

FEIA on behalf of Femern A/S



**Third party review of Fehmarnbelt fixed link plausibility
check report and suitability of baseline plus check data on
marine birds and mammals**

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EXECUTIVE SUMMARY

The EIA for the Fehmarnbelt Fixed Link is founded on baseline environmental monitoring data from 2009 and 2010. The baseline studies are now 5-6 years old. To assess whether the baseline of the EIA is still representing a relevant and reliable baseline, a Plausibility Report has been prepared (FEMO 2016). The objective of the Plausibility Report was to evaluate whether results of the impact assessments remain valid. This third party review considers the evidence in the Plausibility Report regarding numbers and distributions of marine mammals and marine birds, and evaluates relevant wider literature on this topic, to assess the extent to which the baseline data remain relevant and reliable. It is concluded from that review process that the Plausibility Report provides a robust scientific assessment, with sound and well-substantiated conclusions.

With regard to numbers and distributions of marine mammals and birds, the greatest strength of the Plausibility Report is the analysis of the long time-series of monitoring data. These data show clearly that overall the numbers and distributions of animals remain very similar now to what has been reported in the Baseline report and to other years in recent decades. That is also what would be predicted from understanding of the life history and ecology of marine birds and marine mammals, which tend to have high adult survival and consistent distributions from year to year. Given the low natural ability of marine bird and marine mammal populations to grow rapidly, and the high survival of adults that tends to limit population decline, we can anticipate that marine bird and marine mammal populations that may be affected by the Fehmarnbelt fixed link are likely to be broadly stable in total (biogeographic) population size over a period of a small number of years.

The Plausibility Report also presents detailed data on hydrology, climate and lower trophic levels that indicate that the processes determining food supplies for seabirds and marine mammals are essentially the same now as was found in baseline studies. The ecological relationships in the food web are therefore likely to be the same, and that implies that the carrying capacity of the environment for populations of marine mammals and marine birds is unlikely to have altered greatly. The 'bottom-up' ecological drivers of marine bird and marine mammal populations are therefore likely to be similar now to what they were during the baseline studies.

The scientific literature identifies winter weather conditions as an important influence on the distribution of marine birds. Independent of stable regional species populations, fluctuations in regional distributions, and therefore in local numbers in different winters in relation to weather can be considerable, and are likely to be a major influence on the year to year variations in numbers counted in surveys. It would therefore be relevant to consider winter weather as likely to be one of the most important factors influencing the numbers of marine birds affected by the Fehmarnbelt Fixed Link construction work in any particular year.

To support a broadly based plausibility study, new aerial surveys of marine mammal and marine bird numbers and distribution were carried out in 2015. Due to current methodological experiments and developments among general survey approaches, these surveys used both digital aerial survey and visual aerial survey, the latter being the same survey method used in 2009 and 2010. The statistical power of the 2015 aerial surveys is low (especially for visual), and it is difficult to make formal comparisons of data collected by digital methods in 2015 with visual survey data collected in 2009-

2010. However, the numbers estimated from the digital survey are consistent with numbers assessed by other survey methods, and spatial distributions remain similar between the survey periods. The benefits of digital aerial survey are described in detail in the Plausibility Report but the evidence that digital survey does not always produce more accurate estimates of numbers has not been presented. It is not yet the case that we should assume that a digital aerial survey necessarily provides the most accurate estimates of marine bird and mammal numbers. The Plausibility Report in my view overemphasises merits of digital aerial survey relative to other survey methods, and does not cite several studies that have found some apparent weaknesses with empirical data derived from digital methods compared to traditional survey methods. Nevertheless, 2015 aerial surveys tend to support the assessment that marine bird and mammal numbers and distributions remain broadly as found in 2009-2010.

The overall conclusion of this third party review is that the Plausibility Report provides scientifically sound evidence of the relevance and reliability of the baseline data. I note in particular that local year to year variations are an expected uncertainty independent from the survey method chosen. However, these variations do not challenge the assessment because of the robust assessment methodology applied. The degree of detail and quality of the comprehensive and statistically well-founded baseline from 2009-2011 is well suited in relation to the environmental aspects and specific questions of impact assessment linked to the construction of the Fehmarnbelt Fixed Link.

1. INTRODUCTION

The EIA for the Fixed Link across Fehmarnbelt is based on environmental monitoring data from 2009 and 2010, and included data from visual aerial survey of marine birds and marine mammals. The baseline data are used in impact analyses as well as for verification of modelling work supporting the impact assessment. The baseline studies are now 5-6 years old. To verify that the baseline of the EIA is still representing a relevant and reliable baseline, a 'plausibility check' study has been conducted. The objective of the plausibility check study is to evaluate whether results of the impact assessments remain valid. To support a broadly based plausibility check study, five digital and three visual aerial surveys of birds and marine mammals were carried out between January and June 2015, to compare with visual aerial survey data from 2009 and 2010. The plausibility check report (FEMO 2016, presented in FEMO-09-TR0003-RE) runs to 348 pages, an important part of which is analysis of these new bird and mammal survey data and assessment of similarity/difference with the data collected in 2009 and 2010. It is considered desirable to have a third party review of the science underpinning the plausibility check report and the interpretations of the data in that report, to identify any weaknesses in the science and to assess these in the context of best available scientific knowledge and the methods and practices employed more widely in Europe in the processes of designating areas under the Birds Directive and Habitats Directive for conservation of bird and mammal species, and the assessment of impact of marine developments on protected species.

The plausibility report assesses the extent to which numbers of marine birds and marine mammals have remained the same between the baseline data collected in 2009 and 2010, and the plausibility check in 2015. This raises a number of questions:

- a) What determines numbers of marine birds and marine mammals in populations?
- b) What determines the spatial distributions of populations?
- c) How much do numbers and spatial distributions vary among years?
- d) Does the plausibility check report provide a scientifically robust assessment?

These questions are addressed in turn in this third party review.

