English Seabird Conservation and Recovery Plan – Seabird Sensitivity Evidence Review

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Further information

This report can be downloaded from the [Natural England Access to Evidence Catalogue](). For information on Natural England publications contact the Natural England Enquiry Service on 0300 060 3900 or e-mail enquiries@naturalengland.org.uk.

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Background

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in performing our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Natural England commissioned this report to provide up to date, evidence-based, auditable, and transparent assessments of the sensitivity of a range of seabird and waterfowl species to a range of pressures, to inform the development of the English Seabird Conservation and Recovery Plan.

These sensitivity scores will subsequently be used, in combination with assessments of each species' exposure to those pressures and/or the activities which cause them, to assess the vulnerability of each species to those pressures and activities in England. The English Seabird Conservation and Recovery Plan will assess the efficacy of existing measures in managing impacts from the activities causing pressures to which species are vulnerable and will identify actions to address pressures which are considered not to be adequately addressed by existing measures.

Executive summary

The overall aim of the project was to provide Natural England with up-to-date, evidence-based, auditable, and transparent assessments of the sensitivity of a range of waterfowl and seabird species to a range of human-related environmental pressures suitable for the development of vulnerability assessments to inform an English Seabird Conservation and Recovery Plan (ESCaRP). The scope of the project was narrowed to producing resistance and resilience assessments for the same range of human-related environmental pressures so that sensitivity could be derived from this using an agreed approach by Natural England. This report documents how this was achieved, the approach was robust and further refined on the methods used in Pérez-Domínguez and others (2016) and the Feature Activity Sensitivity Tool (FeAST) update (Rogerson and others 2021).

During the first phase of the work, previous approaches to sensitivity assessment were analysed and methodological recommendations were produced. Thereafter, the technical experts at both Natural England and APEM met to define a method of assessment, the details of which are documented herein. The outputs of this process are the resistance and resilience assessments for 36 species of seabirds and waterfowl against 42 pressures, which will be used within the ESCaRP. Each of these combinations was assessed for three spatiotemporal variables: at the colony in the breeding season; away from the colony in the breeding season; and, during the non-breeding season. Each combination was also assessed for two pathways of impact: mortality and displacement. To produce a reproducible output for each assessment, they were carried out against an agreed pressure benchmark, i.e. the intensity at which the pressure was considered to occur during the assessment. The methodology built upon previous work by Pérez-Domínguez and others (2016) and Rogerson and others (2021) and was informed by Tyler-Walters and others (2009, 2018), Tillin and others (2010), ABPmer (2013) and Sinclair and others (2020).

General findings from the assessments were that resistance to pressures is lowest at the colony during the breeding season and highest during the non-breeding season. There is higher resistance generally to pressures applied via the displacement pathway than the mortality across all pressures, although resistance was generally found to be lower to displacement than mortality for pressures for which both pathways are applied. Seabirds exhibit greater resistance to pressures exhibited at the benchmark level than waterfowl with notable exceptions, particularly kittiwake which was assessed as showing the lowest resistance to the range of pressures, as it was the only species to exhibit low resistance as the most frequent assessment result to all three spatiotemporal variables when considered against all pressures and pathways of impact. Kittiwake is a well-studied species, and this result may be due to high confidence in scoring of resistance in comparison to other, less well-studied species or may equally be due to kittiwake being an outlier, with a less robust niche than other species. Resilience was generally higher in waterfowl species than seabird species as this was largely influenced by life-history traits. Waterfowl tend to have higher annual productivity and shorter lifespans than seabirds and populations are able to recover more quickly to declines once pressures are released. The assessments of resilience for the displacement pathway within this report are largely of low confidence as there is little evidence relating to the release of pressures and the time it would take for bird species to move back into areas they had been displaced from.

The assessment method is considered to be robust, repeatable and updateable as new evidence becomes available. Transparent assessments have been undertaken based upon evidence garnered from scientific and grey literature, with clear scoring to reduce bias and effectively inform

an ESCaRP. It is acknowledged that due to gaps in the evidence base and a lack of definition of spatial or population scales, the results are subjective. However, the data are suitable to inform further assessment. Further refinements of approach may include referencing the spatial or population scales of the assessments so that these may be considered when undertaking a location-specific assessment or designing a mechanism for incorporating in-combination or cumulative effects.

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List of abbreviations

BTO – British Trust for Ornithology

ESCaRP – English Seabird Conservation And Recovery Plan

FeAST – Feature Activity Sensitivity Tool

H – high

IE – insufficient evidence to assess sensitivity to the pressure at the benchmark

INIS – invasive non-indigenous species

L - low

M – medium

N - none

QA – quality assurance

SSCS – Scottish Seabird Conservation Strategy

UoA – unit(s) of assessment

1. Project background

1.1 Aims and objectives

The overall aim of the project is to provide up-to-date, evidence-based, auditable, and transparent assessments of the sensitivity of a range of waterfowl and seabird species to a range of human-related environmental pressures, suitable for the development of vulnerability assessments to inform an English Seabird Conservation and Recovery Plan (ESCaRP). This document details:

- a review of existing methods to assessing sensitivity for highly mobile species
- the derivation of the method used to undertake sensitivity assessment for seabirds assessments in this study
- a description of how the method has been applied and
- discussion of the method development and application, and recommendations for improvements-

1.2 Introduction to sensitivity assessments

Assessing sensitivities of marine habitats and species to anthropogenic pressures is an important component of the marine conservation effort in the UK for a number of reasons. For example, using a consistent framework to compare relative sensitivity between habitats and species can help to identify those habitats or species most vulnerable to impacts (e.g., in oil spill contingency plans), help prioritise management activities, and to focus where mitigation measures may be needed when planning developments.

In general terms, sensitivity is considered to be the ability of a receptor (habitat or species) to resist or tolerate a pressure, or conversely, the degree to which it is affected by the pressure, and secondly, the ability (speed and extent) of the receptor to recover from this pressure. These important terms are defined in Table 1.

Table 1: Definition of common terms in sensitivity assessments

Term	Definition
Pressure	The mechanism by which an activity or natural event affects the ecosystem (Tyler-Walters and others 2018).
Pressure benchmark	The standard descriptor of the pressure defined in terms of the magnitude, extent, duration, and frequency of the effect (Tyler-Walters and others 2001).
Resistance	Resistance characteristics indicate whether a receptor can absorb disturbance or stress without changing character (from Holling 1973).

Term	Definition
Resilience	The ability of a receptor to recover from disturbance or stress (from Holling 1973).
Sensitivity	The likelihood of change when a pressure is applied to a feature (receptor) and is a function of the ability of the features to tolerate or resist change (resistance) and its ability to recover from impact (resilience) (Tyler-Walters and others 2018).

In the UK, there are currently several closely related, but nonetheless differing, approaches to assessing the sensitivity of mobile marine species to anthropogenic pressures, however, the general assessment procedure is based on the same basic principles and elements which can be summarised as:

1. Define species or habitat to be assessed
2. Define list of pressures to assess, with descriptions and associated benchmarks
3. Review evidence of effects of pressure on species
4. Score resistance against pressure benchmark
5. Score resilience against pressure benchmark
6. Score sensitivity
7. Document supporting evidence and confidence

There have been various modifications of the basic assessment criteria for assessing highly mobile species. This is because, as highly mobile species move between different marine and coastal habitats they are exposed to different pressures in different places and during different phases of their annual lifecycle (see for example Pérez-Domínguez and others 2016; Sinclair and others 2020).

These modification in criteria have led to deviations in benchmark definitions and scoring levels among current assessment approaches. Changes in scoring levels for resistance and resilience and in benchmarks have a significant impact on the resulting sensitivity score. The purpose of a pressure benchmark is to set a standard level of change (or magnitude, extent, duration) in a given pressure, to ensure that sensitivity of different species or habitats are assessed with respect to the same level of change and are therefore comparable. Setting an appropriate benchmark is critical, in terms of accurately reflecting the likely level of the pressure from the common activities that may cause it, and in terms of differentiating between species that may be more or less sensitive to that pressure and comparing relative sensitivities across different pressures for a species. For example, a pressure benchmark set at a very low level, may result in most species being assessed as having a very low sensitivity, whereas a pressure benchmark set at a very high level may result in most species having a very high sensitivity at that benchmark.

Currently, it cannot be ruled out that the resulting species-by-pressure assessments differ between approaches or, in the worst case, contradict each other. Without detailed background knowledge, it would currently be impossible to explain whether such deviations were due to different assessment protocols, differences in the underlying evidence base, differences in benchmark definitions and interpretations, the subjectivity of expert judgement, or a combination of these factors.

2. Review of existing methods

This section outlines the review, comparison and evaluation of existing seabird species sensitivity assessment approaches set out by Pérez-Domínguez and others (2016) and the Feature Activity Sensitivity Tool (FeAST) (Sinclair and others 2020). The Scottish Seabird Conservation Strategy (SSCS) was also considered, but the method was not available for review. This includes a comparison of the pressure benchmarks and the scoring of resistance, resilience, sensitivity and confidence of the aforementioned approaches. The findings of the review are then used to inform the second stage of the project, determining the best method for undertaking sensitivity assessments for the ESCaRP, whilst considering consistency with Natural England's existing approach. This method was then applied to the 36 seabird species and 42 pressures in scope of this project.

