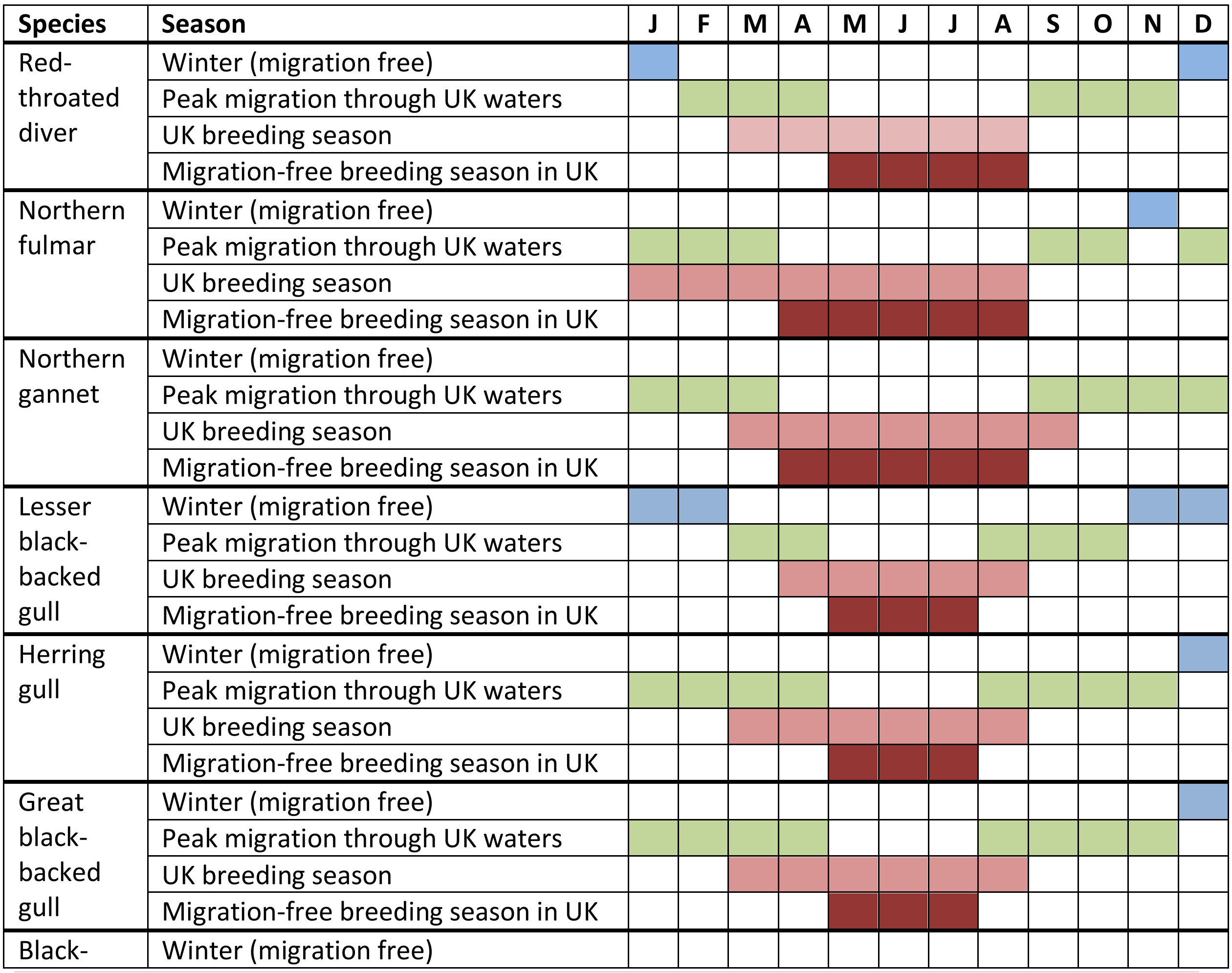
The Natural England BDMPS review (Furness 2015) suggested seasonal periods for seabirds in UK waters as follows: (Table A3.1 and Figure A3.1).

Table A3.1 Definitions of breeding, migration and winter seasons set out in the Natural England BDMPS review (Furness 2015).