2. WHAT DETERMINES NUMBERS OF MARINE BIRDS AND MAMMALS IN POPULATIONS?

Seabirds have high adult survival rates. More than 90% of the breeding adult birds alive in one year are still alive in the next year in most pelagic seabird species, and adult survival rates are only slightly lower in most inshore species of seabirds (Horswill and Robinson 2015). Seabirds show deferred maturity, not starting to breed until several years old. Breeding productivity of seabirds tends to be low, with many seabird species producing only about 0.5 chicks per breeding pair per year, and survival rates of these juvenile birds being relatively low compared to survival rates of adults (Horswill and Robinson 2015). For example, while adult mortality of northern gannet is only 8% per year, more than 57% of young gannets die during their first year of life (Horswill and Robinson 2015). As a consequence, population sizes of seabirds tend to increase only very slowly, and normally do not decrease rapidly either. The main factor determining population size in any one year is the number that was present in the previous year. This means that year to year fluctuations in numbers in seabird populations tend to be small, and change in population size tends to occur over periods of many decades rather than from year to year. For example, the world population of the northern gannet increased continuously from 1900 to 1990, during the entire time being below the environmental carrying capacity and able

to increase without significant constraint. Nevertheless, it achieved an annual increase in numbers in the population of only about 2% per annum through most of this period, decreasing to about 1% per annum since the 1990s (Wanless et al. 2005). Marine waterbirds also tend to have demographic parameters similar to seabirds, with high adult survival but low productivity and juvenile survival. However, there is a spectrum from pelagic seabirds at one extreme to inshore species such as cormorants and red-breasted mergansers at the other. Cormorants, mergansers, greater scaup may produce several chicks per year and although in most years few of these chicks survive, in occasional years chick survival can be higher, resulting in an increase in population size. There is, therefore, variation in the extent to which year to year fluctuations in marine bird populations may occur. In general there is a tendency to stability in numbers over the short term, although numbers may fluctuate rather more in species such as greater scaup (Mendel et al. 2008). Marine mammals also show the kind of demography seen in seabirds, with high survival of adults and low reproductive output, although demographic parameters of marine mammals are more difficult to study than those of marine birds and so are less well parameterised.

Stability in numbers may also result from density-dependence, which is a general feature of animal populations (Newton 1998), and has been identified in many studies of marine bird population dynamics (Coulson et al. 1982; Furness and Birkhead 1984; Lewis et al. 2001; Moss et al. 2002; Coulson 2011; Davis et al. 2013; Hartman et al. 2013; Furness 2015; Jovani et al. 2015). If animal numbers are close to the carrying capacity of the environment for that species, then density-dependent processes tend to hold numbers in check. If numbers increase above carrying capacity then mortality rates increase or fecundity decreases or emigration increases to prevent numbers from growing further (Newton 1998). If numbers fall below carrying capacity, then fecundity increases or mortality rates fall or immigration from other populations increases, allowing population size to move towards carrying capacity (Newton 1998). Carrying capacity may change over time if environmental resources or conditions alter (Newton 1998; Rönkä et al. 2005; Laursen and Møller 2014). For example, changes in abundance of small food-fish on which many seabirds and marine mammals depend may alter carrying capacity of the environment for dependent seabirds and marine mammals. Modelling of harbour porpoise population dynamics indicates that food abundance (i.e. changes to environmental carrying capacity caused by changes in fish stocks) can have an important influence on harbour porpoise dynamics (Danish Energy Agency 2013). Changes in abundance of bivalves may alter the carrying capacity for sea ducks such as scoters and eiders that feed primarily on bivalves (Larsen and Guillemette 2000; Laursen and Møller 2014). There is much evidence that food abundance is the most important factor that determines the carrying capacity for many marine birds and marine mammals (Newton 1998; Oro and Furness 2002; Frederiksen et al. 2005, 2007; Cury et al. 2011; Frederiksen 2014; Langton et al. 2014). Populations of birds, even of species that are normally long-lived as adult birds, can drop dramatically if their food supply is suddenly depleted. For example, in winter 1999/2000, about 31,000 common eiders starved to death in the Wadden Sea apparently as a consequence of the depletion of mussel, cockle and *Spisula* stocks by intensive overfishing by mussel fisheries (Camphuysen et al. 2002). This mass mortality reflected a drastic and un-natural reduction in carrying capacity caused by overfishing, but provides clear evidence of the key link between bird numbers and their food supply.

A good indication of the broad tendency to population stability can be seen from the Waterbird Population Estimates for 2012 (Wetlands International 2016) and for the late 1990s (Wetlands

International 2006). These estimates provide an indication of the mean rate of change of numbers in waterbird populations (Table 2.1). Mean rates of population change were below 1% change per year for 32 species, between 1% and 3% per year for 8 species, and greater than 3% per year for 4 species. The modal and median absolute rate of change was 0% per year. Causes of apparent high rates of population decline for a few species (e.g. common scoter, long-tailed duck) are uncertain; these could theoretically reflect drastic changes in environmental carrying capacity, which are not substantiated for the area, and probably they represent errors in census data (changes in counted totals rather than actual numbers).

Table 2.1. Biogeographic population size estimates for waterbird species. Data from Wetlands International database.

Species	Population mean estimate (1990-2000)	Population mean estimate (2012)	Maximum mean annual rate of change 2000 to 2012 (% per year)
Red-throated diver	300,000	260,000	-1.1
Black-throated diver	375,000	350,000	-0.4
Great crested grebe	360,000	350,000	-0.2
Red-necked grebe	51,000	50,000	-0.1
Slavonian grebe	20,000	19,000	-0.4
Great cormorant	390,000	390,000	0.0
Mute swan	250,000	250,000	0.0
Bewick's swan	20,000	22,000	+0.7
Whooper swan	59,000	59,000	0.0
Bean goose	600,000	550,000	-0.7
Greater white-fronted goose	1,000,000	1,200,000	+1.5
Greylag goose	500,000	610,000	+1.6
Barnacle goose	420,000	770,000	+4.0
Brent goose	200,000	240,000	+1.4
Eurasian wigeon	1,500,000	1,500,000	0.0
Gadwall	60,000	60,000	0.0
Common teal	500,000	500,000	0.0

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Mallard	4,500,000	4,500,000	0.0
Shoveler	40,000	40,000	0.0
Common pochard	350,000	300,000	-1.1
Tufted duck	1,200,000	1,200,000	0.0
Greater scaup	310,000	310,000	0.0
Common eider	760,000	980,000	+2.0
Long-tailed duck	4,600,000	1,600,000	-7.4
Common scoter	1,600,000	550,000	-7.5
Velvet scoter	1,000,000	450,000	-6.0
Common goldeneye	1,150,000	1,140,000	-0.1
Smew	40,000	40,000	0.0
Red-breasted merganser	170,000	170,000	0.0
Goosander	270,000	270,000	0.0
White-tailed eagle	15,000	15,000	0.0
Common coot	1,750,000	1,750,000	0.0
Little gull	123,000	110,000	-0.8
Black-headed gull	4,200,000	4,210,000	+0.0
Common gull	2,000,000	1,640,000	-1.5
Lesser black-backed gull	380,000	380,000	0.0
Herring gull	2,650,000	2,010,000	-2.3
Great black-backed gull	440,000	420,000	-0.3
Sandwich tern	170,000	170,000	0.0
Common tern	1,100,000	980,000	-0.8
Arctic tern	2,000,000	2,000,000	0.0
Common guillemot	4,300,000	4,300,000	0.0
Razorbill	500,000	500,000	0.0