It summarises the important specifics regarding the current methods and details the process to derive sensitivity assessment scores for species-by-pressure interactions. It concludes by making the recommendations needed for improvements to existing methods for assessment of sensitivity in seabirds.

2.1 Review of the pressure benchmarks and scoring of Pérez-Domínguez and others (2016)

The objective of Pérez-Domínguez and others (2016) was to assess the sensitivity of highly mobile species to a range of anthropogenic pressures in order to inform conservation advice for MPAs. The report assesses the sensitivity of 88 species of bird, 13 fish, five mammals and one crustacean to these pressures. Sensitivity was determined based upon a combination of resistance to the pressure through physiological and behavioural tolerance and resilience, the ability of a population to recover from the removal of a pressure. These two traits were combined to give a sensitivity score using a matrix approach.

The methodology of Pérez-Domínguez and others (2016) closely followed that developed by Tillin and others (2010) and the Marine Evidence-based Sensitivity Assessment (MarESA) method (Tyler-Walters and others 2018), using an evidence-based evaluation to base resistance and resilience assessments upon. The method was divided into six principal steps:

1. Screening and appraisal of the key elements: a literature review was undertaken to summarise the key elements of species-pressure associations, the magnitude and direction of effects, and the primary pathway of impact. Species-pressure associations with no direct interaction were labelled "no direct effects" and were not considered further.
2. Benchmarks: a benchmark level of intensity was used as a reference point to assess sensitivity. Benchmarks were set to reflect a hypothetical but realistic level of pressure, resulting from an undefined activity. Where possible, pressure benchmarks from existing sensitivity methods were used (e.g., Tillin and others 2010), but in some cases pressure descriptions and benchmarks were re-defined to be relevant to highly mobile species Where possible benchmarks were quantitative and included a population level effect criterion, considering existing international frameworks and guidance where available. If this was not possible then the presence of the pressure was used as a benchmark criterion,

3. Resistance scoring: Resistance was defined into four categories based upon expected population responses to the application of the pressure at the benchmark level. Scoring was based upon the evidence gained in the screening and appraisal step as well as expert opinion and were linked to expected decline in the local population at the benchmark pressure intensity. They were scored as follows:
    - No resistance – a severe decline (greater than 50%) of the local population;
    - Low – a significant decline (11-50%) of the local population;
    - Medium – a moderate decline (up to 10%) of the local population; and
    - High – no population decline within the local population.
4. Resilience scoring: Resilience was scored independently of resistance and based on the likelihood and timescales that a feature would return to an area for a displacement effect or, that the population would recover from a mortality effect. For the mortality effect pathway, bird features were scored on the basis of their lifespan, age at first maturity, adult mortality rate. Times periods of three, six and twelve years were used to define the resilience scores. Resilience scores were categorised as follows:
    - Very low resilience – prolonged species recovery of greater than twelve years;
    - Low – full recovery within six to twelve years;
    - Medium – full recovery within three to six years; and
    - High – full recovery in less than three years.
5. Sensitivity scoring: Sensitivity scores were generated using a 4*4 matrix to cross tabulate the resistance and resilience scores, giving four different sensitivity scores, high, medium and low sensitivity, and not sensitive. The matrix was precautionary, with more scoring outcomes weighted towards a high sensitivity result than the other results.
6. Confidence scoring: Confidence scores were assigned to the scores for resistance and resilience. Confidence scores were index linked, using a scoring system to determine the quality of the information, applicability of the evidence and degree of concordance within the evidence base for both resistance and resilience. Evidence which was based upon peer reviewed papers or established sources of grey literature, based upon the same pressures, arising from similar activities, acting in comparable areas and showing strong agreement on the direction and magnitude of impact was scored highly for confidence. Conversely, evidence which was based upon expert opinion, utilised proxies and lacked concordance or agreement on magnitude scored poorly for confidence. Confidence was divided into three categories, high, medium and low and was scored for both resistance and resilience. The lowest score was taken forward as the overall confidence score for the sensitivity assessment. Confidence scores associated with the resistance and resilience scoring were brought forward and the lower score was taken for the combined sensitivity confidence score.

In addition to these steps, if there was insufficient evidence to assess, a proxy assessment was undertaken using information from a functional group. When there was no clear evidence to undertake a species-specific or proxy assessment then the species-pressure association was scored “not enough evidence to assess”.

Due to the wider scope (beyond just seabirds) of Pérez-Domínguez and others (2016) benchmarks were not developed particularly with seabirds in mind. As such some of the benchmarks used, whilst quantitative, are inappropriate for assessing marine bird species, as there is often no evidence available at the benchmark level to allow an assessment. In addition, there is limited consideration of spatiotemporal factors, with species being assessed separately during the breeding and non-breeding season, but without consideration to pressures acting with differing intensities at sea or on land. Also, consideration is only given to effects at the population level and not at the individual level. Evidence of individual responses or loss may be as relevant as evidence reflected at a population scale, e.g., collision risk assessments require both aspects.

2.2 Review of the pressure benchmarks and scoring of Feature Activity Sensitivity Tool (FeAST) update

The FeAST is a web-based application which allows users to investigate the sensitivity of marine features (habitats, species, geology, and landforms) in Scottish seas, to pressures arising from human activities. FeAST, hosted by NatureScot, is supported through the FeAST Working Group (a subgroup of the Marine Biodiversity Programme Board) and underwent a review process early in 2021. Scoring for the FeAST was updated in 2021 (Rogerson and others 2021). This update was for 36 seabird species to 36 human induced pressures.

The FeAST assessment approach was based upon the methods from Pérez-Domínguez and others (2016), incorporating an updated evidence base and assessment recommendations from a ongoing work to support the Scottish Seabird Conservation Strategy. The method recommendations, which were then applied to the 36 seabird species, are reported in full in Rogerson and others (2021).

Some of the existing quantitative benchmarks were found to be too quantitative and specific to be easily scored against, and these were replaced by qualitative benchmarks describing the emergence or presence of the pressure in the environment (e.g., the benchmark for the pressure ‘visual disturbance’ was defined as ‘the visual disturbance of biota by anthropogenic activities’ rather than the quantified measure used in other methods). Pressures in the initial FeAST list, that were scoped as having an indirect effect on marine birds, were retained in the pressure list, but were given additional consideration as to whether these pressures had an indirect effect on the birds via the prey species. ‘Reduction in availability or quality of prey’ was added as an additional pressure and included in the assessments. The FeAST update also introduced a climate change pressure, which was split into six categories; five related to direct effects (e.g., sea surface temperature, ocean acidification) and one related to the indirect effect of changes in prey availability as a result of climate change.

Resistance scores (known as tolerance scores in the FeAST) followed the same definitions as used by Pérez-Domínguez and others (2016) and in the existing FeAST assessments and were based on perceived impact to the species’ population, based on the evidence.

Resilience scores (known as recovery scores in the FeAST) differ from those in Pérez-Domínguez and others (2016), as all received a “low” or “medium” score based on species-specific life-history traits. The assessment did not use a “very low” resilience score, but this score was retained within the sensitivity scoring matrix to align with non-avian features in the FeAST. The resilience time periods varied from Pérez-Domínguez and others (2016), and were scored as follows:

- Low recovery potential – full recovery expected within 10-25 years,
- Medium recovery potential – full recovery expected within 2-10 years, and
- High recovery potential – full recovery expected within 2 years.

All seabirds were scored as ‘low’ due to their life-history traits. This meant that any variations in the resulting sensitivity scores for seabirds was entirely due to variation in resistance score.

As with Pérez-Domínguez and others (2016), sensitivity scores were determined using a 4*4 matrix of resistance (tolerance) and resilience (recovery). The matrix used to determine sensitivity in the FeAST update was less precautionary than that used in Pérez-Domínguez and others (2016), with fewer combinations of resistance and resilience leading to a high sensitivity score (four versus eight in Pérez-Domínguez and others (2016)).

If there was insufficient data within the assessment to determine a resistance (tolerance) score but it was considered through expert opinion that there remained scope for potential impacts upon the species, a score of "sensitive" was assigned. A "sensitive" score was also assigned if during the QA process, the scoring was found to be contradictory.

The method for undertaking confidence scoring was taken directly from Pérez-Domínguez and others (2016). Assessments were carried out at the species level and did not include a spatiotemporal element.

2.3 Review of the pressure benchmarks and scoring of birds for the Scottish Seabird Conservation Strategy

The results of the draft Scottish Seabird Conservation Strategy assessments were made available as part of the FeAST update (Rogerson and others 2021) undertaken in 2021. However only the draft assessments and scores were available and used in the comparison of approaches. The methodologies and scoring matrices were not available for the comparisons and so they could not be considered when comparing methodologies.

