OSPAR CEMP Guideline

Common Indicator: Marine bird breeding productivity (B3)

(OSPAR Agreement 2016-10)[1] [2]

This OSPAR biodiversity indicator replaces the 'Marine bird breeding success/failure' indicator implemented in IA2017.

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[1] This document exists in English only

[2] Update 2022

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1 Introduction

The OSPAR Common Indicator: B3 – Marine bird breeding productivity will contribute to assessments of the state of marine bird populations in the framework of OSPAR Quality Status Reports and assessments of Good Environmental Status under the Marine Strategy Framework Directive: MSFD primary criterion D1C3 - The population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity, and survival rates) of the species are indicative of a healthy population which is not adversely affected due to anthropogenic pressures (Commission Decision EU 2017/848).

This indicator describes changes in breeding productivity in marine birds, defined as the mean number of fledged chicks produced per breeding pair, clutch or nest per year, and seeks to quantify the impact of the observed level of breeding productivity on population growth potential. The indicator is derived from annual data on the number of chicks fledged per pair, clutch or nest of marine bird species at breeding sites (typically colonies) throughout the NE Atlantic.

As long-lived species with delayed maturity, changes in productivity of marine birds are expected to reflect changes in environmental conditions long before they are evident as changes in population size. Changes in breeding productivity can thus serve as an early warning of impending changes in population abundance.

The breeding productivity of marine birds could be a valuable indicator of GES achievement, especially in areas where fisheries and birds target the same prey. The indicator could also provide evidence of other impacts, from e.g. human disturbance, contaminants and predation by invasive species.

This indicator derives time series of mean breeding productivity for each species and OSPAR region with sufficient data. Through a demographic modelling approach, the expected impact of the observed level of breeding productivity on population growth rate is estimated. Species-specific thresholds for expected growth rates are derived from the criteria used by the International Union for the Conservation of Nature (IUCN) to establish species conservation status. The frequency of failure to pass these thresholds is aggregated for OSPAR regions and for functional groups of marine birds.

In this context, 'marine birds' include the following taxonomic groups that are commonly aggregated as 'waterbirds' and 'seabirds':

Waterbirds: shorebirds (order Charadriiformes); spoonbills (order Pelecaniformes); ducks, geese and swans (Anseriformes); divers (Gaviiformes); and grebes (Podicipediformes);

Seabirds: petrels and shearwaters (Procellariiformes); gannets and cormorants (Suliformes); skuas, gulls, terns and auks (Charadriiformes).

Shorebirds, some duck species and some gulls feed on benthic invertebrates in soft intertidal sediments and on rocky shores. Spoonbills feed on tiny fish and invertebrates in very shallow waters. Geese mostly graze on exposed eelgrass beds (i.e. *Zostera* spp.). All other marine birds, including some gulls, spend the majority of their lives at sea, feeding on prey living within the water column (i.e. plankton, fish and squid) or picking detritus from the surface or diving for invertebrate benthos (diving ducks). Divers, piscivorous and benthivorous ducks, grebes, cormorants, gulls and terns tend to be confined to inshore waters; whereas petrels, shearwaters, gannets, skuas and auks venture much further offshore and beyond the shelf break.

2 Monitoring

2.1 Purpose

As long-lived species, changes in productivity of marine birds are expected to reflect changes in environmental conditions before they are evident in changes in population size. An analysis of the breeding failure indicator used in the Intermediate Assessment 2017 for nine species in UK North Sea waters (Cook et al., 2014) provides evidence of a link to fishing pressure. The results of Cook et al. (2014) suggest that breeding productivity of seabirds could be an indicator of GES in parts of the North Sea where fisheries and seabirds target the same prey. The indicator could also provide evidence of other impacts, from e.g. climate change, human disturbance, contaminants and predation by invasive species. There are strong links to management, especially with regard to food availability, human disturbance and predation (including invasive non-indigenous mammals).

2.2 Quantitative Objectives

Temporal trend and spatial distribution for the monitoring programme

The monitoring required for indicator B3 is on the annual mean breeding productivity (number of chicks fledged per pair, clutch or nest) of marine birds at colonies and in survey plots throughout the NE Atlantic. A separate indicator is constructed for each species in each OSPAR Region or potentially sub-division thereof.

Monitoring should be conducted on a site by site basis, but needs to be representative of each region and sub-division thereof. Monitoring should be representative of all sub-regions in order to identify impacts and threats.

2.3 Monitoring Strategy

Data collection is currently carried out and funded by national monitoring schemes, often with considerable input from volunteer seabird enthusiasts. The contribution of monitoring data by Contracting Parties for the assessment of indicator B3 for the Quality Status Report 2023 is described in Annex 1. It also identifies gaps in data availability (see Table A1-1) and describes the potential for an operational indicator B3 in each OSPAR Region.