Black guillemot	10,500	10,500	0.0
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Given the low natural ability of marine waterbird and marine mammal populations to grow rapidly, and the high survival of adults that tends to limit population decline, we can anticipate that marine bird and marine mammal populations that may be affected by the Fehmarnbelt fixed link are likely to be broadly stable in total (biogeographic) population size over a period of a small number of years. Numbers likely to change most may be numbers of geese, where a long-term increase in some goose populations (Table 2.1) appears to be widespread as a consequence of increased protection from human exploitation and disturbance during winter. Sea duck numbers appear also to change more than numbers of most other marine birds, although the causes of change in sea duck numbers are not clearly established and may include issues with census methods. However, spatial distributions of all waterbirds may alter local population densities, and this topic is considered in the next section.

3. WHAT DETERMINES THE SPATIAL DISTRIBUTIONS OF POPULATIONS?

During the breeding season, the distribution of marine birds is primarily determined by the locations of suitable breeding habitat (Furness and Birkhead 1984; Mitchell et al. 2004), although immature birds may remain in the same areas used by birds in the nonbreeding season (Mendel et al. 2008). For seabirds breeding mostly occurs in colonies, with the colonies located close to predictable areas with good feeding opportunities, and where birds can breed safe from predators and disturbance (Mitchell et al. 2004). Some sea ducks are also colonial breeders, or at least tend to aggregate in suitable breeding habitat. Many of the marine birds that are present in large numbers in the Skagerrak and southern Baltic Sea in the nonbreeding season migrate to breed at higher latitudes (Mendel et al. 2008). While birds are present in the nonbreeding season, their spatial distribution is likely to be determined mainly by the spatial distribution of suitable foraging habitat and key prey species (Sonntag et al. 2006). However, spatial distribution can also be influenced by human disturbance, distribution of predators, and weather conditions that influence foraging by marine birds, such as extent of sea ice, and storminess (Mendel et al. 2008). We can, therefore, expect the spatial distribution of marine birds and marine mammals to correspond to a large extent to spatial distributions of their key prey. This is particularly the case for marine birds that feed on benthic prey such as bivalves, as there will be limited areas where the sea depth and bivalve densities are suitable for foraging. Spatial distributions of marine birds and mammals that feed on mobile prey (such as juvenile herring) may be less strongly restricted spatially, but the distributions of fish tend also to be constrained by predictable physical features of the environment and exert 'bottom up' control of predators at higher trophic levels (Frederiksen et al. 2007).

4. HOW MUCH DO NUMBERS AND SPATIAL DISTRIBUTIONS VARY AMONG YEARS?

'Hot spots' for harbour porpoise tend to be persistent over decades and are determined primarily by physical (hydrographical) features that influence the spatial distribution and density of the preferred prey of harbour porpoises (Heinänen and Skov 2015). High densities of harbour and grey seals tend to be correlated with areas of high fish prey density close to suitable haul-out sites (Cunningham et al. 2009; Oksanen et al. 2014; Cordes and Thompson 2015). High densities of marine birds tend to occur in consistent marine areas from year to year, and while this is especially true around breeding colonies

during the breeding season (Kober et al. 2010, 2012; Wilson et al. 2014), it is also the case for inshore marine birds in the nonbreeding season (Garthe et al. 2012, Garthe et al. 2015, Lawson et al. 2015), and for offshore seabirds in the nonbreeding season (Garthe et al. 2012, Kober et al. 2010, 2012). Where the distribution of prey is consistent across years, the distributions of dependent predators such as marine mammals and marine birds are also likely to show year to year consistency.

Distribution of long-lived birds may also be influenced by the extent to which individuals return each year to spend the winter in the same winter home range. This behaviour seems to be common among many species of migratory marine birds, but the extent to which individuals are site-faithful seems to vary among species. There is probably an evolutionary aspect to this. Individuals of species that learn where to obtain food that is consistently available at specific sites may show a strong tendency to be site faithful between winters, whereas individuals of species that feed on more ephemeral or nomadic prey that do not show regular distribution patterns across years may show little site fidelity. Sometimes, this behaviour is most easily seen with rare birds which return year after year to the same wintering site. For example, a white-billed diver returning for many years to exactly the same location in Scotland, a great northern diver with a bill deformity, seen each winter at the same site, a North American ring-billed gull spending some weeks each year in the same harbour in west Scotland. Evidence of a more scientific nature is provided by tracking studies of marine birds over multiple years, which have tended to show examples of winter site fidelity, but sometimes (though less frequently) also examples of birds moving to a different site between winters, or even within a winter. The tendency of individual birds to return each winter to the same wintering area will also tend to maintain a consistent pattern of numbers and spatial distribution of marine birds from year to year.

Evidence regarding year to year variations in numbers and distributions of marine birds and marine mammals, with a particular focus on the populations in the regions near to the Fehmarnbelt, is presented for particular species of relevance in Appendix 1. Furthermore, Garthe et al. (2012) showed that the distribution patterns and numbers of seabirds tended to be consistent across years in German Baltic waters, and the designation of an SPA for marine birds in the German Baltic (Pomeranian Bay) was based on this consistent distribution pattern.

5. DOES THE PLAUSIBILITY CHECK REPORT PROVIDE A SCIENTIFICALLY ROBUST ASSESSMENT?

The greatest strength of the Plausibility Report is the analysis of the long time-series of survey data monitoring numbers of marine mammals and marine birds. These data show clearly that overall the numbers and distribution of animals remains very similar now to what has been reported in the Baseline report. That conclusion is scientifically robust. That situation is also what would be predicted from understanding of the life history and ecology of marine birds and marine mammals, as outlined in sections 2 and 3 of this review.