2.4 Comparison of existing methodologies

The existing assessment approaches, Pérez-Domínguez and others (2016) and Rogerson and others (2021), were analysed to determine the best methods to be applied for assessing sensitivity for the purpose of the ESCaRP. Differences between the approaches were noted as well as additional changes that were considered for the ESCaRP. When reviewing the two methods, consideration was given to:

- suite of pressures included for assessment
- the consideration of spatiotemporal effects on the assessment,
- which pathways were considered for each assessment,
- whether the effects of a pressure upon a species were considered at a population or individual level,
- criteria used to score resistance,
- criteria used to score resilience,
- approach used to determine sensitivity scores, and
- how the pressure benchmarks were created.

Table 2. Comparison of methods for assessing seabird sensitivity by Pérez-Domínguez and others (2016) and Rogerson and others (2021)

Issue for consideration	Pérez-Domínguez and others (2016)	Rogerson and others (2021)
Suite of pressures	36 pressures included, 10 of which identified as 'no direct effects' and not assessed further.	36 pressures included. Indirect pressures screened out. Inclusion of pressures for prey availability and climate change.
Effects of spatiotemporal variables (e.g., season, location) on the assessment	Spatiotemporal effects not fully addressed, although for each species, breeding and non-breeding birds were assessed separately. This was identified in the conclusion as an area of potential further study.	Spatiotemporal effects not considered. No distinction made between breeding and non-breeding birds.
Effect pathway of pressure	Considered three pathways, mortality, reduction in fitness and displacement but assessment was carried out against that which elicited the highest sensitivity, which was chiefly the mortality pathway.	Resistance (tolerance) score based on changes to mortality, breeding success, or displacement resulting in local population decline. Different effect pathways were not considered separately.
Assessment of pressure on individual versus population	Impacts of the application of the pressure to determine resistance in a species were done at a population level.	Resistance (tolerance) score assessed on how likely the pressure would impact the species at population, not individual level. However, previous work has considered the use of individual-based sensitivity assessments, although currently, only in relation to some non-avian highly mobile species (e.g., cetaceans, seals, sharks, etc.)
Criteria for scoring resistance	Resistance based on % reduction in local population, divided into four categories.	Followed same approach and thresholds as Pérez-Domínguez and others (2016).
Criteria for scoring resilience	Resilience score for displacement effects based on likely time to local population to return, and score for	Resilience scores based only on life-history traits, with all seabirds being assigned a score of 'low.'

Issue for consideration	Pérez-Domínguez and others (2016)	Rogerson and others (2021)
	mortality effects, based on life-history traits.	
Approach for determining sensitivity	Sensitivity derived from 4*4 matrix of resistance and resilience, with a precautionary weighting; 8 of the 16 possible outcomes scored as high sensitivity, 4 medium, 3 low and one not-sensitive.	Sensitivity derived from a 4*4 matrix of resistance (tolerance) and resilience (recovery), with a less precautionary weighting; 4 of the 16 possible outcomes scored as high sensitivity, 6 medium, 5 low, and one not-sensitive.
Creation of pressure benchmarks	Pressure benchmarks sought to be quantitative, using population level thresholds. Where a quantitative benchmark was not considered possible, then a qualitative benchmark was used.	Pressure definitions and benchmarks broadly similar to those in Pérez-Domínguez and others (2016) but were built on previous work by Sinclair and others (2020).

These specific aspects of the methods were considered, for the following reasons. Some pressures may act with differing intensity, during the same season, at sea or on land (at breeding sites/colonies) and this has not previously been assessed. Moreover, effect pathways can differ significantly, with pressures acting via displacement from suitable breeding/non-breeding habitat, indirectly through depletion of resource availability, or directly via mortality or reduced physiological condition, reproductive success, and individual fitness – all of which may influence overall population viability.

Potential impacts have been assessed at the population level and consideration of whether it is appropriate to also consider individual level impacts, such as those included within collision risk modelling.

Scoring criteria for resistance, resilience and sensitivity were considered due to the significant effect they have on the resulting balance of sensitivity scores.

As defined by Pérez-Domínguez and others (2016), both the resistance and resilience to a pressure depend upon the level or intensity of that pressure. Thus, in order to ascribe single scores to the resistance and resilience of a species to a pressure and hence its sensitivity, it is necessary to define a benchmark intensity or level of that pressure at which that assessment is made. The benchmark levels act as reference points to assess whether, according to the life history and ecology of the species, it is reasonable to expect deviations in demography/population structure or (in the case of highly mobile species) displacement from normal habitats.

Both previous approaches used qualitative benchmarks where it was difficult to determine a meaningful quantitative benchmark, which may influence how robust these assessments of sensitivity are.

2.5 Determining methods for assessing seabird sensitivity

Following the review and comparison of the previously used methodologies for carrying out sensitivity assessment for highly mobile species, APEM and Natural England met to establish the current methodology. The priority for a new method was to maintain consistency with the existing methods used by Natural England where possible and incorporate changes only where they would benefit the aims and objectives of the ESCaRP. For example, ensuring that the output provided sufficient differentiation between assessments to allow priority species or pressures to be identified, and to provide suitable granularity for the vulnerability assessment. As the two methods being compared had evolved from earlier methods that had initially been developed to assess benthic habitats and species, some recommendations for the current methodology were to ensure better applicability to seabird species.

Pressures for both methods had been initially derived from a published OSPAR marine pressures list (OSPAR, 2011), with subsequent amendments made as each method was developed further (e.g., some pressures being split in two). The pressure descriptions from Pérez-Domínguez and others (2016) were reviewed to ensure that all were appropriate and allowed a quantitative benchmark to be set where possible. To allow comparison with previous work, amendments were made only if the pressure description was unsuitable for seabirds. Pressure benchmarks from both Pérez-Domínguez and others (2016) and Rogerson and others (2021) were compiled, and these were worked through to define the pressure benchmark and description for each of the pressures requiring assessment during this project. It was agreed that, where possible, benchmarks should be quantitative and should align with previous work. Novel benchmarks were rejected unless there was an advantage to the assessment if these were employed i.e., they were measurable rather than qualitative. The full list of pressures and pressure benchmarks is included within **Table A 2**.

2.6 Recommendations

After comparing the existing methodologies for seabird sensitivity assessment and consideration of the aims of the project, thirteen recommendations were considered for undertaking the final Sensitivity Assessment. These recommendations were reviewed by Natural England, and a decision was made to accept, reject, or amend the recommendation in each case. These are presented below in Table 3.

Table 3. List of recommendations for new method for seabird sensitivity assessment.

Recommendation and Decision
Recommendation: Removal of the "very low" resilience category in future assessments. The "very low" category was used by Pérez-Domínguez and others (2016) but not in the FeAST update (Rogerson and others 2021) and it was felt that the evidence base was unlikely to allow such fine divisions to be distinguished. **Decision:** Recommendation accepted.
Recommendation: To use the time periods for scoring resilience of a species / population provided in the FeAST update (Rogerson and others 2021). Pérez-Domínguez and others (2016) and FeAST differ in their approach to recovery. The adoption of the FeAST approach ensures Natural England aligns with both NatureScot and with the MarESA method, which is used for assessment of sensitivity of benthic habitats and species (Tyler-Walters and others 2018) **Decision:** Recommendation accepted.
Recommendation: Take a conservative approach to scoring resilience (recovery) based on general life-history traits related to reproduction potential (e.g., lifespan, fecundity) assuming that species-specific recovery potential at the population level is independent of the route of impact. Resilience scoring for Pérez-Domínguez and others (2016) was based upon the pressure and route of impact with different scoring criteria for pressures impacting via displacement versus mortality/reduced fitness, whereas FeAST was fixed to life history traits. **Decision:** Recommendation rejected. This was due to the decision to assess sensitivity via mortality and displacement pathways separately, and a more nuanced approach to resilience scoring would be required, particularly for the displacement pathway. It was agreed to integrate pressure and spatiotemporal specific effects into the resilience scoring along with general life-history traits, as undertaken in Pérez-Domínguez and others (2016). It was considered important to determine whether resilience, particularly with regard the displacement pathway, varied by time of year or location i.e., do seabirds recolonise areas at different speeds dependent upon whether the bird is breeding or not, or whether the pressure is applied at the breeding colony or away from the breeding colony.
Recommendation: Where possible, use quantitative criteria for assessing resistance towards potential population effects (e.g., evidence of specific population decline), supported with expert judgement where quantitative data is deficient but there is contextual information. Adjust confidence scoring accordingly to indicate the lack of published evidence when expert judgement is used. **Decision:** Recommendation accepted.
Recommendation: Consider using a novel matrix for combining resilience and resistance scores to assess species-by-pressure sensitivity (based on previously used matrices), taking existing standards and combinatory effects on sensitivity scores into account. The existing