Most schemes have a central data storage mechanism (e.g., national database). Most countries monitor a sample of their sites, with some but not all monitored annually. However, some countries do not have a monitoring scheme for breeding productivity of marine birds.

2.4 Monitoring Methods

Monitoring breeding productivity is more straightforward in some species than others, so species-specific methods have been designed and are widely used (see e.g., Walsh et al. 1995). Generally monitoring is conducted by observing a sample of breeding territories or nests within a colony and recording progress from laying through hatching to fledging. This requires one or two observers visiting a colony several times during the breeding season (i.e., usually May-Aug, but varies with species). Time-lapse photography can also be used to monitor breeding productivity, and may be favourable where access to breeding sites is difficult.

The time required for data collection depends on the number of sites and types of marine bird being surveyed. Each national monitoring programme currently manages time allocations. The minimum number of monitoring sites depends on species and the inherent variability in trends between locations.

Monitoring costs in most countries are minimised by using volunteer observers, but professional observers are sometimes used to monitor the less accessible sites – especially in the Arctic. Hence, monitoring costs will vary between countries depending on the number of sites to be monitored, the accessibility of these sites and on how much of the monitoring can be done by volunteers. During colony visits for productivity monitoring, some data on abundance for common indicator B1 (marine bird abundance) can also be collected. Monitoring costs for both indicators are thus not necessarily additive.

2.5 Quality assurance/ Quality Control

Each national monitoring scheme has QA/QC protocols, but European standards should be developed. A minimum standard should be to follow internationally recognised monitoring methods (e.g., Walsh et. al. 1995; Koffijberg et. al. 2011).

2.6 Data reporting, handling and management

Each national monitoring scheme has its own data storage mechanism. Within each region and sub-division therein, indicator B3 is constructed from all available data from constituent CPs. CPs are asked to submit their data in response to data calls issued to OSPAR HoDs via written procedure.

The frequency of OSPAR data calls is to be decided, but will be no more frequent than annually.

Data are stored in the OSPAR Marine Bird Database hosted by the ICES Data Centre via the ICES Biodiversity Data Portal at https://www.ices.dk/data/data-portals/Pages/Biodiversity.aspx

Data undergo a series of validation checks during the uploading process.

The following data were requested from contracting parties: counts of young fledged (preferably or fail that counts of young hatched), per species per monitoring plot per year.

Data entry forms can be downloaded from https://www.ices.dk/data/data-portals/Pages/Biodiversity.aspx

Guidance for submitting data is available at https://www.ices.dk/data/Documents/biodiversity/Birds_Reporting_Format_Guidance.pdf

3 Assessment

This indicator is generated using time-series of annual mean breeding productivity (number of chicks fledged per pair) of marine bird species at sites (colonies and survey plots) throughout the NE Atlantic. A separate indicator should be constructed for each species in each region.

The indicators for each species are constructed from a time-series of annual estimates of breeding productivity at a sample of sites. Not all the sites in the sample will have been observed every year in the time-series.

3.1 Preparation of data

Spatial aggregation of data

This indicator is assessed for each OSPAR Region (see Figure 1).

It would be preferable to assess breeding productivity at a higher spatial resolution, e.g. the sub-divisions used for the marine bird abundance indicator (B1), and also for the breeding success/failure indicator in IA2017. In particular, OSPAR region I (Arctic Waters) is very large and highly heterogeneous, and pooling data from different parts of this region may hide relevant spatial variation in population status. However, for many species the amount of data available in each sub-division is too low to allow assessment at a finer scale. In future assessments, it may be possible to assess the indicator for the more data-rich species at the sub-division level.