The time series of counts indicate that most populations have remained approximately stable, or have shown small rates of change over many years. Therefore, empirical evidence indicates that it is appropriate to expect that numbers that would be affected by the proposed development would be much as reported based on the Baseline report data. The Plausibility Report labels these long-term time series of survey monitoring as 'supplementary data sources' and evaluates those data in an Appendix (Appendix C), which gives the impression that those data are somehow of a lower

importance and quality. In my opinion, those data are the strongest empirical evidence supporting the viewpoint that numbers have tended to remain consistent across years.

The Plausibility Report does not explicitly give the context of marine mammal and marine bird biology that is relevant to and an important aspect for this assessment, but simply presents empirical evidence. In my view, the fundamental principles of marine mammal and marine bird biology are highly relevant, as they predict on the basis of fundamental population ecology that the numbers and distributions of these animals are likely to remain stable except where ecological conditions ('drivers' such as weather conditions or food distribution) have altered. There is, therefore, a well-founded theoretical underpinning that has been omitted from the Plausibility Report that supports, from a theoretical ecology perspective, and which provides the contextual explanation for the empirical observation, that marine bird and mammal numbers and distribution tend to remain consistent from year to year. That theoretical basis is outlined in sections 2 and 3 in this review. In my opinion, the theoretical framework supports the empirical evidence that is clearly presented in the Plausibility Report: numbers and distributions of marine mammals and marine birds tend to be consistent from year to year, but vary somewhat in relation to annual variations in environmental drivers. In this case, key environmental drivers and controls appear to be the abundance, general surplus and distribution of food resources (e.g. Larsen and Guillemette 2000; Danish Energy Agency 2013; Laursen and Møller 2014), and fluctuations in winter weather conditions (e.g. Austin and Rehfishch 2005; Mendel et al. 2008; Hartman et al. 2013; Pearce-Higgins and Holt 2013; Fox et al. 2016; Ost et al. 2016).

In my view, the Plausibility Report gives too much emphasis on digital aerial survey as a tool to assess numbers and distribution of marine mammal and marine bird populations, and as a consequence of that focus the report underplays the important role of long-term survey data in establishing the natural year to year variability in numbers and distribution. Digital aerial survey has been adopted by the German Federal Maritime Agency BSH as the standard method for ecological monitoring of marine bird and marine mammal numbers and distribution in relation to offshore wind farm development. It has the considerable advantage that the survey data remain as a digital record that can be scrutinised at any time in the future, allowing any anomalies to be checked or new analyses to be carried out. This is a major strength of the method and fully justifies its use as a standard survey approach. However, digital aerial survey methods are relatively newly developed, and are still being improved (Thaxter and Burton 2009; Buckland et al. 2012; Mendel et al. 2016). There are examples where studies have found evidence that estimates obtained from digital aerial surveys may be less accurate than estimates derived from other more established survey methods (Burt et al. 2009; Thaxter and Burton 2009; Connelly et al. 2015; Williams et al. 2015; Williamson et al. 2016), and there have been studies demonstrating that different digital aerial survey methods produce results that may differ significantly (Mendel et al. 2016). Correction factors to make visual aerial survey data comparable to ship-based survey data have been studied (e.g. Markones and Garthe 2012, Bellebaum et al. 2014, Bradbury et al. 2014), but such correction factors are not yet well established for digital aerial survey. Indeed, there are only preliminary comparisons that suggest that some species are detected in larger numbers by digital aerial survey than by visual aerial survey while some other species may be detected in smaller numbers (Mendel et al. 2015). In particular, small birds that occur in small numbers may be overlooked by aerial survey compared to ship-based surveys and it seems that species such as Slavonian grebe and black guillemot, which fall into this category, may be particularly under-represented in aerial surveys (Mendel et al. 2015, S. Garthe pers. comm.).

Various correction factors can be applied to digital aerial survey data to allow for marine mammals missed by aerial survey. For example, harbour porpoise numbers can be corrected for animals swimming too deep to be seen on photographs using data in Teilmann et al. (2013) who report distributions of swimming depth in different months. However, those corrections assume that swimming depths of animals carrying data loggers are representative of animals not encumbered with devices which may not be the case (Berga et al. 2015), and make no allowance for seasonal variation in water transparency which may also affect detection in photographs. An alternative approach to making corrections to digital aerial survey data on harbour porpoise relative densities to convert these to absolute densities has been proposed by Williamson et al. (2016), but those corrections would provide slightly different estimates from the ones derived from using the data in Teilmann et al. (2013). This example shows the evolving nature of digital aerial survey methods and data analysis and is an example of the fact that there remains uncertainty in estimates of numbers even from what is now becoming the most widely used method to survey marine birds and marine mammals at sea.

The benefits of digital aerial survey are described in detail in the Plausibility Report but the evidence that digital survey does not always produce more accurate estimates of numbers has not been presented. It is not yet the case that we should assume that a digital aerial survey necessarily provides the most accurate estimates of marine bird and mammal numbers. However, comparison studies have shown that different survey methods (ship-based surveys, visual or digital aerial surveys) do tend to agree in the description of the spatial distribution patterns of marine birds (Thaxter and Burton 2009, Markones and Garthe 2012, Bradbury et al. 2014, Connelly et al. 2015; Williams et al. 2015; Williamson et al. 2016), as also reported in the Plausibility Report.

Despite the lower reliance given in the Plausibility Report to survey and population monitoring data obtained by methods other than digital aerial survey, the Plausibility Report provides strong evidence that numbers and distributions of marine mammals and marine birds in the Fehmarnbelt area are currently similar to the numbers and distributions reported in the Baseline reports and are broadly similar to numbers and distributions found in other recent years. This observation can be underpinned by knowledge of the population dynamics of marine birds and marine mammals, and by the tendency for those populations to be regulated by their food abundance and distribution. The Plausibility Report presents detailed data on the hydrology, climate and lower trophic levels that indicate that the processes determining food supplies for seabirds and marine mammals are now still essentially the same as was found in the Baseline studies. The ecological relationships in the food web are therefore likely to be the same, and that implies that the carrying capacity of the environment for populations of marine mammals and marine birds is unlikely to have altered greatly. The 'bottom-up' ecological drivers of marine bird and marine mammal populations are therefore likely to be similar now to what they were during the baseline studies.