Species	Winter (migration-free)	Peak spring migration through UK waters	UK breeding season	Migration-free breeding season in UK	Peak autumn migration through UK waters
Red-throated diver	Dec-Jan	Feb-Apr	Mar-Aug	May-Aug	Sep-Nov
Northern fulmar	Nov	Dec-Mar	Jan-Aug	Apr-Aug	Sep-Oct
Northern gannet	-	Dec-Mar	Mar-Sep	Apr-Aug	Sep-Nov
Lesser black-backed gull	Nov-Feb	Mar-Apr	Apr-Aug	May-Jul	Aug-Oct
Herring gull	Dec	Jan-Apr	Mar-Aug	May-Jul	Aug-Nov

Species	Winter (migration-free)	Peak spring migration through UK waters	UK breeding season	Migration-free breeding season in UK	Peak autumn migration through UK waters
Great black-backed gull	Dec	Jan-Apr	Mar-Aug	May-Jul	Aug-Nov
Black-legged kittiwake	-	Jan-Apr	Mar-Aug	May-Jul	Aug-Dec
Sandwich tern	Oct-Feb	Mar-May	Apr-Aug	Jun	Jul-Sep
Roseate tern	Oct-Mar	Apr-May	May-Aug	Jun-Jul	Aug-Sep
Common tern	Oct-Mar	Apr-May	May-Aug	Jun	Jul-Sep
Arctic tern	Oct-Mar	Apr-May	May-Aug	Jun	Jul-Sep
Little tern	Oct-Mar	Apr-May	May-Aug	Jun	Jul-Sep
Common guillemot	Nov	Dec-Feb	Mar-Jul	Mar-Jun	Jul-Oct
Razorbill	Nov-Dec	Jan-Mar	Apr-Jul	Apr-Jun	Aug-Oct
Atlantic puffin	Sep-Feb	Mar-Apr	Apr-Aug	May-Jun	Jul-Aug

Figure A3.1 Graphical illustration of the breeding, migration and winter seasons set out in the Natural England BDMPS review based on data in Table 1.



Species	Season	J	F	M	A	M	J	J	A	S	O	N	D
legged kittiwake	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Sandwich tern	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Roseate tern	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Common tern	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Arctic tern	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Little tern	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Common guillemot	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Razorbill	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												
Atlantic puffin	Winter (migration free)												
	Peak migration through UK waters												
	UK breeding season												
	Migration-free breeding season in UK												

The Norfolk Vanguard offshore wind farm is distant from almost all large UK breeding seabird colonies (beyond mean maximum foraging range) except for northern fulmar, northern gannet, and lesser black-backed gull (Table A3.2).

In the case of northern gannet, Norfolk Vanguard is 200 km from Flamborough & Filey Coast pSPA and the mean maximum foraging range of breeding gannets is 229 km (Thaxter et al. 2012). It has been shown that maximum foraging range of breeding gannets varies (increases) with colony size (Wakefield et al. 2013) and since the Flamborough & Filey Coast pSPA gannet colony is one of the smaller colonies of this species, it is likely that the foraging range of birds from that colony is generally smaller than for gannets from larger colonies. Furthermore, tracking of breeding adult gannets from that colony suggests that few forage in the area of the Norfolk Vanguard site (Langston and Teuten 2012, Langston et al. 2013). We therefore consider it unlikely that breeding adult gannets from Flamborough & Filey Coast pSPA will be present in significant numbers at the Norfolk Vanguard site.

In the case of lesser black-backed gull, Norfolk Vanguard is 90 km from the Alde-Ore Estuary SPA and the mean maximum foraging range of breeding lesser black-backed gulls is 141 km according to Thaxter et al. (2012). However, from a detailed tracking study during incubation and chick-rearing, Camphuysen et al. (2015) reported foraging ranges of 2029 trips as averaging 32 km for males and 21 km for females, with 95% of trips less than 60.5 km. That suggests that breeding adult lesser black-backed gulls are unlikely to regularly travel the 90 km from the Alde-Ore Estuary SPA to Norfolk Vanguard. Thaxter et al. (2015) tracked breeding adult lesser black-backed gulls from the Alde-Ore SPA in 2010, 2011 and 2012 and found mean foraging ranges offshore of 33 km, 25 km and 15 km in these three seasons. Very few tracks approached the Norfolk Vanguard area in 2010 and none in 2011 or 2012, although maximum ranges were 159 km, 124 km and 159 km in the three seasons, indicating that breeding adults from that colony may occasionally reach the Norfolk Vanguard site. However, it seems likely that lesser black-backed gulls at the Norfolk Vanguard site in summer are mostly immature or nonbreeding birds rather than commuting breeding adults from the Alde-Ore Estuary SPA.