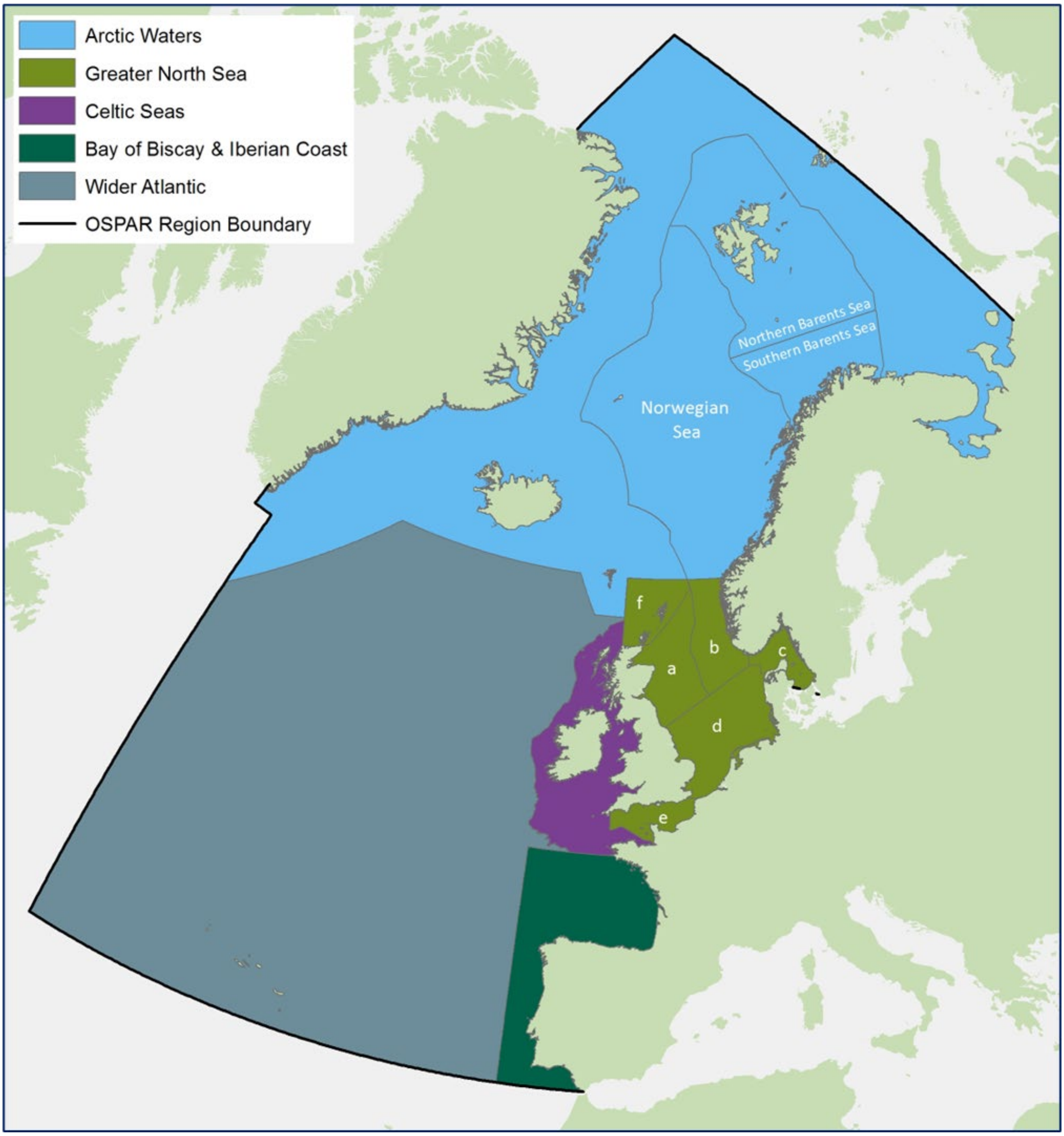

Figure 1. Marine Bird assessment units (Filename: CEMP_B3_fig_1).

3.2 Species aggregation – functional groups

Species were assigned to the functional groups given in Table 1. The species assessed and the functional groups to which they were assigned, are given in the table in Annex 2. The table also lists additional species which could be brought into the indicator following inclusion of additional OSPAR Regions and/or if existing monitoring programmes were extended.

These functional groups were proposed by JWGBIRD (ICES 2014) and have been adopted in the EU Commission Decision (2017/848)[3].

Table 1: Marine bird functional groups (filename: B3 Table-a_functional-groups_20220901).

Functional group	Typical feeding behaviour	Typical food types	Additional guidance
Surface feeders	Feed within the surface layer (within 1–2 m of the surface)	Small fish, zooplankton and other invertebrates	"Surface layer" defined in relation to normal diving depth of plunge-divers (except gannets)
Water column feeders	Feed at a broad depth range in the water column	Pelagic and demersal fish and invertebrates (e.g. squid, zooplankton)	Include only spp. that usually dive by actively swimming underwater; but including gannets. Includes species feeding on benthic fish (e.g. flatfish).
Benthic feeders	Feed on the seafloor	Invertebrates (e.g. molluscs, echinoderms)	
Wading feeders	Walk/wade in shallow waters	Invertebrates (molluscs, polychaetes, etc.)	
Grazing feeders	Grazing in intertidal areas and in shallow waters	Plants (e.g. eelgrass, saltmarsh plants), algae	Geese and dabbling ducks

3.3 Assessment criteria

Parameter/metric

'Expected annual population growth rate', i.e. the rate at which the population would be expected to grow per year, given the current level of breeding productivity.

The impact that a given level of breeding productivity has on population growth depends on the entire life history of the species, and also on current levels of other demographic parameters, notably survival. By combining estimates of breeding productivity with the observed trend in population abundance (B1 indicator) in a demographic model, the expected annual growth rate is estimated. This value is compared to species-specific thresholds derived from internationally recognised criteria for assessment of conservation status. The thresholds used correspond to a decline of 30% in abundance over three generations, which is the IUCN criterion for listing a species as Vulnerable (VU) (IUCN 2012). A decline of 30% over three generations corresponds to a per-generation growth rate of $\sqrt[3]{0.7}$ = 0.888. Converting this to species-specific annual growth rate thresholds requires a customised demographic model (see section 3.5).