The scientific literature identifies winter weather conditions as an important influence on the distribution of marine birds. For example, spatial distribution and diet of herring gull varies between winters depending on the amount of ice cover of marine and intertidal habitats (Garthe et al. 2003). The fluctuations in regional distributions, and therefore in local numbers in different winters in relation to weather can be considerable, and are likely to be a major influence on the year to year variations in numbers counted in surveys that are reviewed in section 4 of this review. Year to year variations in numbers of marine birds within regional survey areas often exceed 10% and can

occasionally exceed 50%, as seen in counts in the UK in different winters. Fluctuations also vary among species, with apparently much higher year to year variation in counts of sea ducks in the UK (median change from year to year often being around 10% but sometimes as much as 30%) whereas year to year variation in counts of gulls in the UK tends to be much less (median change mostly being less than 10%). While year to year variations may differ in the Fehmarnbelt area to those observed in the UK, both are likely to be responses to annual variations in breeding success and annual variations in winter weather, so similar levels of year to year natural variation in numbers would be likely. It would also, therefore, be relevant to consider winter weather as likely to be one of the most important factors influencing the numbers of marine birds affected by the Fixed Link construction work.

6. ACKNOWLEDGEMENTS

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APPENDIX 1. Evidence regarding year to year variations in numbers and distributions of marine birds and marine mammals, with a particular focus on the populations in the region near to the Fehmarnbelt

A 1.1 Divers

Red-throated divers and black-throated divers winter in the southern Baltic and Skagerrak where they feed mostly on small fish, though they may take large herring in spring (Guse et al. 2009). Their distribution tends to be consistent from winter to winter, determined by food distribution and hydrography (Garthe et al. 2015). However, they move further south-west in colder winters, moving away from areas with ice cover (Mendel et al. 2008). Red-throated divers and black-throated divers avoid ships and disturbance by ships may increase their energy expenditure and reduce their foraging time, leading to reduced physical condition and indirect mortality (Mendel et al. 2008). Divers are therefore likely to show spatial distributions with lower densities within shipping and ferry routes (Schwemmer et al. 2011).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of red-throated divers in Great Britain (BTO 2016) changed by 21.5% on average from one year to the next (median 18.0%, 50% of values lie between 11.6% and 26.6%, range 0.9% to 91% for 20 comparisons between successive winters up to 2013/14). Annual indices of numbers of black-throated divers in Great Britain (BTO 2016) changed by 15.4% on average from one year to the next (median 11.9%, 50% of values lie between 7.1% and 25.2%, range 1.1% to 43% for 20 comparisons between successive winters up to 2013/14).

A 1.2 Grebes

In contrast to the situation with red-breasted mergansers, wintering numbers of great crested grebes in the German marine area (predominantly in the Baltic) were highest in cold winters, because birds move from freshwater to marine areas in colder winters. Peak winter numbers at the German Baltic Sea coast were about 5 to 20 times higher in cold winters than in mild winters (Mendel et al. 2008). Furthermore, great crested grebes move further west from the eastern and central Baltic regions when cold weather results in those areas freezing up (Durinck et al. 1994) so that numbers at the Fehmarnbelt are likely to be even higher during particularly cold winters. (Mendel et al. 2008). Mendel et al. (2008) describe great crested grebes as '*moderately vulnerable to shipping traffic*' and conclude that disturbance by ships in winter may increase their energy expenditure and reduce the birds' physical condition or may lead to indirect mortality. This may be especially likely when cold weather displaces birds from their preferred feeding areas and increases their thermoregulatory energy costs. Similar arguments may also apply for red-necked grebes and Slavonian grebes.

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of great crested grebes in Great Britain (BTO 2016) changed by 6.4% on average from one year to the next (median 4.9%, 50% of values lie between 2.9% and 9.2%, range 0% to 16% for 29 comparisons between successive winters up to 2013/14). Annual indices of numbers of red-necked grebes in Great Britain (BTO 2016) changed by 14.6% on average from one year to the next (median 8.8%, 50% of values lie between 3.6% and 15.0%, range 0.7% to 69% for 20 comparisons between successive winters up to 2013/14). Annual indices of numbers of Slavonian grebes in Great Britain (BTO 2016) changed by 11% on average from one year to the next

(median 8.9%, 50% of values lie between 4.1% and 15.8%, range 0.9% to 34% for 20 comparisons between successive winters up to 2013/14).

A 1.3 Great cormorant

Great cormorant populations have tended to increase in recent decades after human persecution was reduced, but there is strong evidence that density-dependent regulatory mechanisms have increased as the population has moved towards carrying capacity (Mendel et al. 2008). Numbers wintering in the Baltic vary considerably depending on the extent of sea ice, but have been on an increasing trend since the 1990s (Mendel et al. 2008).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of great cormorants in Great Britain (BTO 2016) changed by 6.6% on average from one year to the next (median 6.0%, 50% of values lie between 4.2% and 7.9%, range 0% to 25% for 26 comparisons between successive winters up to 2013/14).

A 1.4 Swans

Mute swan, whooper swan and Bewick's swan numbers and spatial distribution have been approximately stable over the last two decades in the study area (Pihl et al. 2015, cited in plausibility check report).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of mute swans in Great Britain (BTO 2016) changed by 5.0% on average from one year to the next (median 4.8%, 50% of values lie between 2.6% and 6.7%, range 0% to 12% for 47 comparisons between successive winters up to 2013/14). Annual indices of numbers of whooper swans in Great Britain (BTO 2016) changed by 13.6% on average from one year to the next (median 10.6%, 50% of values lie between 5.9% and 18.6%, range 0% to 35% for 47 comparisons between successive winters up to 2013/14). Annual indices of numbers of Bewick's swans in Great Britain (BTO 2016) changed by 26.7% on average from one year to the next (median 17.6%, 50% of values lie between 11.0% and 24.1%, range 0% to 142% for 47 comparisons between successive winters up to 2013/14).

A 1.5 Geese

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of taiga bean geese in Great Britain (BTO 2016) changed by 17.1% on average from one year to the next (median 13.2%, 50% of values lie between 9.4% and 19.3%, range 0.6% to 72% for 32 comparisons between successive winters up to 2013/14). Annual indices of numbers of European white-fronted geese in Great Britain (BTO 2016) changed by 36.0% on average from one year to the next (median 26.9%, 50% of values lie between 11.1% and 42.3%, range 0.7% to 188% for 47 comparisons between successive winters up to 2013/14). Annual indices of numbers of greylag geese in Great Britain (BTO 2016) changed by 10.4% on average from one year to the next (median 9.1%, 50% of values lie between 4.1% and 12.8%, range 0% to 39% for 48 comparisons between successive winters up to 2013/14). Annual indices of numbers of Greenland barnacle geese in Great Britain (BTO 2016) changed by 8.2% on average from one year to the next (median 8.6%, 50% of values lie between 2.6% and 12.5%, range 0% to 23% for 25 comparisons between successive winters up to 2013/14). Annual indices of numbers of Svalbard barnacle geese in

Great Britain (BTO 2016) changed by 8.4% on average from one year to the next (median 7.8%, 50% of values lie between 3.1% and 12.7%, range 0% to 25% for 48 comparisons between successive winters up to 2013/14). Annual indices of numbers of dark-bellied brent geese in Great Britain (BTO 2016) changed by 14.5% on average from one year to the next (median 12.8%, 50% of values lie between 4.8% and 22.5%, range 0% to 38% for 47 comparisons between successive winters up to 2013/14).