Recommendation and Decision
matrices from for Pérez-Domínguez and others (2016) and the FeAST update differ in their weighting. In addition, the omission of “very low” resilience would lead to a 4*3 matrix as opposed to the 4*4 matrices used in previous approaches. **Decision:** Recommendation accepted.
Recommendation: Consideration of using a precautionary “Sensitive” score for sensitivity assessments in cases where species-specific evidence is missing but negative impacts cannot be excluded based on circumstantial evidence and expert judgement. **Decision:** This recommendation was agreed upon but with an amendment of assigning a score of ‘insufficient evidence to assess sensitivity to the pressure at the benchmark’ in place of a ‘sensitive’ score as it was considered that this was both precautionary and robust, and was consistent with Natural England’s existing approach.
Recommendation: Consideration of the use of proxy species (for cases which lack species-specific evidence) with clearly defined groupings based on phylogenetic association and biological similarity (feeding / foraging behaviour, habitat niche / resource exploitation). Proxy species allow the assessment of species with deficient evidence bases, albeit with low confidence, as reflected in the confidence scores. **Decision:** Recommendation accepted.
Recommendation: Scoping of pressures, and pressure benchmarks, regarding their relevance to seabirds prior to assessments, leading to a reduced list of scoped-in pressures to be assessed. **Decision:** This recommendation was rejected, as it was decided that it was important to document that these pressures had been considered, but were not directly affecting the receptor species. Those pressures with no direct functional relevance to the species being assessed were to be included within the assessment but with a “not relevant” or “no direct effects” score within the sensitivity score of the assessment.
Recommendation: Alignment of the current pressure definitions used in previous assessments and conversion into a stringent, abbreviated definition catalogue. There are differences in the pressure definitions used in Pérez-Domínguez and others (2016) and the FeAST update. Aligning pressure definitions allows more effective comparison with FeAST. **Decision:** This recommendation was amended to align pressures should the definition require change (e.g., if the current definition was tailored towards benthic habitats and species) and if there was a significant benefit in amending the pressure definition, e.g., in terms of improving clarity, and allowing more consistency in application.
Recommendation: Clarification and documentation of relevant pressure and pressure benchmark definitions, including the spatiotemporal route of action (breeding vs. non-breeding, on land vs. at sea).

Recommendation and Decision
Decision: Recommendation accepted.
Recommendation: Consider inclusion of the pressure "climate change" defined as the combined or cumulative effects of those direct pressures that are influenced by climate change. Climate change was not included as a standalone pressure in Pérez-Domínguez and others (2016) but was within the FeAST update. **Decision:** This recommendation was rejected, as the direct impacts of climate change are attributable to other pressures and defining a meaningful benchmark would be unsatisfactory. It was considered that the effects of climate change would be considered elsewhere in the ESCaRP, through a review, and not through sensitivity assessment.
Recommendation: Maintenance of confidence of evidence scoring methodology, which is the same among existing approaches. **Decision:** Recommendation accepted.
Recommendation: Use of clear notation whether an assessment was made with reference to the breeding period, the non-breeding period, or based on combination of both periods. Spatiotemporal variables and their impact upon sensitivity to a pressure at the benchmark intensity were not considered in previous approaches. **Decision:** This recommendation was accepted but with further definition of breeding season at the colony, breeding season away from the colony and non-breeding season.

A final recommendation, made by Natural England in discussion with APEM, was to include three pressures that were in addition to the 39 currently used by Natural England.

Indirect pressures are not included in the sensitivity assessments by Pérez-Domínguez and others (2016) or Rogerson and others (2021). Multiple pressures that act indirectly upon birds, will do so by affecting the supporting habitat, or availability of prey, or by other means. It is often not possible to relate the resulting impacts on bird species back to the specific initial pressure, or multiple pressures, that may have indirectly caused that impact. To resolve this problem, a decision was made in the FeAST update (Rogerson and others 2021), to include a new pressure, 'reduction in availability or quality of prey,' which would be a direct pressure through which those pressures which have an indirect impact on birds via changes in prey resources could be included. In developing the method for ESCaRP, a similar decision was made by Natural England and APEM. To address pressures which acted indirectly via impacting prey resources or supporting habitat availability, two new pressures were added, 'reduction in availability, extent, or quality of supporting habitat' and 'reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities,' The third pressure that was added was 'uncontrolled increase of native competitor/predator species.' In the initial list of 39 pressures provided by Natural England, the impacts resulting from invasive non-native species are addressed. However, it is recognised that for many seabird species, predation or competition from native species such as badgers, foxes and crows, are a significant issue.

2.7 Determining units of assessment

The first step in setting up a method for assessing sensitivity of seabirds is to determine the various units of assessment. This is important because birds will be subjected to different pressures depending on where they are and what stage of their life cycle they are at. An individual unit of assessment is determined by combining:

1. the pressures experienced by a species of seabird;
2. the pathway by which it experiences that pressure (displacement or mortality); and,
3. the species and location of the bird (spatiotemporal variable).
    a. at the breeding colony (known as colony in the assessment),
    b. away from the breeding colony during the breeding season (breeding) and
    c. non-breeding (non-breeding).

For the purpose of this assessment, at the breeding colony was defined as at, or in close proximity to, the nesting location of the species during the breeding season and would include pressures encountered whilst away from the immediate nesting location such as pressures encountered whilst birds rafted adjacent to the colony or for freshwater breeding species, pressures encountered on the breeding waterbody.

Away from the breeding colony was defined as time spent not in close proximity to the breeding colony during the breeding season, generally on foraging trips, but also pressures experienced by wandering non-breeding birds during the breeding season.

The non-breeding season was considered all locations and timings outside the breeding season.

Only pressures experienced within English waters were considered.

Not all species were assessed for all spatiotemporal variables due to the ecology of the species in English waters and whether they occurred as migrant, resident, breeding or non-breeding species. For example, species such as red-throated diver only occur in English waters during the non-breeding season, while others such as Arctic tern are present only during the breeding season. Also, not all pressures were assessed for both routes of impact as they may only cause an effect through one. As such, the number of UoA for each species and pressure varied, leaving a total of **4368** UoA.

A single evidence base was compiled for all UoA within a species*pressure combination. This would include information relevant to all spatiotemporal variables and pathways of impact, and assessments would only be carried out using the applicable information held within the evidence base to the specific UoA. Keywords for undertaking the literature search were determined and were based upon those used for the FeAST update (Rogerson and others 2021) with tailoring for amendments to pressure descriptions or pressure benchmarks (**Table A 2**). For new pressures, these were similar in scope to existing search terms to produce comparable results. Natural England provided APEM with excel templates for the assessments and literature review database so that the results were compatible with Natural England’s existing database architecture.

3. Methods for assessing seabird sensitivity to pressures

Following the review of existing methods, the production and review of recommendations, and determination of units of assessment, as described in Section 2, the final method was agreed between APEM and Natural England. The method, broken down into twelve steps, is presented below.

3.1 Definition of pressures and benchmarks

As discussed in section 132, pressure definitions and benchmarks were predominantly the same as those used in previous methods, with some amendments made to ensure applicability to seabird species, and to ensure clarity of the pressure benchmark to ensure it's consistent application. The full list of pressures, with their associated benchmarks, and the pathway by which they can affect seabirds are shown in Table A 2.

3.2 Collation and quality assurance (QA) of data from previous assessments

The evidence bases which the assessments were derived from were developed from those within Pérez-Domínguez and others (2016) and the FeAST update (Rogerson and others 2021). Pérez-Domínguez and others (2016) is the intellectual property of Natural England and permission was given for the use of the FeAST update (Rogerson and others 2021) by NatureScot. For each species and pressure, text from previous evidence, and literature summaries from the existing draft assessments were copied into a new document. The existing assessments for both breeding and non-breeding seasons for each bird feature were checked. Where evidence differed between seasons (breeding and non-breeding), all evidence base paragraphs and reference lists were incorporated into the new assessments. All references which were used in previous assessments were saved into a species-specific bibliography and marked with the relevant pressure. All references were searched for using Google Scholar, and all available PDF documents were downloaded into species and pressure specific folders to be used in the sensitivity assessment process.

3.3 Literature search

A robust and repeatable method was developed to compile a concise and relevant evidence base to use in the assessments. New evidence was gathered from published peer reviewed and grey literature using Google Scholar. The advanced search function was used to filter literature for individual species and pre-defined standardised keywords related to particular pressures. These keywords are listed in **Appendix 2**. The first five pages of the search results were checked for relevant material, and available PDFs of references that appeared useful were saved.

For 31 species that had previously been assessed in the FeAST update (Rogerson and others 2021), literature searches were done for new pressures added for the current assessment (above water noise, vibration, introduction of other substances, reduction in availability, extent or quality of supporting habitat and increase in native predator or competitor species). Moreover, six previously assessed pressures with updated benchmarks required literature searches only for specific keywords which relate to the updated benchmark and were agreed between Natural England and APEM. These pressures were: Introduction of light (O4), Litter (O1), Wave exposure changes (H5), Water flow changes (H3), Transition elements and organometal contamination (P1) and Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities (B8). Four species that were not assessed in the FeAST update (Rogerson and others 2021) but had been assessed in Pérez-Domínguez and others (2016) required literature searches for all assessed pressures from 2015 onwards. These were: Mediterranean gull, black-necked grebe, roseate tern and Balearic shearwater. In addition, yellow-legged gull which had not featured in any previous assessments required a complete literature search for all pressures.