3 EU Commission Decision (2017/848) - laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU

3.4 Spatial Analysis and / or trend analysis

Breeding productivity is assessed for each OSPAR region. For data-rich species, assessments could also be performed for the sub-divisions used for the abundance indicator (B1). In order to be included, monitoring data from at least two colonies and at least ten years should be available.

3.5 Assessment values

The calculation of the assessment values (expected annual population growth rate) involves the following steps:

This section lists the steps required to assess the indicator for each species and in each Region.

1. Estimate annual mean breeding productivity (number of chicks fledged per pair), and its standard error. The method takes account of missing data at individual sites and generates a reproducible time series.
2. Calculate a six-year retrospective running mean breeding productivity (e.g. the value for 2019 is based on the years 2014-2019).
3. Construct a simplified baseline demographic matrix model (female-based) for the species. The number of age classes in the model, and the starting values for survival of the different age classes, are based on expert knowledge and/or literature reviews (primarily Horswill & Robinson 2015). The model assumes that all individuals start to breed at a given age, that breeding productivity and survival are unchanged after this age (i.e. no senescence), that 90% of all adults attempt to breed each year and thus are included in the estimates of breeding productivity, and that sex ratio is 1:1.
4. Tune the baseline model to the observed abundance trend (B1 Marine Bird Abundance indicator), for the period considered in each Region. This involves:

    a) Estimate the mean observed population growth rate for the period with available data by regressing the log-transformed abundance indicator against year, and back-transforming the estimated regression slope.

    b) Construct a stochastic version of the matrix model (10,000 simulations), by substituting values drawn from normal distributions defined by annual mean breeding productivity and its standard error into the baseline model, and run it for the period considered in each Region. For each simulation, estimate the stochastic population growth for the period considered in each Region.

    c) Compare observed population growth rate to the simulated mean stochastic growth rate, and adjust values of survival for the different age classes until the two measures of population growth rate are the same. There is no unique solution, and some trial and error is necessary.

    d) Further tune the baseline model by adjusting breeding productivity to obtain a stable population (i.e. growth rate = 1). Use matrix algebra to calculate the generation time (i.e., mean age of reproducing females) of the population based on this version.

5. Calculate the growth rate corresponding to the IUCN red list thresholds of 30% decline over three generations (using the generation time calculated in the previous step) or 10 years, which indicates a species is Vulnerable (IUCN 2012).

6. For marine birds, three generations is always more than 10 years. To derive threshold values of λ (the annual asymptotic growth rate) for a specific species or population, baseline demographic models were used to assess generation time (Caswell 2001). The growth rate λT was then calculated as $\sqrt{(1 - TIUCN)}\ 3{*}GT$, where GT = generation time and TIUCN = IUCN threshold value for Vulnerable species = 0.3).

7. Substitute the values of running mean breeding productivity into the tuned model, and run it for the period considered in each Region. Calculate for each year the expected (asymptotic) growth rate using matrix algebra. These values represent the expected long-term annual growth rate of the population, if breeding productivity was maintained at the mean level observed in the most recent six-year period.

8. Plot this time series against year, and compare against the threshold as calculated in step 6.

9. For species that have a predicted growth rate below the threshold, it can be compared against other thresholds that correspond to other IUCN red-list categories:

   - EN (endangered): ≥ 50 % decline

   - CR (critically endangered): ≥ 80 % decline (IUCN 2012)

10. The thresholds for Endangered and Critically Endangered are calculated as in Step 6 above, by changing values of TIUCN to 0.5 or 0.8, respectively.

The approach outlined above produces a time series of expected annual growth rates, each of which reflects mean breeding productivity in the current and the five previous years. The assessment is performed for the most recent year in this time series. However, the full time series of expected annual growth rates can be used to show changes over time and inform higher-level assessments of changes in GES (see section 3.7).