A 1.6 Wigeon

There has been a gradual northward shift in the wintering range and population distribution in winter of the Eurasian wigeon, with changes in numbers from year to year being influenced by breeding success which is affected by climate (Fox et al. 2016). Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of Eurasian wigeon in Great Britain (BTO 2016) changed by 8.9% on average from one year to the next (median 7.9%, 50% of values lie between 4.5% and 12.2%, range 0% to 28% for 47 comparisons between successive winters up to 2013/14).

A 1.7 Gadwall

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of gadwall in Great Britain (BTO 2016) changed by 10.6% on average from one year to the next (median 9.6%, 50% of values lie between 4.2% and 15.2%, range 0% to 33% for 47 comparisons between successive winters up to 2013/14).

A 1.8 Shoveler

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of shoveler in Great Britain (BTO 2016) changed by 10.2% on average from one year to the next (median 8.7%, 50% of values lie between 4.2% and 13.2%, range 0% to 38% for 47 comparisons between successive winters up to 2013/14).

A 1.9 Common pochard

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of common pochard in Great Britain (BTO 2016) changed by 8.2% on average from one year to the next (median 6.5%, 50% of values lie between 2.5% and 12.6%, range 0.4% to 21% for 47 comparisons between successive winters up to 2013/14).

A 1.10 Tufted duck

Tufted duck winter distribution is strongly influenced by winter temperature (Lehikoinen et al. 2013). Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of tufted ducks in Great Britain (BTO 2016) changed by 5.3% on average from one year to the next (median 4.4%, 50% of values lie between 2.3% and 7.1%, range 0% to 20% for 47 comparisons between successive winters up to 2013/14).

A 1.11 Greater scaup

Greater scaup, which feed mainly on bivalve molluscs, are considered to be 'nomadic' during the nonbreeding season and wintering numbers in local areas may fluctuate markedly between years

(Mendel et al. 2008). The population index for German marine areas varied between about 10,000 and 110,000 birds with no clear long-term trend (Mendel et al. 2008). This species is also very sensitive to disturbance by shipping, and avoids areas with ferry traffic and shipping lanes (Mendel et al. 2008).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of greater scaup in Great Britain (BTO 2016) changed by 32.9% on average from one year to the next (median 19.7%, 50% of values lie between 10.9% and 41.8%, range 4% to 278% for 47 comparisons between successive winters up to 2013/14).

A 1.12 Common eider

Mass mortality of over 20,000 common eiders occurred in the Dutch Wadden Sea when cockle and mussel fisheries depleted eider food supply, drastically reducing the carrying capacity of the environment (Camphuysen et al. 2002). A large decline of wintering numbers of eiders in Danish waters from 1990 to 2002 has been attributed to mass mortality from food shortage, disease epidemics and hunting pressure (Mendel et al. 2008, Ekroos et al. 2012). In contrast, where food supply has not been changed by human activities, numbers of common eiders have remained 'relatively stable' over the long term, for example varying from 40,000 to normally no more than 100,000 birds during winter in the German Wadden Sea and around 190,000 in winter in the German Baltic (Mendel et al. 2008). Like greater scaup, common eiders are easily disturbed by shipping, and tend to avoid busy shipping routes and ferry routes (Mendel et al. 2008, Schwemmer et al. 2011), but otherwise tend to aggregate over areas with high densities of bivalve molluscs in shallow water.

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of common eiders in Great Britain (BTO 2016) changed by 11.3% on average from one year to the next (median 10.6%, 50% of values lie between 5.2% and 13.5%, range 1.8% to 34% for 27 comparisons between successive winters up to 2013/14).

A 1.13 Long-tailed duck

Numbers of long-tailed ducks in the southern Baltic and Skagerrak may vary as a consequence of the extent of sea ice in the Baltic Sea (Mendel et al. 2008, Bellebaum et al. 2014), but their distribution tends to map onto the distribution of shallow sea with fine sand sediments holding concentrations of bivalves (Mendel et al. 2008). Numbers in the Baltic in winter have declined between 1993 and 2010 but increased again slightly since 2010 (Bellebaum et al. 2014).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of long-tailed ducks in Great Britain (BTO 2016) changed by 36.0% on average from one year to the next (median 23.5%, 50% of values lie between 10.4% and 45.4%, range 1% to 251% for 47 comparisons between successive winters up to 2013/14).

Wetlands International data as shown in the table above show a dramatic decline of the biogeographic population of -7,4 % per year, which in 6 years would result in a 32 % decline. However, this change cannot be detected from the surveys in the Fehmarnbelt. Here data rather indicate expected local variation in accordance with the literature cited above.

A 1.14 Common scoter

Common scoters are also specialists feeding on bivalves during the nonbreeding season, often much further offshore but in relatively shallow water (up to 20m deep). As with scaup and eider, they are easily disturbed by shipping (Mendel et al. 2008, Schwemmer et al. 2011). Mendel et al. (2008) state that common scoters '*move frequently between wintering sites*' so that local numbers may vary as birds move between foraging patches. Studies of common scoters around Horns Rev I offshore wind farm found that the spatial distribution of common scoters changed with changes in the distribution of bivalve molluscs, in particular changing in response to the spread of the alien invasive species American razor clam (Danish Energy Agency 2013). Birds depleted the bivalves in areas of high prey density, and subsequently switched to feed on alternative patches as the best sites were depleted (Danish Energy Agency 2013).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of common scoters in Great Britain (BTO 2016) changed by 34.5% on average from one year to the next (median 33.3%, 50% of values lie between 12.5% and 50.0%, range 0% to 120% for 47 comparisons between successive winters up to 2013/14).