3.4 Literature review and evidence bases

For species and pressures that had previously been assessed in FeAST as part of the FeAST update (Rogerson and others 2021) the evidence base text was copied over and read. If anything was unclear or information was missing, the PDF copy of the references was referred to. The evidence bases were organised, and any proxy information from species outside of those in this assessment or with no close phylogenetic relation, was removed. For the six pressures with updated benchmarks, the newly downloaded literature was read, and short summaries were added to the original evidence to finalise the updated evidence base. Where old references were deemed no longer relevant, or where new species-specific references were able to replace older, less specific references, these citations were removed and updated. Each citation in the evidence bases were given unique identifiers and the reference were added to a reference database. For the five new pressures and the four species not previously assessed in FeAST or Pérez-Domínguez and others (2016), new evidence base paragraphs were written using the species-specific references saved from the literature searches. For yellow-legged gull, full evidence bases for all pressures were written from the saved literature. Evidence bases were the same for the three assessed spatiotemporal variables (breeding away from the colony, breeding at the colony and non-breeding) and two pathways (mortality and disturbance).

3.5 Evidence bases for indirect pressures

Human-induced pressures do not always act directly on seabird mortality or behaviour. Agreement between APEM and Natural England provided a list of pressures scoped as being pressures that have no direct effects on seabird and waterfowl species. Effects of these pressures would be indirect via other assessed pressures. For these indirect pressures, no specific literature review was performed. In the final assessment spreadsheet pressures with indirect effects were marked as such and included no evidence base or further scoring. The pressures included within the assessment but scored as “not relevant” or “no direct effects” were as follows:

- Abrasion/disturbance of the substrate on the surface of the seabed;
- Deoxygenation;
- Electromagnetic changes;
- Genetic modification & translocation of indigenous species;
- Habitat structure changes – removal of substratum (extraction);

- Nutrient enrichment;
- Organic enrichment;
- Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion;
- Physical change (to another seabed type);
- Physical change (to another sediment type);
- Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion;
- Salinity decrease;
- Salinity increase;
- Smothering and siltation rate changes (Heavy);
- Smothering and siltation rate changes (Light);
- Temperature decrease;
- Temperature increase;

3.6 Assessments and scores

The process used in developing the sensitivity assessments involves a systematic process of:

- examining the biology or ecology of the species concerned;
- compiling evidence of the effect of a given pressure on the species in question;
- assessing the resistance and resilience of the UoA to the pressure at the benchmark intensity;
- documenting the evidence used; and
- justifying the assessments.

The scoring criteria for resistance and resilience are detailed within the tables in the following sections. The resistance of each UoA to a pressure is assessed at a defined intensity of the pressure (the pressure benchmark) and the UoA's resilience is based primarily on its ecology whilst considering any pressure specific effects which may also have effect. Specifically, the resistance score was assessed on how likely the pressure would impact the species at a population level not at an individual level.

3.7 Resilience score

Resilience describes the ability of a species to recover from disturbance or stress caused by a pressure, once that pressure has ceased (Table 1). Where the effect pathway of the pressure was mortality, resilience scoring was determined based on life-history traits (**Table 4**). The life-history parameters are aligned with those in the FeAST update (Rogerson and others 2021) with some additional life-history criteria included.

For all species, lifespan, fecundity and survival rates were checked using British Trust for Ornithology's (BTO) Bird Facts (Robinson 2005). If a species' life-history criteria sat between two resilience categories, the category with the most criteria was chosen. If the life-history criteria were split evenly between two categories, as a precaution, the category with the lowest resilience potential was selected as the score. All seabirds have a low resilience score to additional mortality because of their longevity, low fecundity, and low natural adult mortality. However, some marine waterfowl could be assessed as medium resilience based on their moderate lifespan and higher fecundity.

Table 4: Mortality resilience criteria for scoring

Resilience score	Definition	Life-history criteria
Low	Full recovery of the population to pre-impact size expected within >10 years	Long-lived species (10 years with deferred age at maturity) First breeds when more than 3 years old Low natural mortality (<15%) Low fecundity/reproductive success (<2 chicks per pair per annum)
Medium	Full recovery expected within >2 to ≤10 years	Bird species with moderate lifespans (5-10 years) First breed when 2-3 years old Moderate natural mortality rates (15-25%) Moderate fecundity/reproductive success (2-5 chicks per pair per annum)
High	Full recovery expected within 2 years	Short-lived bird species (up to 5 years) First breed at one year of age High natural annual mortality (>25%) High fecundity/reproductive success (>5 chicks per pair per annum)

Where the effect pathway of the pressure was displacement, resilience score was determined by the criteria in **Table 5.** This relied largely on expert judgement based on the ecology of the seabird / marine waterfowl species such as: breeding behaviour, foraging behaviour, flight heights and flight agility. Wherever possible this was backed up by available literature. However, this was often not feasible resulting in low confidence associated with displacement resilience scores.

Table 5: Displacement resilience criteria for scoring

Resilience score	Definition
Low	Full recovery from a displacement expected in >10 years following cessation of activities giving rise to the pressure in the site.
Medium	Full recovery from a displacement expected within >2 to ≤10 years following cessation of activities giving rise to the pressure in the site.
High	Full recovery from a displacement expected within 2 years following cessation of activities giving rise to the pressure in the site.

3.8 Resistance score

The resistance score indicates the level to which a receptor can absorb disturbance or stress. In the case of seabirds, this is measured at the population level, with resistance scores based on a measure of population decline.

Using the evidence base paragraphs (as described in section 3.4) and the benchmarks for each pressure (see Table A 2), a resistance score was determined for using the criteria in **Table 6**. The resistance scoring criteria follows the resistance definitions from Pérez-Domínguez and others (2016) and are also consistent across existing FeAST application definitions applied to other mobile species assessments using the population-based approach. If there was no specific evidence on population decline, changes to mortality or breeding success were included in the evidence base and the assessment of resistance was based on perceived severity of the pressure at the benchmark level to the feature's population. If there was evidence for differing severities of impact for a pressure then the worst-case scenario was assumed, resulting in a precautionary resistance score. If the benchmark was quantitative and the evidence base did not explicitly match the benchmark criteria, expert judgement along with the evidence base was used to infer the population-level severity of the pressure at benchmark levels. If there was no relevant species-specific information or the evidence base was considered insufficient to assess the impact of the pressure at the benchmark, resistance was marked as 'IE' (insufficient evidence to assess sensitivity to the pressure at the benchmark).

Table 6: Resistance criteria for scoring

Resistance score	Definition
None	A **severe decline** (>50%) in the estimated size of the local population as a result of increased mortality, reduced reproductive success, displacement or any other mechanism.
Low	A **significant decline** (>10 and ≤50%) in the estimated size of the local population as a result of increased mortality, reduced reproductive success, displacement or any other mechanism.

Resistance score	Definition
Medium	A **moderate decline** (loss of up to 10%) in the estimated size of the local population as a result of increased mortality, reduced reproductive success, displacement or any other mechanism.
High	**No population decline** is expected. Effects affecting key functional and physiological attributes of the species (e.g. food intake rate, energy expenditure rate) may occur but are buffered from feeding through to changed rates of reproduction or mortality and hence population size by virtue of species flexibility to respond to pressure e.g. by redistribution, dietary shifts, increased foraging effort, etc.

3.9 Confidence score

The method for scoring confidence was taken from the MarESA handbook (Tyler-Walters and others 2018) and was originally used in Tillin and others (2010). Separate confidence scores were determined for both resilience and resistance scores. The confidence for the Resistance score was based on the compiled evidence base, an evidence confidence score was assigned for each UoA using the criteria outlined in **Table 7**. The three criteria for assessing confidence scores were evaluated separately and combined for an overall confidence score. Scores greater than 12 resulted in a "high" confidence score, if scores fell between 6 and 12, a "medium" confidence score was given, and if scores were less than 6, a "low" confidence score was given. The resistance confidence score was "low" if proxy species statements were used or if only general species statements were applicable instead of species-specific information within the evidence base.

For the confidence of the Resilience score, if the effect pathway was mortality all species were likely to receive "high" confidence score as the key information on marine bird breeding and survival is established (Robinson 2005). The confidence would be "medium" or "low" if it were not possible to access evidence for the majority of criteria of the resilience score. However, if the effect pathway was displacement the confidence score was likely lower as this relied largely on expert judgement based on the known ecology of seabird/marine wildfowl species.