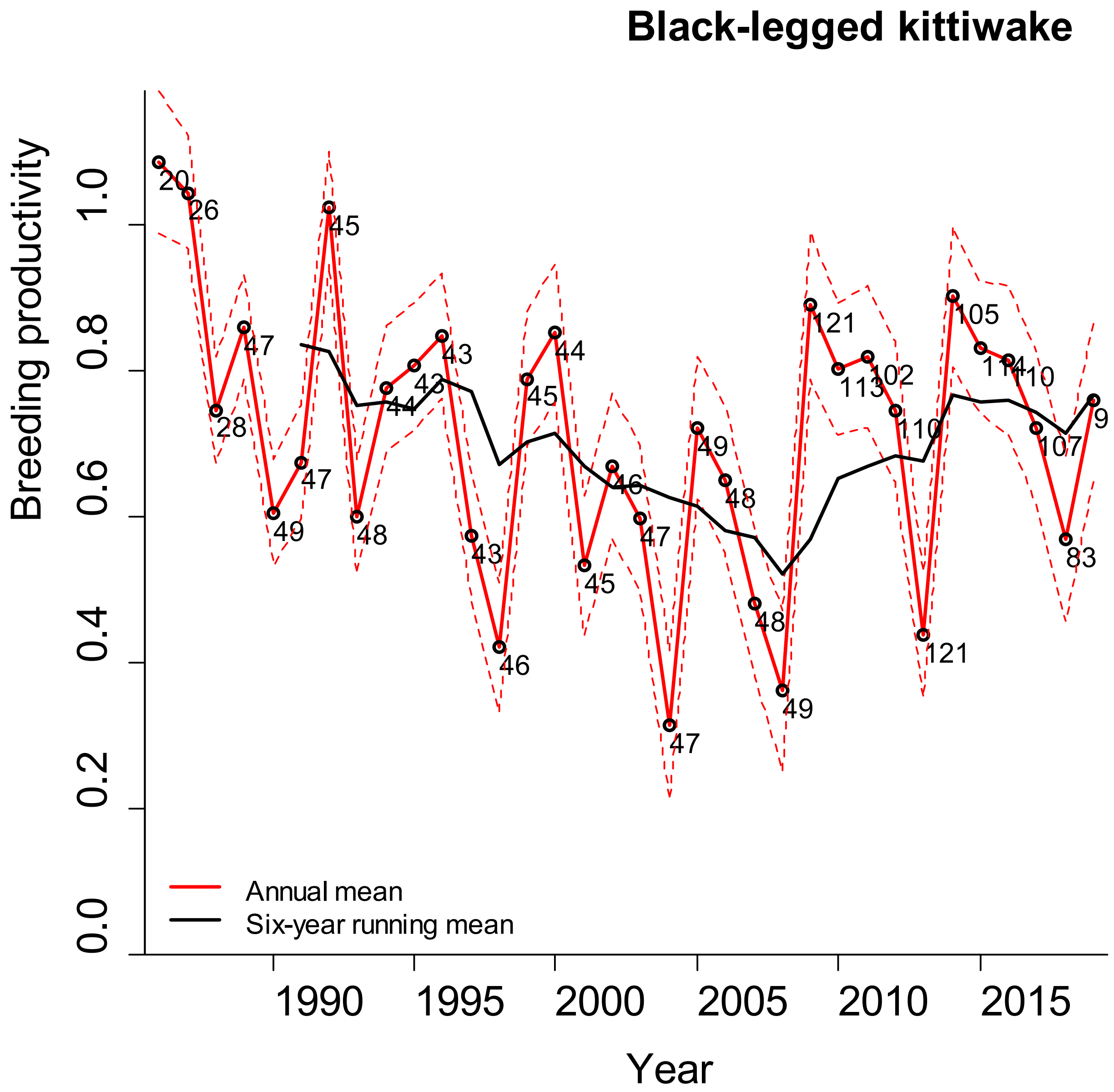

Figure 2. (File name: CEMP_B3_fig_2.jpg). Mean annual breeding productivity (fledged chicks/pair) of black-legged kittiwake in OSPAR region II (the Greater North Sea) 1986-2019. The solid red line shows the estimated marginal means for each year, with dashed lines showing 95% confidence limits. Labels below the data points show the number of survey plots with available data for each year. The solid black line shows the retrospective six-year running mean, with the most recent value (mean of 2014-2019) being 0.767 fledged chicks/pair. This is the output of step 1) above.