Wetlands International data as shown in the table above show a dramatic decline of the biogeographic population of -7,5 % per year, which in 6 years would result in a 32 % decline. This decline, however, is currently disputed in the scientific community and numbers are expected to be revised with higher numbers again. In the case of the plausibility study the detected increase in total numbers and redistribution in the surveyed area lies within the typical range of local variation in accordance with the literature.

A 1.15 Velvet scoter

Velvet scoter numbers showed no trend from 1977 to 2007, but showed evidence of density-dependent regulation of population size and an impact of winter climate (Hartman et al. 2013). In winter when numbers reach a peak, in the German Baltic, velvet scoters are mostly found in the eastern part (Mendel et al. 2008). As with common scoter, this species feeds mostly on molluscs, so its distribution tends to map onto suitable areas of shallow sea (less than 20m deep) with high densities of bivalve molluscs. They are easily disturbed by shipping (Mendel et al. 2008), so tend to avoid ferry and shipping lanes. As with common scoters, velvet scoters move between foraging patches, tending to deplete areas with high densities of molluscs and then move on to other suitable patches. As a result, their spatial distribution may alter within winters as prey patches are depleted, and may alter between winters if the settlement pattern of bivalves varies from year to year.

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of velvet scoters in Great Britain (BTO 2016) changed by 37.7% on average from one year to the next (median 30.7%, 50% of values lie between 13.2% and 53.3%, range 0% to 154% for 47 comparisons between successive winters up to 2013/14).

A 1.16 Smew

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of smews in Great Britain (BTO 2016) changed by 45.9%

on average from one year to the next (median 35.1%, 50% of values lie between 15.8% and 59.5%, range 2.5% to 286% for 47 comparisons between successive winters up to 2013/14).

A 1.17 Red-breasted merganser

Mendel et al. (2008) report that numbers of red-breasted mergansers in German waters in winter vary from year to year, with lowest counts occurring in coldest winters. Lowest counts in the coldest winters were only about 10% of the numbers in peak winters. In contrast, wintering numbers are higher in the Netherlands in colder winters, suggesting that birds move further south in response to cold winter weather.

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of red-breasted mergansers in Great Britain (BTO 2016) changed by 12.8% on average from one year to the next (median 10.5%, 50% of values lie between 4.2% and 17.5%, range 0% to 56% for 47 comparisons between successive winters up to 2013/14).

A 1.18 Goosander

Goosander winter distribution is strongly influenced by winter temperature (Lehikoinen et al. 2013). Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of goosanders in Great Britain (BTO 2016) changed by 15.4% on average from one year to the next (median 13.0%, 50% of values lie between 6.1% and 23.2%, range 1% to 51% for 47 comparisons between successive winters up to 2013/14).

A 1.19 White-tailed eagle

White-tailed eagle numbers have been increasing in many European countries in recent years, suggesting that these populations had been held below carrying capacity by human impacts, or that carrying capacity has increased. There is little evidence to suggest the latter. Increases in numbers in the Fehmarnbelt area seem likely over coming years if this general trend continues.

A 1.20 Little gull

Little gulls are mainly present in the Fehmarnbelt area during autumn when this species migrates from breeding grounds in Finland, the Baltic States, Belarus and Russia towards wintering grounds in west Europe and northwest Africa (Mendel et al. 2008). Huge flocks of little gulls may arrive during migration, sometimes stopping for several weeks to feed, but numbers can vary considerably from year to year (Garthe and Schwemmer 2008), and from day to day within years, with peak numbers often appearing in coastal waters after storms (Natural England 2012).

A 1.21 Black-headed gull

Black-headed gulls are found only in small numbers at sea in the Baltic Sea, as this species is found predominantly in terrestrial habitats (Mendel et al. 2008). The numbers at sea may vary considerably if small proportions of those using inland habitats switch to feeding at sea, but this species obtains little food from fishing vessels in the Baltic (Garthe and Scherp 2003).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of black-headed gulls in Great Britain (BTO 2016)

changed by 7.3% on average from one year to the next (median 5.8%, 50% of values lie between 2.0% and 11.3%, range 0.9% to 22% for 20 comparisons between successive winters up to 2013/14).

A 1.22 Common gull

Common gulls will switch between marine and terrestrial habitats and foods in an opportunistic way. As a result, numbers at sea may vary considerably depending on the relative availabilities of different food types (Mendel et al. 2008). Common gulls follow fishing vessels in the Baltic and their local distribution and abundance may vary in relation to the activities of fisheries and the amount of discarding taking place (Garthe and Scherp 2003).

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of common gulls in Great Britain (BTO 2016) changed by 7.2% on average from one year to the next (median 6.1%, 50% of values lie between 3.3% and 10.0%, range 0% to 17% for 20 comparisons between successive winters up to 2013/14).

A 1.23 Lesser black-backed gull

Lesser black-backed gulls occur in German Baltic waters in small numbers, but at all times of year. The estimated population size in the German Baltic in 2000-2007 was 60 in spring, 160 in summer, 130 in autumn and 111 in winter (Mendel et al. 2008). Lesser black-backed gulls are opportunistic feeders, but will aggregate at fishing vessels to feed on discards. Local distribution and numbers are likely to vary from year to year, and day to day, depending on the activities of the local fishing fleets.

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of lesser black-backed gulls in Great Britain (BTO 2016) changed by 18.5% on average from one year to the next (median 12.6%, 50% of values lie between 6.0% and 25.0%, range 0% to 72% for 20 comparisons between successive winters up to 2013/14).

A 1.24 Herring gull

The herring gull is by far the most numerous large gull species in the southern Baltic Sea (Mendel et al. 2008). The German midwinter population of herring gulls has been estimated at 210,000 birds (2000 to 2005) with about 130,000 of these at sea. About 70,000 of these are in German Baltic waters (Mendel et al. 2008). The population index for herring gull numbers in German Baltic waters varied from 0.3 in 1995 to 1.1 in 1992 with no clear long-term trend between 1991 and 2005 (Mendel et al. 2008). So numbers have varied by a factor of about 3.5 between lowest and highest counts in those winters. Herring gull distribution in winter in German Baltic appears to be influenced by winter weather severity (S. Garthe pers. comm.). In the Baltic Sea, the herring gull is the most common and abundant gull species attending fishing boats, especially during winter (Garthe and Scherp 2003). Local distribution and numbers are likely to vary from year to year, and day to day, depending on the activities of the local fishing fleets, but also on winter weather conditions.