Table 7: Confidence criteria for scoring

Evidence confidence assessment	Quality of information sources	Applicability of evidence	Degree of concordance
High Confidence	Based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies on the feature.	Assessment based on the same pressures arising from similar activities, acting on the same type of feature in comparable area (i.e. Ireland, UK).	Evidence agrees on the direction and magnitude of impact.
	Score = 5	Score = 5	Score = 5
Medium Confidence	Based on some peer reviewed papers but relies heavily on grey literature or expert judgement on feature or similar feature.	Assessment based on similar pressures on the feature in other areas.	Evidence agrees on direction but not magnitude of impact.
	Score = 3	Score = 3	Score = 3
Low Confidence	Based on expert judgement, which is not clearly documented.	Assessment based on proxies for pressures e.g. natural disturbance events.	Evidence does not agree on concordance or magnitude.
	Score = 1	Score = 1	Score = 1

3.10 Sensitivity score

Recording a sensitivity score for each UoA was one of the original components of the project. However, for ease of Natural England's data processing procedures, the assignation of sensitivity scores was undertaken by Natural England after the end of the project. As such the outputs of this process are not considered within this report, and the discussion of results in focused on the individual resistance and resilience scores. In order to derive sensitivity scores, a matrix was designed by the technical teams at APEM and Natural England to ensure a balanced output, building upon those used in FeAST update (Rogerson and others 2021) and Pérez-Domínguez and others (2016). Sensitivity scores were derived using the matrix shown in **Figure 1** combining resistance and resilience scores.

Resilience		Resistance			
		None	**Low**	**Medium**	**High**
		A severe decline (>50%) in the estimated size of the local population	A significant decline (>10 and ≤50%) in the estimated size of the local population	A moderate decline (loss of up to 10%) in the estimated size of the local population	No decline in the estimated size of the local population
Low	Full recovery of the population to pre-impact size expected within >10 years	High	High	Medium	Low
Medium	Full recovery expected within >2 to ≤10 years	High	Medium	Medium	Low
High	Full recovery expected within 2 years	High	Medium	Low	Not sensitive

Figure 1: Novel sensitivity matrix for deriving sensitivity scores

3.11 Proxy species

If there was insufficient evidence to undertake a sensitivity assessment for a specific species*pressure combination, when feasible a proxy species was used. In agreement between Natural England and APEM only species within the assessment were used as proxy species. Species in the same genus e.g., *Larus* gulls were preferred. If there were no congeners in the same genus, the closest related species in the same family and in the same foraging guild were used as proxies. When no phylogenetically linked species were available, the closest proxy in terms of niche was used, considering a combination of life history, foraging guild, habitat preference, migration strategy and seasonality. Proxy species were confirmed by a project leader. Information from phylogenetic proxies was incorporated into the existing evidence base to allow scoring. Use of evidence related to proxy species was clearly documented in the evidence base paragraphs. If scoring for resistance of a given UoA was still not possible then a full proxy of the assessment was suggested. These full proxy suggestions were recorded separately, and have not been included within the assessment, or in the analysis presented in the results below.

3.12 Quality assurance

A double stage quality assurance (QA) process was undertaken for each species and pressure to reduce subjectivity bias and to ensure robust assessments. The majority of resilience and resistance scores for pressures were assigned independently for one species by a single consultant. For the first round of QA, evidence base paragraphs were assessed by a second consultant and blind independent resilience and resistance scores given. Both scores were then provided to APEM's expert ornithologists, James Spencer and Tim Coppack to assign final scores. Both rounds of QA were carried out for all pressures for an entire species to ensure consistency of scoring among pressures.

Upon submission of the completed assessment, further QA was undertaken by the experts at Natural England to identify anomalies within the dataset through analysis of data gradients. Any issues flagged at this stage were reviewed by APEM's expert ornithologists and either accepted or, in consultation with Natural England after discussion of justification, rejected.

4. Results

Each of the 36 species was assessed against 42 pressures and within this there were further UoA covering up to three spatiotemporal variables and two pathways of impact. In the results section here we seek to outline the broader themes of the assessment and look at each pressure in turn, identifying seasonal and locational sensitivities and outliers within the assessments. Thereafter the species are addressed to draw out identifiable trends in the data.

4.1 Analysis by pressure

In total there were **4368** UoA considered. Of these, it was determined that there was no mechanism for direct effects for **17** pressures, totalling **1547** UoA. These pressures were not taken any further in the assessment. A further **2821** UoA were taken forward to the full assessment.

Resistance scores

The broadest approach to identify trends within the resistance scores is to look at the frequency a score is allocated to each spatiotemporal variable or pathway. The raw frequencies for each score are presented in **Table 8** and the percentage of assessed scores at each resistance level for each variable, omitting Insufficient Evidence, are shown in parentheses. Removing Insufficient Evidence and converting the frequency scores to a percentage allows easier identification of patterns within the data.

Table 8: Frequency of Resistance Scores for spatiotemporal and effect pathway variables for each unit of assessment. Percentage of scores as a total of those which had sufficient evidence to assess (insufficient evidence excluded) are shown in parentheses. Scores in bold indicate peak results for each variable.

Variable	Insufficient evidence	High	Medium	Low	None
Spatiotemporal variables					
Breeding	323	104 (18.1%)	**327 (56.7%)**	144 (25.0%)	1 (0.2%)
Colony	**296**	87 (16.1%)	247 (45.7%)	202 (37.3%)	5 (0.9%)
Non-breeding	**412**	169 (25.1%)	347 (51.6%)	157 (23.3%)	0 (0%)
Effect pathway variables					
Displacement	**603**	190 (28.3%)	326 (48.6%)	152 (22.7%)	3 (0.4%)
Mortality	428	170 (15.2%)	**595 (53.2%)**	351 (31.4%)	3 (0.2%)

In all cases where assessments were scored for resistance, medium was the highest frequency result, but it is evident that in general birds showed lowest resistance to pressures at the colony and highest resistance during the non-breeding season for the three spatiotemporal variables. For the effect pathways, there was greater resistance to displacement than mortality across all UoA with 28.3% of scores for the former being assessed as high resistance versus 15.2% for the latter. This pattern is reversed when you come to the frequency of occurrence of the low resistance score with 22.7% of assessments scored as low for displacement and 31.4% for mortality. The fundamental trend within the data are that seabirds and waterfowl exhibit least resistance at the colony and most during the non-breeding season and that seabirds and waterfowl show greater resistance to pressures applied via the displacement pathway than they do via the mortality pathway.

Table 9 breaks down the scoring for each pressure that was assessed into the differing resistance scores, totalled by the number of UoA recording that level of resistance in the assessment to provide a frequency score i.e. for Visual Disturbance (pressure B1), of the 182 UoA, none had insufficient evidence to assess sensitivity to the pressure at the benchmark, 47 UoA showed a high score of resistance, 86 medium, 48 low and one UoA showed no resistance. Overall, of the remaining UoA, 1031 were determined to have insufficient evidence to assess the resistance score, with 360 being scored as high resistance, 921 as medium resistance, 503 as low resistance and six as no resistance.

Table 9: Total UoA scored for each level of resistance, giving frequency of scores for each of the assessed pressures, where IE = insufficient evidence, H = high, M = medium, L = low, and N = no resistance. Scores in bold represent the peak frequency for each pressure.

Pressure code	Pressure name	IE	H	M	L	N
L3	Reduction in availability, extent, or quality of supporting habitat	**94**	7	47	34	0
B1	Visual Disturbance	0	47	**86**	48	1
B3	Introduction or spread of invasive non-indigenous species (INIS)	25	**62**	46	46	3
B4	Introduction of microbial pathogens	15	0	**47**	29	0
B5	Removal of target species	8	2	19	**62**	0
B6	Removal of non-target species	4	0	**47**	40	0
B7	Uncontrolled increase of native competitor/predator species	**102**	21	23	35	1

Pressure code	Pressure name	IE	H	M	L	N
B8	Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities	38	8	**80**	55	1
D3	Changes in suspended solids (water clarity)	12	**44**	33	2	0
H3	Water flow (tidal current) changes, including sediment transport considerations	**91**	0	0	0	0
H4	Emergence regime changes, including tidal level change	**91**	0	0	0	0
H5	Wave exposure change	**54**	0	31	6	0
O1	Litter	7	5	**53**	26	0
O3	Underwater noise changes	29	**42**	20	0	0
O4	Introduction of light	**88**	19	64	11	0
O5	Barrier to species movement	5	25	**46**	15	0
O6a	Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)	4	15	**59**	13	0
O6b	Collision BELOW water with static or moving objects not naturally found in the marine environment	7	**51**	32	1	0
O7	Above water noise	**40**	6	30	15	0
O8	Vibration	**91**	0	0	0	0
P1	Transition elements & organo-metal (e.g. TBT) contamination	17	0	**62**	12	0
P2	Hydrocarbon and PAH contamination	6	2	**47**	36	0

Pressure code	Pressure name	IE	H	M	L	N
P3	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	26	3	**46**	16	0
P4	Introduction of other substances (solid, liquid or gas)	**88**	0	2	1	0
P5	Radionuclide contamination	**89**	1	1	0	0

Of the 26 pressures assessed, three, i.e., Water flow (H3), Emergence regime changes (H4) and Vibration (O8), were found to have insufficient evidence to assess resistance for all UoA. In addition, Introduction of other substances (P4) and Radionuclide contamination (P5) had three and two UoA scored respectively.

Scores were not possible for Water flow (H3). While some limited evidence was available it was directional, i.e., relating to increase **or** decrease, whereas the benchmark referred to “a change in peak mean spring tide / riverine bed flow velocity of between 0.1 m/s to 0.2 m/s” which is bimodal and the effects of an increase in velocity of flow would in most instances be offset by the same relative decrease in velocity.