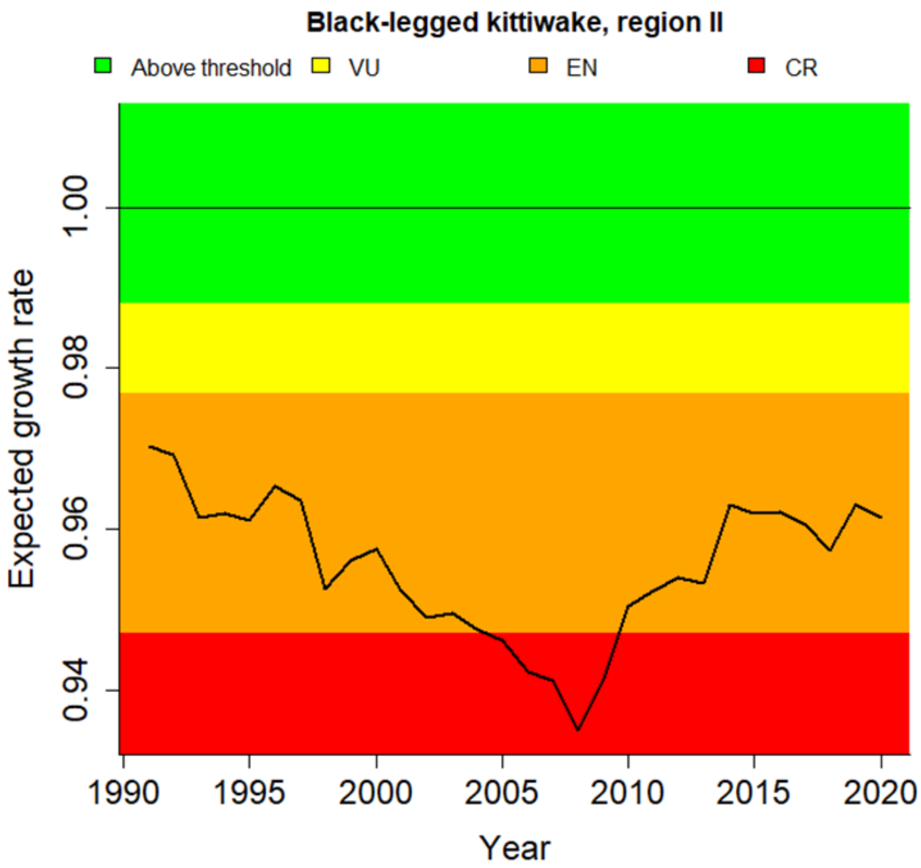

Figure 3. (File name: B3_Fig_e_kittiwake_20220902.jpg) Expected annual population growth rate of black-legged kittiwake in OSPAR region II, the Greater North Sea, 1991-2020 (black line). The colour-coded background shows the threshold values; values in the green zone are above the threshold, whereas values in the other zones are below. For illustration, the figure also shows a breakdown for the red list categories of Vulnerable (VU), Endangered (EN) and Critically Endangered (CR). In this case, the assessment value (the value for 2019 on the black line) is 0.963, which is well below the threshold value of 0.988. This corresponds to an expected decline of 3.7% per year, or 67% over three generations (29.5 years for black-legged kittiwake). Current levels (six-year retrospective mean) of breeding productivity in black-legged kittiwakes in OSPAR region II are thus too low to prevent the population from declining towards extinction, and correspond to the red list category Endangered. Model output indicates that with the mean levels of survival inferred for the study period, a breeding productivity of 1.15 fledged chicks/pair would be required to stabilise the population.

3.6 Development of assessment methods

This indicator has been developed in response to the known limitations of its predecessor in IA2017, marine bird breeding success/failure. The OSPAR/HELCOM/ICES Joint Working Group on Marine Birds (JWGBIRD) acknowledged these limitations already when developing the indicator (ICES 2015):

- The threshold set for breeding failure (0.1 fledged chick/pair) is arbitrary.
- Using the same threshold for breeding failure for all species is potentially misleading, as the impact of a given (low) level of breeding productivity depends on the species' life history, and also varies over space and time.

- Consistently poor (but not catastrophic) breeding productivity will affect population growth, without showing up in the success/failure indicator. This will affect some species more than others.

The development of the approach presented here was initiated by JWGBIRD at its annual meetings in 2018 and 2019 (ICES 2018, 2020), and completed as part of the NEA PANACEA project in 2021-22. Full details will be published in a peer-reviewed international journal.

The demographic modelling approach used here is relatively simple and does not fully use the information contained in the monitoring data. For example, low breeding productivity in a specific year would be expected to lead to lower population growth (possibly decline) some years later, when young birds recruit to the breeding population. Such year-specific links are not explicitly considered in the current approach. For some species and in a subset of colonies, annual adult survival is also monitored, and this parameter contains vital information for understanding population change. To address these issues, the natural next development would be to implement Integrated Population Models (Robinson et al. 2014), which can use all types of raw demographic data. Such models could replace the current B1 and B3 indicators (and potentially the B5 indicator), and would allow short-term prediction of likely population trends in the years following the assessment.

3.7 Presentation of assessment results

In addition to the species-specific plots of annual breeding productivity in Figure 2 and expected population growth rate in Figure 3, the following methods of presentation are recommended:

Species Traffic lights

Similar to the breeding success/failure indicator in IA2017, a colour-coded summary figure gives a quick overview of the assessment results (Figure 4). Green cells indicate that the expected population growth rate based on the six-year retrospective running mean breeding productivity was above the threshold for red-listing as Vulnerable, while red cells were below the threshold. Higher threat categories are indicated by two-letter codes (EN = Endangered, CR = Critically Endangered).