Breeding northern fulmars have a mean maximum foraging range of 400 km (Thaxter et al. 2012), and there are reported cases of breeding fulmars travelling from the UK to the mid-Atlantic on foraging trips, so many colonies in the UK are within theoretical range of the Norfolk Vanguard site. However, northern fulmars tend to forage over oceanic waters and are relatively scarce in southern North Sea waters (Camphuysen and Garthe 1997), so the Norfolk Vanguard site represents marginal foraging habitat for northern fulmars whose feeding distribution is closely linked to hydrography (Camphuysen and Garthe 1997) and is unlikely to be on a route used by commuting fulmars from breeding colonies, as very few fulmars breed south of Norfolk Vanguard and their preferred foraging habitat lies almost entirely far to the north of the site. It therefore seems likely that northern fulmars at the Norfolk Vanguard site in the breeding season are predominantly immature or nonbreeding birds rather than commuting breeders from UK colonies.

Table A3.2. Distances between Norfolk Vanguard offshore wind farm and the nearest large (i.e. SPA) colony of key seabird species in relation to the foraging ranges of breeding adult seabirds. Cases where the mean maximum foraging range reported by Thaxter et al. (2012) is greater than the distance to Norfolk Vanguard are highlighted in yellow.

Species	Nearest SPA breeding population	Approximate distance (km) of nearest SPA breeding population from Norfolk Vanguard	Mean foraging range (km) of breeding adults according to Thaxter et al. (2012)	Mean maximum foraging range (km) of breeding adults according to Thaxter et al. (2012)
Red-	Caithness &	700	4.5	9

Species	Nearest SPA breeding population	Approximate distance (km) of nearest SPA breeding population from Norfolk Vanguard	Mean foraging range (km) of breeding adults according to Thaxter et al. (2012)	Mean maximum foraging range (km) of breeding adults according to Thaxter et al. (2012)
throated diver	Sutherland peatlands			
Northern fulmar	Flamborough & Filey Coast	200	47.5	400
Northern gannet	Flamborough & Filey Coast	200	92.5	229
Lesser black-backed gull	Alde-Ore Estuary	90	71.9	141
Herring gull	Alde-Ore Estuary	90	10.5	61
Great black-backed gull	Isles of Scilly	680	No data	No data
Black-legged kittiwake	Flamborough & Filey Coast	200	24.8	60
Sandwich tern	Alde-Ore Estuary	90	11.5	49
Roseate tern	North Norfolk Coast	80	12.2	17
Common tern	Breydon Water	52	4.5	15
Arctic tern	Coquet Island	360	7.1	24
Little tern	Minsmere-Walberswick	70	2.1	6
Common guillemot	Flamborough & Filey Coast	200	37.8	84
Razorbill	Flamborough & Filey Coast	200	23.7	49
Atlantic puffin	Flamborough & Filey Coast	200	4.0	105

It is, therefore, sensible to expect that any seabirds present at Norfolk Vanguard during the UK breeding season are likely to be migrants passing through UK waters on their way to higher latitude breeding areas where the breeding season starts later, or are likely to be immatures or nonbreeders that are remaining in the wintering area through the summer rather than returning to their higher latitude breeding areas. Therefore, we would propose to use the migration seasons defined in Table A3.1 for impact assessment rather than make the unlikely assumption that birds passing through the Norfolk Vanguard area in the migration period would belong to UK breeding colonies despite those being distant from the site.

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APPENDIX 4. METHODS FOR POPULATION MODELLING

Summary

- The methods used to model seabird populations for impact assessments are summarised including whether or not density dependence is included.
- Options for providing additional support for the inclusion of density dependence are proposed for discussion.

Population modelling provides a tool for predicting the effects on a population resulting from changes in demographic rates. Baseline predictions can be obtained using current (or baseline) rate estimates, which can then be compared with those obtained following adjustment to those rates. This provides an indication of the magnitude of population effect which may result from a predicted change in that rate. Thus, the long-term effects of a reduction in survival due to additional mortality (e.g. collisions with turbines) can be predicted and a determination made of the consequences for the population.

Population models, in common with all models, are used to simplify complex systems in order to provide insights into the key mechanisms. There is a trade-off between model complexity and utility. More complex models can capture more of the reality of the system of interest, but this is usually at the expense of a reduced ability to interpret the results. Simple models are straightforward to understand, but may omit too much detail for their predictions to be considered reliable.