Emergence regime changes (H4) had a benchmark (see **Table A 2** for pressure benchmark definitions) of “Intertidal species and habitats not uniquely defined by intertidal zone: A one-hour change in the time covered or not covered by the sea for a period of one year. Intertidal species and habitats (and landscapes) defined by intertidal zone: An increase in relative sea level or decrease in high water level of 1 mm for one year over a shoreline length >1 km”. As seabirds and waterfowl are unlikely to be directly affected by the length of time the habitat is uncovered and there was no evidence related to this found during the literature search, all resistance scores were considered insufficient evidence to assess. Vibration (O8) was not scored due to an absence of evidence found in the literature searches.

The benchmark for Introduction of other substances (P4) referred to exogenous substances. Most evidence referring to pollutants and contaminants fit into the more specific pressure descriptions. Yellow-legged gull was noted to be vulnerable to exogenous substances as scavengers with highly flexible behaviour which are able to exploit anthropogenic food sources (i.e. dumps and landfills). The three UoA with scores refer to this species. Radionuclide contamination (P5) was only scored for red-throated and black-throated diver, with reference to a single piece of research which found plutonium contamination within red-throated divers in the Baltic Sea region, with limited impacts and when assessed at the benchmark level was considered to show high resistance.

Four additional pressures had the highest number of UoA scoring insufficient evidence to assess the resistance exhibited: Uncontrolled increase of native competitor and/or predator species (B7), Wave exposure changes (H5), Introduction of light (O4) and Above water noise (O7). For the Uncontrolled increase of native competitor and/or predator species pressure (B7), there was a lack of evidence, or what evidence was found during the literature search was equivocal whilst for the other three pressures there was a lack of species-specific information against a background of generic evidence that indicated sensitivity to the pressure. As such assessment of resistance was not possible in the majority of cases.

Uncontrolled increase of native competitor and/or predator species (B7) had a spread of resistance from high to none of those UoA that were assessed. The UoA exhibiting high resistance were exclusively away from the colony, either breeding (4 UoA) or non-breeding (15), where the risk of predation or competition is lessened, with the exception of yellow-legged gull. This species is a dominant apex predator in the coastal environments of southern Europe and breeds in largely inaccessible locations, reducing the impact of mammalian predators. Only one UoA was assessed as having no resistance to this pressure, kittiwake at the colony via the mortality pathway, as this species has been shown to be highly vulnerable to egg and chick predation by great black-backed gulls which can impact colony viability (Veitch and others 2016).

There were 37 UoA that were given resistance scores for the Wave exposure changes (H5) pressure. Of these, 31 were scored as medium resistance and a further six were low resistance. Of the six UoA that were assessed as low resistance five of these were at the colony with risk attached to returning to nest in rough sea conditions and reduced breeding success due to greater wave exposure. Arctic tern was considered to have a low resistance to displacement through the action of this pressure during the non-breeding period as increased wave exposure reduces fishing success in this species (Bengtson 1966).

Of those units assessed for Introduction of light (O4), 64 were considered to exhibit medium resistance, with no obvious outliers as 19 UoA were assessed as high resistance and a further 11 UoA at low resistance. Of the 11 units adjudged to have low resistance to the Introduction of light (O4), seven were at the colony. Other patterns of resistance were less pronounced.

51 UoA were given resistance scores for Above water noise (O7). Of those six were scored at high resistance, 30 at medium resistance and a further 15 at low resistance. The UoA scored as high resistance were all away from the colony but there were no obvious patterns to those units assessed as medium or low significance.

Four pressures had high resistance as the most common outcome from an assessment: Introduction or spread of invasive non-indigenous species (INIS) (B3), Changes in suspended solids (water clarity) (D3), Underwater noise changes (O3) and Collision below water with static or moving objects not naturally found in the marine environment. Of these four pressures, three create direct impacts on birds whilst they are underwater. For most species this has no impact at the colony and for many species the time spent underwater is small, relative to the time spent above the water and so exposure to the pressure is reduced. When considering the Introduction or spread of invasive non-indigenous species (INIS) (B3) it is worth noting that there are no INIS which predate seabirds and waterfowl at sea in England and as such it is only at the colony where this pressure is likely to exert an impact when introduced mammalian species such as mink, rats and hedgehogs can cause an effect.

Three UoA, all at the colony, were assessed as having no resistance to the Introduction or spread of INIS (B3). Common gull were found to increase in productivity and population when American mink were eradicated (Craik 2000) and black guillemot colonies have been destroyed and displaced by mink predation in the Baltic Sea (Nordstrom and others 2003). Of the 46 UoA adjudged to have low resistance to this pressure, 37 were at the colony whilst of those judged to have high resistance to INIS, 60 of 62 UoA were away from the colony.

When considering Changes in suspended solids (D3), only black-necked grebe was found to have a low resistance to poorer water clarity as they are visual predators and foraging efficiency decreases when visibility dropped below 40cm (Kloskowski and others 2010). No trends were obvious on the level of resistance exhibited by UoA for water clarity with the remaining assessments split between high (44) and medium resistance (33).

Underwater noise changes (O3) were assessed at high for 42 UoA and medium for 20 UoA with 29 UoA not assessed due to insufficient evidence. There were no outliers for this pressure although only three UoA were assessed as medium resistance when at the colony, with the remainder assessed as high resistance or insufficient evidence.

Seven UoA were considered to have insufficient evidence to assess resistance to Collision below water (O6b) and of these, three referred to yellow-legged gull which had no species-specific evidence to base an assessment on and four referred to diving ducks (eider and long-tailed duck) which had conflicting evidence with regard the likelihood of impact. Of the remaining UoA, one was assessed as low resistance to below water collisions, cormorant, which relies on tactile cues rather than visual acuity below water when foraging (Isaksson and others 2020).

One pressure, Removal of target species (B5), had low resistance as the most frequent assessment result. This relates to the direct removal of individuals from a population and the benchmark is “Deliberate removal of the species by humans through e.g., hunting, culling, harvesting, the removal/ destruction of nests/ eggs etc.”. 62 UoA were assessed as low resistance to this. No spatiotemporal pattern is obvious from the results despite an understanding that there will be greater effect during the breeding season and at the colony. One species, puffin, was assessed as having high resistance to the removal of target species pressure. This species is widely exploited through hunting in the North Atlantic but there have been limited signs of population level impacts caused by this (Denlinger & Wohl 2001).

The remaining ten pressures have medium resistance as the commonest assessment result. There are relatively few outlying results when considering resistance for these pressures. The pressure Visual disturbance (B1) had one UoA scored as having no resistance, black guillemot at the breeding colony, as a study by Cairns (1980) showed a large drop in breeding success in an area where there were high levels of human contact in comparison with a less disturbed colony nearby. Kittiwake during the breeding season is considered to exhibit no resistance to a Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities (B8). The sensitivity of kittiwakes to a reduction in sandeel stocks and the impact upon breeding success has been widely researched (e.g., Gill and others 2002; Oro & Furness 2002) and provides a robust evidence base to support this species having an outlying score for this pressure. For pressure P2 (Hydrocarbon and PAH contamination), two UoA were assessed as high resistance. Both referred to lesser back-backed gulls as Camphuysen and others (2011) states that colour-ringed individuals have been seen to have survived oiling incidents and recover to breed thereafter, showing self-cleaning capacity. The other outlying results from this subset of pressures was for three UoA exhibiting high resistance to Synthetic compound contamination (P3). The three UoA were all for Puffin, as this species shows low-levels of bioaccumulation of contaminants than other seabird species and these are less likely to cause mortality at the benchmark level (the non-compliance with any Annual Average Environmental Quality Standards (AA-EQS), non-conformance with probable effect levels (PELs), Environmental Assessment Criterias (EACs), Effect range – Low (ER-Ls) within site).

Confidence scores (resistance)

As was outlined in the methods, the level of confidence in each resistance assessment was scored using the criteria in **Table 7**. The frequency of the different confidence scores for each pressure that was assessed are presented below in **Table 10**. Of the 22 pressures with resistance assessments receiving confidence scores, 13 had medium confidence as the highest frequency score, seven had insufficient evidence to assess as the highest frequency confidence score with two pressures having low confidence as the highest frequency confidence. No resistance assessments had high confidence as the highest frequency confidence score.

Table 10: Number of UoA resistance scores assigned to each level of confidence, giving frequency of confidence scores for resistance assessments, where IE = insufficient evidence, H = high, M = medium, and L = low. Scores in bold indicate the peak frequency for each pressure.