Species (common name)	Arctic Waters	Greater North Sea	Celtic Seas	Bay of Biscay & Iberian Coast
Northern fulmar		EN	CR	
Great skua		EN		
Arctic skua		CR		
Herring gull		CR↓	EN	
Common gull		CR↓		
Lesser black-backed gull	↑	EN↓	↑	
Great black-backed gull		EN	↑	
Black-headed gull		CR↓		
Black-legged kittiwake	CR	EN	EN	
Roseate tern				
Common tern		CR↓	VU↑	
Arctic tern		CR↓	EN↓	
Little tern		↑		
Sandwich tern		↑		
Eurasian spoonbill				
Eurasian oystercatcher		CR		
Pied avocet		EN↑		
Great cormorant			EN	
European shag	↑			
Northern gannet				
Razorbill	EN		VU↑	
Black guillemot	EN↓			
Atlantic puffin	VU	VU↑		
Common guillemot		↑		
Brünnich's guillemot	EN			
Insufficient data / Not breeding	Breeding productivity too low to sustain population			
	Breeding productivity sufficient to sustain population			

Assessment status of each species in each region in 2019 (except 2016 for Bay of Biscay and Iberian coast). Species are listed by feeding guild: surface feeders, wading feeders and water column feeders. When breeding productivity was too low to sustain the population, the two-letter codes show the corresponding IUCN threat status: VU (Vulnerable), EN, (endangered), CR (Critically Endangered). Hatching indicates that these cells are expected to be completed in the final version. Arrows indicate change in IUCN threat status since a retrospective assessment of the status in 2014, using the same method. An arrow pointing up thus indicates an improvement in status since the previous assessment period.

Figure 4. Summarized results of the B3 assessment. (File name: B3_Table-c_results_species_20220902.xlsx). For each species in each OSPAR region, the colour indicates whether the expected annual population growth rate is above or below the threshold for red-listing as Vulnerable.

Multispecies assessments (see Figures 5 and 6)

A multispecies assessment for each OSPAR region is performed by calculating the proportion of species that pass the species-specific thresholds of expected annual population growth rate, for all species or for functional groups, see Figure 5. As for indicator B1, 75% of species assessed are required to pass the threshold for GES to be obtained.

Threshold achieved (≥75%)				
Threshold failed (<75%)				
	Percentage of species above assessment value for breeding productivity			
Functional group	**Arctic Waters**	**Greater North Sea**	**Celtic Seas**	**Bay of Biscay and Iberian coast**
Wading feeders		33% (3)		
Surface feeders	80% (5)	21% (14)	58% (12)	100% (2)
Water column feeders	43% (7)	83% (6)	60% (5)	
All	58% (12)	39% (23)	59% (17)	100% (2)

Figure 5. File name: B3_Table-b_results_all_20220902). Multispecies assessment (overall and of individual feeding guilds) in OSPAR regions I, II, III and IV. GES is considered to be obtained if at least 75% of species assessed pass the species-specific threshold (see Figure 4).

Retrospective multispecies assessments allow assessment of changes in GES since IA2017 (and QSR2010) to be derived; see example in Figure 6.