Thus, the aim should be to develop simple models which still capture the key features, however all models are inevitably a compromise. In the case of seabird population models the primary components are demographic rates (survival and reproduction), with additional complexity in the form of age specific rates, as well as rates of exchange between colonies (i.e. immigration and emigration) and factors which modify the demographic rates. The latter can include relationships with environmental variables (e.g. sea-surface temperatures, winter storms, etc.), population density (i.e. intra-specific competition), other species (e.g. predator and prey populations or inter-specific competition) and interactions with human activities (e.g. fisheries and wind farms). In practice it is not often possible to incorporate factors such as these in a population model due to limited data availability.

Population models are typically based around age based demographic rates (e.g. survival and reproduction) arranged in a matrix (e.g. Caswell 2001). This formulation permits understanding of the relative contributions of each demographic rate to the overall population growth rate. It also allows individual rates to be varied to aid understanding of how changes may affect the population. For example, if an introduced predator reduces seabird breeding success (e.g. rats accidentally introduced to an island) the rate used in the model can be reduced accordingly and the population consequences predicted.

Such modelling is a very powerful and useful tool for understanding how changes may affect populations. However, a key consideration is how much complexity should be incorporated into the model, bearing in mind the trade-off between realism and the ability to interpret outputs.

One of the factors which can have a large influence on model predictions is intra-specific competition for resources, typically referred to as density dependence since the strength of effect is related to the size (or density) of the population. Examples of density dependent effects which may regulate seabird populations include competition for limited nesting space and interference competition whilst feeding on aggregated prey (i.e. as the density of feeding individuals increases the average individual success rate decreases). Density dependence acting in this manner reduces average demographic rates as the population increases, slowing population growth and stabilising the population at the environment's carrying capacity. If the population size falls, the strength of the density dependence regulation decreases, allowing the demographic rates to increase and permitting the population to recover (within limits). Thus, the population is buffered (to some degree) against effects which could otherwise trigger irretrievable declines (hence this is known as compensatory density dependence). [Note: density dependence can also be depensatory, for example if it becomes harder to find a mate as the population declines close to extinction (these are referred to as Allee effects). That form of density dependence is not considered further here as it will only be expected to apply to populations much smaller than those of primary concern for North Sea offshore wind farms.]

While the theoretical basis for density dependent regulation is well established (not least the self-evident fact that populations do not continue to increase indefinitely), empirical evidence of the mechanisms involved is difficult to obtain. This is especially true for species like seabirds with relatively long generation times and which are effectively unobservable for the majority of their life-cycles. Nevertheless, there is considerable evidence for the presence of density dependence in many seabird populations (see Annex 4.1 – extract from documentation presented during the East Anglia THREE assessment). However, while populations exhibit patterns of change consistent with regulation, the mechanisms have remained harder to determine. This creates a challenge for seabird population modelling: how to balance the fact that density dependence operates with the limited understanding of causal mechanisms. In partial acknowledgement of this, recent examples of seabird population model impact assessment have included simulations conducted both with and without density dependence. The latter, density independent, models have no feedback between population size and demographic rates. Therefore, reductions in one demographic rate are not buffered through compensation in others, with the consequence that predicted population effects for a given impact magnitude are larger.

Statutory advisors have shown an understandable preference for the more precautionary density independent models, whilst acknowledging they are unrealistic, and this has remained the case despite much discussion between statutory advisors and population modellers working on behalf of developers.

This note has been produced to stimulate further discussions on these points with Natural England (NE) and the RSPB with the aim of exploring option for addressing concerns about the use of density dependent models and finding an agreed way forward. The following section suggests how this could be approached, but this will be refined following Evidence Plan discussions. The starting point for these discussions is that while NE recently accepted there is robust evidence of density dependence in the North Sea kittiwake population (EA3 examination), the mechanism has not been established. The consequence of this was that NE continued to advise use of density independent results for impact assessment.

The timescales available for currently proposed offshore wind farm developments are very unlikely to permit the collection of empirical quantification of density dependence. Therefore, it is proposed that a more comprehensive modelling sensitivity analysis is undertaken. This will include consideration of alternative points at which regulation is applied (e.g. immature survival, adult survival, reproduction, etc.), alternative functional relationships (e.g. Weibull, ceiling, etc.) and varying strengths of response. The aim will be to clarify how much these different model formulations affect the results obtained and identify agreed methods for future modelling with the aim of generating more reliable predictions for impact assessment.