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of herring gulls in Great Britain (BTO 2016) changed by 11.1% on average from one year to the next (median 8.5%, 50% of values lie between 5.0% and 16.3%, range 1% to 30% for 20 comparisons between successive winters up to 2013/14).

A 1.25 Great black-backed gull

Counts show that great black-backed gull numbers at the German Baltic coast peak in winter and consist mainly of birds from breeding areas in the northern Baltic (Mendel et al. 2008). During summer, numbers at the German Baltic coast are small, and consist mainly of immature birds (Mendel et al. 2008). Particularly in winter, this species may be encountered far from shore, and dense concentrations may occur locally at sea, often correlated with the distribution of fishing boats as this species feeds very extensively on discards in winter (Garthe and Scherp 2003). Up to 40% of birds in winter are found associated with fishing vessels (Mendel et al. 2008). Local distribution and numbers are likely to vary from year to year, and day to day, depending on the activities of the local fishing fleets. Mendel et al. (2008) reported the population index of great black-backed gull numbers during January at the German Baltic coast as fluctuating from 0.5 to 1.6, indicating a three-fold variation in numbers between years, but with no significant long term trend over the study period from 1992 to 2005. Although the index shows evidence of autocorrelation, with numbers in consecutive years tending to be similar, the index fell from the peak of 1.6 in 1993 to 0.7 in 1994, showing that large changes can occur from one year to the next even over large survey areas.

Long-term survey data from Britain provide an example of how much numbers may vary from one winter to the next. Annual indices of numbers of great black-backed gulls in Great Britain (BTO 2016) changed by 7.0% on average from one year to the next (median 4.3%, 50% of values lie between 2.3% and 7.7%, range 0% to 23% for 20 comparisons between successive winters up to 2013/14).

A 1.26 Sandwich tern

Sandwich tern breeds at colonies in the Baltic and is a passage migrant through the southern Baltic, but densities of this species in coastal waters in the Baltic are generally much lower than in coastal waters of the German North Sea (Mendel et al. 2008). Sandwich terns feed mainly on sandeels, sprats and young herring, so their distribution may vary if the abundances and distributions of these species vary from year to year.

A 1.27 Common guillemot

Common guillemots in the Kattegat and Skagerrak and western Baltic Sea (Kiel Bight) in winter are thought mostly to originate from North Sea colonies (Peterz and Oldén 1987; Heubeck et al. 1991; Skov et al. 1995), whereas common guillemots in the central and eastern Baltic Sea in winter are almost certainly from Baltic colonies (Mendel et al. 2008). Anker-Nilssen et al. (1988) used biometrics of 826 common guillemots (18% of which were adults) killed by oil in the Skagerrak in January 1981 to infer that most were probably from Scottish or south Norwegian colonies. Common guillemots from British colonies show changes in distribution over decades that relate to long-term changes in abundance of sandeels, sprats and young herring in the North Sea and in Danish waters (Heubeck et al. 1991; Lyngs and Kampp 1996), indicating considerable flexibility in their nonbreeding distribution in order to follow the distribution and abundance of their preferred fish prey. Skov et al. (2000) found that the distribution of common guillemots in winter in the Skagerrak and Kattegat correlated most closely with the distribution of young herring. To the extent that juvenile herring spatial distribution changes from year to year, common guillemot distribution is likely to follow those changes.

A 1.28 Razorbill

Razorbills wintering in the Skagerrak and Kattegat may originate from breeding populations in the northern British Isles (Wernham et al. 2002) or in the Baltic Sea, while birds wintering in the southern Baltic Sea are almost all from the Baltic breeding population (Mendel et al. 2008). Anker-Nilssen et al. (1988) used biometrics of 308 razorbills (66% of which were adults) killed by oil in the Skagerrak in January 1981 to infer that 55% were probably from Scottish colonies, and 45% from Baltic colonies. However, numbers of razorbills coming into the Skagerrak and Kattegat from Britain seem to vary considerably, apparently depending on the abundance of sprats and juvenile herring in the North Sea, and possibly the abundance of sprats and juvenile herring in the Skagerrak and Kattegat (Blake 1983, 1984), although razorbills wintering in that area take a variety of fish prey including gobies, sandeels and sticklebacks (Mendel et al. 2008). Skov et al. (2000) found that the distribution of razorbills in winter in the Skagerrak and Kattegat correlated most closely with the distribution of young herring. To the extent that juvenile herring spatial distribution changes from year to year, razorbill distribution is likely to follow those changes.

A 1.29 Black guillemot

When the northern Baltic Sea freezes up, the black guillemots from that area move into the southern Baltic Sea to spend the winter there. Numbers in the southern Baltic Sea are therefore likely to be determined mainly by the amount of sea ice further north, reflecting colder winters (Mendel et al. 2008).

A 1.30 Harbour porpoise

There has been one pronounced long-term shift in harbour porpoise distribution in UK waters. Harbour porpoise densities were high at Shetland in 1994-1999 but very low in 2006-2011 (Heinänen and Skov 2015). This shift in distribution is most likely to be associated with the collapse of the sandeel stock at Shetland, as this was thought to be the main prey of harbour porpoises at Shetland. However, studies in UK waters over three decades using data collected under the Joint Cetacean Protocol have concluded that 'hot spots' for harbour porpoise tend to be persistent over decades and are determined primarily by physical features that influence the spatial distribution and density of the preferred prey of harbour porpoises (Heinänen and Skov 2015). This indicates that harbour porpoise numbers and distribution are unlikely to change much from year to year except where there have been drastic changes in abundance of key prey fish stocks, and this also appears to apply to Baltic harbour porpoises (Benke et al. 2014; Viquerat et al. 2014; Sveegaard et al. 2015).

A 1.31 Harbour seal

Harbour seals tend to show high fidelity to haul-out sites, and little or no seasonal pattern in abundance at individual haul-out sites and foraging areas (Cordes and Thompson 2015). Satellite tagging of harbour seals has shown that most individuals stay within 25km of their main haul-out site (Cunningham et al. 2009). The site fidelity and limited foraging range of harbour seals indicates that harbour seal numbers and distribution are unlikely to change much from year to year.

A 1.32 Grey seal

Although grey seals in the North Sea and Atlantic show very extensive movements between areas, in the Baltic Sea the grey seal tends to show only limited movements and a high level of site fidelity

(Oksanen et al. 2014). The site fidelity and limited foraging range of Baltic grey seals indicates that grey seal numbers and distribution within the Baltic are unlikely to change much from year to year.