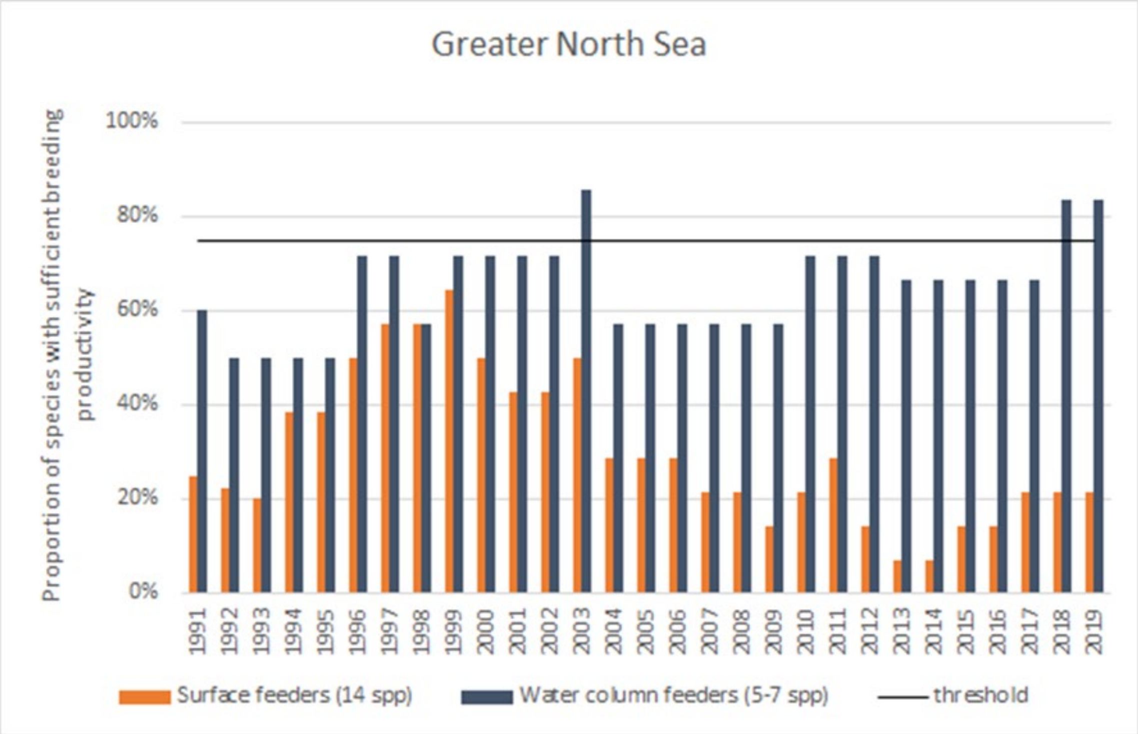

Figure 6. (File name: CEMP_B3_fig_6.jpg). Changes in the proportion of marine bird species assessed in each functional group, which have sufficiently high expected annual growth rate to pass the threshold for red-listing as vulnerable, in each year 1991-2019 in the Greater North Sea. The black line shows the community-level threshold of 75% for GES.

4 Change Management

Change management of the indicator and the document is carried out by JWGBIRD which reports to ICG-COBAM that in turn is a group under BDC.

5 References

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Annex 1

Species List - B3 Marine bird breeding productivity

The species that can be considered for B3 assessments of breeding marine birds and the functional groups to which they are assigned are given in the table below. This is a preliminary list that will be reviewed by JWGBIRD. Accepted scientific names from WoRMS are provided, the sequence of species follows the taxonomic order of Gill et al. (2022). (File name: CEMP_B3_Annex_1)

Species		**Functional group**				
Extended English name	**Scientific Name**	**Grazing feeders**	**Wading feeders**	**Surface feeders**	**Water column feeders**	**Benthic feeders**
King eider	*Somateria spectabilis*					x
Common eider	*Somateria mollissima*					x
Velvet scoter	*Melanitta fusca*					x
Red-breasted merganser	*Mergus serrator*				x	
Eurasian oystercatcher	*Haematopus ostralegus*		x			
Pied avocet	*Recurvirostra avosetta*		x			
Common ringed plover	*Charadrius hiaticula*		x			
Kentish plover	*Charadrius alexandrinus*		x			
Ruddy turnstone	*Arenaria interpres*		x			
Dunlin	*Calidris alpina*		x			
Common redshank	*Tringa totanus*		x			
Black-legged kittiwake	*Rissa tridactyla*			x		
Ivory gull	*Pagophila eburnea*			x		
Slender-billed gull	*Chroicocephalus genei*			x		
Black-headed gull	*Larus ridibundus*			x		

Mediterranean gull	*Larus melanocephalus*			x		
Common gull	*Larus canus*			x		
Great black-backed gull	*Larus marinus*			x		
Glaucous gull	*Larus hyperboreus*			x		
European herring gull	*Larus argentatus*			x		
Yellow-legged gull	*Larus michahellis*			x		
Lesser black-backed gull	*Larus fuscus*			x		
Sandwich tern	*Sterna sandvicensis*			x		
Little tern	*Sternula albifrons*			x		
Roseate tern	*Sterna dougallii*			x		
Common tern	*Sterna hirundo*			x		
Arctic tern	*Sterna paradisaea*			x		
Great skua	*Stercorarius skua*			x		
Arctic skua	*Stercorarius parasiticus*			x		
Little auk	*Alle alle*				x	
Brünnich's guillemot	*Uria lomvia*				x	
Common guillemot	*Uria aalge*				x	
Razorbill	*Alca torda*				x	
Black guillemot	*Cepphus grylle*				x	
Atlantic puffin	*Fratercula arctica*				x	
Red-throated diver	*Gavia stellata*				x	
European storm-petrel	*Hydrobates pelagicus*			x		
Leach's storm-petrel	*Oceanodroma leucorhoa*			x		

Band-rumped storm-petrel	*Oceanodroma castro*			x		
Monteiro's storm-petrel	*Oceanodroma monteiroi*			x		
Northern fulmar	*Fulmarus glacialis*			x		
Cory's shearwater	*Calonectris borealis*			x		
Manx shearwater	*Puffinus puffinus*			x		
Barolo shearwater	*Puffinus baroli*			x		
Bulwer's petrel	*Bulweria bulwerii*			x		
Northern gannet	*Morus bassanus*				x	
Great cormorant	*Phalacrocorax carbo*				x	
European shag	*Phalacrocorax aristotelis*				x	
Eurasian spoonbill	*Platalea leucorodia*		x			