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Annex 4.1 – Updated extract from East Anglia THREE Ornithology Response to NE Section 56 Consultation and Updated Cumulative Collision Risk Tables EIA impacts on kittiwake and great black-backed gull (minor changes have been from the original text)

Following discussions with Natural England during Evidence Plan meetings a PVA model for kittiwake was developed and presented for the assessment of kittiwake impacts at the wider North Sea scale. Following review of the ES, Natural England advised that further consideration of two key aspects was required: the role of density dependent regulation and the appropriate reference population to use.

With respect to density dependence, Natural England (2016) stated:

'There appears to be little clear evidence to suggest compensatory density dependence is operating on the kittiwake population at a North Sea scale, therefore Natural England advises that the assessment should focus on outputs from the density independent models.'

Most demographic parameters of seabirds are likely to show some density-dependent variation (Newton 1998). Cairns (1987) pointed out that life history theory predicts that seabird breeding success will show a compensatory density-dependent response at an earlier stage of reduced food abundance and adult survival is likely to show less response until food abundance is drastically reduced. Age at first breeding may vary in a compensatory density-dependent way at an intermediate level. Empirical evidence provides some support for Cairns' predictions (Cury et al. 2011; Furness 2015). There are extensive data on breeding success of kittiwakes, showing that breeding success declines with reduction in food supply which is consistent with but does not prove compensatory density-dependent limitation by food supply (Frederiksen et al. 2005; Furness 2007).

Furness and Birkhead (1984) showed that the spatial distribution of kittiwake colonies indicated compensatory density-dependent competition for resources in the marine areas around colonies; numbers breeding at neighbouring colonies were influenced by the neighbouring kittiwake colony size.

Mean age of first breeding of male kittiwakes decreased from 4.59 years in 1961-70 to 3.69 in 1981-90 (Coulson 2011). The lower age of first breeding in the 1980s coincided with a much increased adult mortality, and Coulson (2011) interpreted that as evidence that competition for nest sites at the colony influenced age of first breeding so acted in a compensatory density-dependent manner.

Coulson (2011) showed that the annual rate of increase in size of 46 kittiwake colonies in the UK between decadal national censuses in 1959 and 1969 was inversely related to colony size. Colonies of 1-10 pairs in 1959 increased on average by 70% up to 1969. Colonies of 10-100 pairs in 1959 increased on average by 20% up to 1969. Colonies of 100-1000 pairs in 1959 increased on average by 5%. Colonies of 1000-10,000 pairs in 1959 increased on average by 3%. This implies very strong compensatory density-dependence. It is unclear just from these changes in numbers which particular demographic parameters were affected, but Coulson (2011) inferred that the most likely candidate is the rate of net immigration into each colony. Coulson (2011) concluded from his detailed observational studies, and from population modelling, that the main reason for the progressive differences in growth of an individual colony is the balance between immigration and emigration of immature birds. Frederiksen et al. (2005) found that for the period 1986-2000, there was no relationship between colony size and colony growth rate, and suggested that compensatory density-dependence occurred during the expansion phase but not necessarily at all stages of population change.

A compensatory density-dependent reduction in colony growth rate is also clearly evident from data on colony size over a period of decades for colonies studied in detail. Numbers at Marsden (Tyne & Wear) showed a rate of increase that progressively decreased as numbers grew (Coulson 2011, Figure 11.5). Numbers at nearby Coquet Island (Coulson 2011, Figure 11.6) show exactly the same trend with colony size. However, numbers grew rapidly at Coquet at the same time that growth had virtually ceased at the nearby Marsden colony (in the 1990s). This shows clearly that the rate of growth was a colony-specific feature related to local competition, and was not a consequence of region-wide variations in conditions. According to Coulson (2011) '*examination of the rates of increase of kittiwake colonies with time almost always showed the same pattern*' as described above. This pattern implies compensatory density-dependence at individual colonies according to local conditions.

Most kittiwake colonies in the UK North Sea have declined in breeding numbers in the last few years, most strongly in the north. Decreases in numbers appear to have been greater in large colonies than in small ones (Stroud et al. 2016), suggesting a density-dependent effect with competition increasing most in the largest colonies as resources have declined.

Jovani et al. (2015) found empirical evidence from the data on the distribution of colony sizes of seabirds (including kittiwakes) in relation to breeding season foraging range for density-dependence through competition for resources around breeding colonies.

In conclusion, there is strong evidence, summarised above, for compensatory density dependence acting on the kittiwake population of the UK, although exact mechanisms remain to be determined and there is some evidence to suggest that the strength of density-dependence may vary in relation to environmental conditions.

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APPENDIX 5. DISPLACEMENT ASSESSMENT

Summary

- The challenges of estimating annual displacement for species for which different numbers of nonbreeding seasons have been identified and discussed.
- A method for standardising assessments across species by defining single nonbreeding season populations is proposed and the relevant population sizes provided.

Natural England advise that impacts of displacement of seabirds by offshore wind farms should be assessed by constructing a matrix, inputting the seasonal mean maximum numbers of the focal species into a matrix of displacement rates from 0 to 100% and consequent mortality from 0 to 100%. From this matrix, an assessment is made of whether the mortality caused by displacement is likely to exceed 1% of baseline natural mortality of the focal population. Population modelling is advised if mortality due to displacement might exceed 1% of baseline natural mortality of the population. For auks, the recommendations have tended to be between 30% and 70% of birds being displaced and between 1% and 10% of displaced birds dying as a consequence of displacement, although all values within the matrix may be considered.

Natural England advise that where BDMPS populations are considered, the estimate of mortality should be derived by summing estimates for each of the seasonal BDMPS populations. That approach leads to unequal assessments for different species, because the number of seasonal BDMPS populations differs among species. As a consequence, if displacement and mortality were identical for common guillemot and razorbill, the NE approach would estimate a higher impact on razorbill (with three nonbreeding seasonal BDMPS populations) than on common guillemot (with one nonbreeding seasonal BDMPS population) simply as an artefact of the approach used by NE, even if the actual impact was identical for the two species. Therefore, we suggest that to avoid this, the best solution is to use a single nonbreeding season BDMPS population for all seabird species.

In Table A5.1 we present suggested single nonbreeding BDMPS seasons and population estimates for the appropriate (UK North Sea waters) region relevant to Norfolk Vanguard for species that had been allocated more than a single nonbreeding season in Furness (2015). The single nonbreeding seasons proposed in Table 1 will remove the anomalous position that NE's recommended method results in a lower estimated impact for seabirds with fewer seasonal BDMPS seasons, and will therefore produce estimates that are directly comparable across species. Note that the suggested single nonbreeding season BDMPS population scale is retained at a level similar to that in the season when largest numbers are present, and does not add the population scales of the component seasonal populations in Furness (2015) and therefore does not reduce the estimated impact by summing populations across seasonal periods. In that sense, the approach we suggest is not accounting for the possibility that different birds are present in the different seasonal populations, but rather this approach standardises the assessment so that all species are now being treated in exactly the same way, rather than having anomalies in impact size caused by differences across species in the number of seasonal components being summed.

Table A5.1. Proposed single nonbreeding season BDMPS seasons and population estimates for seabirds, based on the NE BDMPS report (Furness 2015).

Species	**BDMPS (individuals), season and name of area of UK waters (from Furness 2015)**	**Suggested single nonbreeding BDMPS (individuals)**
Red-throated diver	UK SW North Sea (winter: Dec-Jan) 10,177 UK North Sea (migrations: Sep-Nov, Feb-Apr) 13,277	*UK North Sea (nonbreeding: Sep-Apr) 13,000*
Northern fulmar	UK North Sea (winter: (Nov) 568,736 UK North Sea (migrations: Sep-Oct, Dec-Mar) 957,502	*UK North Sea (nonbreeding: Sep-Mar) 950,000*
Northern gannet	UK North Sea & Channel (autumn: Sep-Nov) 456,298 UK North Sea & Channel (spring: Dec-Mar) 248,385	*UK North Sea & Channel (nonbreeding: Sep-Mar) 450,000*
Great skua	UK North Sea & Channel (autumn: Aug-Oct) 19,566 UK North Sea & Channel (winter: Nov-Feb) 143 UK North Sea & Channel (spring: Mar-Apr) 8,485	*UK North Sea & Channel (nonbreeding: Aug-Apr) 19,000*
Lesser black-backed gull	UK North Sea & Channel (autumn: Aug-Oct) 209,007 UK North Sea & Channel (winter: Nov-Feb) 39,314 UK North Sea & Channel (spring: Mar-Apr) 197,483	*UK North Sea & Channel (nonbreeding: Aug-Apr) 200,000*
Black-legged kittiwake	UK North Sea (autumn: Aug-Dec) 829,937 UK North Sea (spring: Jan-Apr) 627,816	*UK North Sea (nonbreeding: Aug-Apr) 800,000*
Razorbill	UK North Sea & Channel (migrations: Aug-Oct, Jan-Mar) 591,874 UK North Sea & Channel (winter: Nov-Dec) 218,622	*UK North Sea & Channel (nonbreeding: Aug-Mar) 590,000*