Pressure code	Pressure name	IE	H	M	L
L3	Reduction in availability, extent, or quality of supporting habitat	**94**	3	47	38
B1	Visual Disturbance	0	29	**107**	46
B3	Introduction or spread of invasive non-indigenous species (INIS)	25	13	63	**81**
B4	Introduction of microbial pathogens	15	4	**52**	20
B5	Removal of target species	8	9	**44**	30
B6	Removal of non-target species	4	17	**49**	21
B7	Uncontrolled increase of native competitor/predator species	**102**	3	44	33
B8	Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities	38	25	**75**	44

Pressure code	Pressure name	IE	H	M	L
D3	Changes in suspended solids (water clarity)	12	1	**41**	37
H5	Wave exposure change	**54**	1	13	23
O1	Litter	7	7	**54**	23
O3	Underwater noise changes	29	1	25	**36**
O4	Introduction of light	**88**	4	42	48
O5	Barrier to species movement	5	12	**56**	18
O6a	Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)	4	23	**50**	14
O6b	Collision BELOW water with static or moving objects not naturally found in the marine environment	7	6	**65**	13
O7	Above water noise	**40**	0	21	30
P1	Transition elements & organo-metal (e.g. TBT) contamination	17	0	**46**	28
P2	Hydrocarbon and PAH contamination	6	25	**48**	12
P3	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	26	3	**39**	23
P4	Introduction of other substances (solid, liquid or gas)	**88**	0	0	3

Pressure code	Pressure name	IE	H	M	L
P5	Radionuclide contamination	**89**	0	0	2

As confidence in resistance scores is linked entirely to the depth or unanimity of the evidence base, discussion of spread and outliers is less useful than with resistance scoring itself. To that end, it is more useful to outline which pressures have a relatively well-formed evidence base and which do not by considering them by highest frequency confidence resistance score. It is notable that whilst **186** UoA have high confidence in the resistance scoring, no individual pressure has high confidence as the most frequent result. **981** UoA are scored as having medium confidence in the resistance scoring and **623** having low confidence. **1031** UoA were not given confidence scores for resistance as they had insufficient evidence to assess their resistance scoring. There were no notable patterns in confidence of resistance in relation to the pathway of impact (mortality or displacement).

This table suggests that there is a well-evidence base for the 13 pressures with medium confidence as the highest frequency result when assessing the confidence of the resistance scores. The two pressures scoring low confidence, Introduction of INIS (B3) and Underwater Noise Changes (O3), are both shown to have broadly negative effects but there is a lack of species specific and spatiotemporally specific evidence which led to a greater reliance on professional judgement when determining the result. Of the remaining seven pressures, there is commonality in the lack of evidence on their effect, and whilst they may cause deleterious effect at the benchmark, there are a lack of broader studies that would elevate the scores to a low confidence and allow assessment.

Resilience scores

Table 11 presents the frequency of resilience scores by pressure. This includes all assessments which were scored for resilience. The criteria for resilience scoring are presented for both the mortality pathway and displacement pathway in **Table 4** and **Table 5** respectively. In total **744** UoA were determined to have insufficient evidence to assess the resilience score, with **573** being scored as high resilience, **388** as medium resilience and **1116** as low resilience.

Table 11: Total UoA scored for each level of resilience, giving frequency of scores for each of the assessed pressures, where where IE = insufficient evidence, H = high, M = medium, L = low, and N = no resilience. Scores in bold indicate the peak frequency for each pressure.

Pressure code	Pressure name	IE	H	M	L
L3	Reduction in availability, extent, or quality of supporting habitat	**67**	21	35	59
B1	Visual Disturbance	0	70	36	**76**

Pressure code	Pressure name	IE	H	M	L
B3	Introduction or spread of invasive non-indigenous species (INIS)	22	40	39	**81**
B4	Introduction of microbial pathogens	4	0	16	**71**
B5	Removal of target species	3	0	13	**75**
B6	Removal of non-target species	0	0	16	**75**
B7	Uncontrolled increase of native competitor/predator species	**77**	27	26	52
B8	Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities	26	49	34	**73**
D3	Changes in suspended solids (water clarity)	9	**72**	10	0
H3	Water flow (tidal current) changes, including sediment transport considerations	**75**	15	1	0
H4	Emergence regime changes, including tidal level change	**91**	0	0	0
H5	Wave exposure change	36	**45**	10	0
O1	Litter	3	0	13	**75**
O3	Underwater noise changes	17	**69**	4	1
O4	Introduction of light	54	46	20	**62**
O5	Barrier to species movement	4	**63**	22	2
O6a	Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)	1	0	15	**75**

Pressure code	Pressure name	IE	H	M	L
O6b	Collision BELOW water with static or moving objects not naturally found in the marine environment	1	0	15	**75**
O7	Above water noise	31	**52**	7	1
O8	Vibration	**87**	4	0	0
P1	Transition elements & organo-metal (e.g. TBT) contamination	10	0	12	**69**
P2	Hydrocarbon and PAH contamination	6	0	13	**72**
P3	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	11	0	16	**64**
P4	Introduction of other substances (solid, liquid or gas)	**57**	0	7	27
P5	Radionuclide contamination	**52**	0	8	31

Thirteen pressures had the highest number of UoAs scored with low resilience, with five scoring high resilience most frequently and seven having insufficient evidence as the most frequent score. 287 UoA were scored for resilience despite having no resistance score, as resilience scores, being underpinned by life history traits, are largely independent of resistance and if the assumed impact could be determined, whether assessable or not, then a resilience score could be generated. Resilience scores were generated for all UoA that received a resistance score. The five pressures receiving high as the most frequent resilience score were only assessed against the displacement pathway and not the mortality pathway as a route of impact for that pressure. In contrast, of the 1547 UoA scored at low resilience, 1183 were for the mortality pathway, with just 364 via the displacement pathway. As such it can be broadly determined that resilience scores are higher for assessments carried out using the displacement pathway than the mortality pathway. Once pathways are accounted for, there are no obvious patterns in the resilience scores.

Confidence scores (resilience)

The level of confidence in each resilience assessment was scored using the criteria in **Table 7**. The frequency of the different confidence scores for each pressure that was assessed for resilience are presented below in **Table 12**. Of the 22 pressures with resilience assessments receiving confidence scores, 14 had high confidence as the highest frequency score, six had insufficient evidence to assess as the highest frequency confidence score, and five pressures had low confidence as the highest frequency confidence. No resilience assessments had medium confidence as the highest frequency confidence score for resilience.

Table 12: Number of UoA resilience scores assigned to each level of confidence, giving frequency of confidence scores for resilience assessments, where IE = insufficient evidence, H = high, M = medium, and L = low. Scores in bold indicate the peak frequency for each pressure.

Pressure code	Pressure name	IE	H	M	L
L3	Reduction in availability, extent, or quality of supporting habitat	67	**69**	16	30
B1	Visual Disturbance	0	**94**	33	55
B3	Introduction or spread of invasive non-indigenous species (INIS)	22	**88**	16	56
B4	Introduction of microbial pathogens	4	**86**	1	0
B5	Removal of target species	3	**87**	1	0
B6	Removal of non-target species	0	**90**	1	0
B7	Uncontrolled increase of native competitor/predator species	**77**	59	13	33
B8	Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities	26	**81**	18	57
D3	Changes in suspended solids (water clarity)	9	1	21	**60**
H3	Water flow (tidal current) changes, including sediment transport considerations	**75**	0	0	16
H4	Emergence regime changes, including tidal level change	**91**	0	0	0
H5	Wave exposure change	36	0	8	**47**
O1	Litter	3	**86**	2	0
O3	Underwater noise changes	17	1	12	**61**
O4	Introduction of light	54	**71**	11	46

Pressure code	Pressure name	IE	H	M	L
O5	Barrier to species movement	4	1	33	**53**
O6a	Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)	1	**89**	1	0
O6b	Collision BELOW water with static or moving objects not naturally found in the marine environment	1	**89**	1	0
O7	Above water noise	31	0	9	**51**
O8	Vibration	**87**	0	0	4
P1	Transition elements & organo-metal (e.g. TBT) contamination	10	**79**	2	0
P2	Hydrocarbon and PAH contamination	6	**84**	1	0
P3	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	11	**79**	1	0
P4	Introduction of other substances (solid, liquid or gas)	**57**	34	0	0
P5	Radionuclide contamination	**52**	39	0	0

Of the 14 pressures with high confidence as the most frequent confidence score for resilience, 73.7% of UoA are for the mortality pathway and just 26.3% are for the displacement pathway. Conversely, of the five pressures with low confidence as the most frequent resilience score, 100% of UoA are for the displacement pathway. This underlines a lack of evidence for determining the resilience of species when a pressure causing a displacement reaction is removed. Conversely resilience from the mortality pathway relies on life-history traits such as reproductive rate and this is well researched and understood in seabird and waterfowl species. There are no clear patterns for confidence in resilience scoring when considering pressure-specific or spatiotemporal variables.

4.2 Analysis by species

In this section, the results for individual species will be explored to identify broad trends in scoring by species with some consideration of phylogenetic relationships and feeding guilds. These results are broken down by spatiotemporal variable and pathway of impact. As with the pressures section, those pressures for which it has been determined there are no direct effects are omitted from the results.

Resistance

A full breakdown of resistance by species is provided in **Table A 4** within **Appendix 3** , but due to the size of the table, pulling out meaningful trends is more difficult. In order to identify trends in the data, filtering using a broader approach helps. In **Table 13** the number of species exhibiting a level of resistance most frequently is presented. Insufficient Evidence is the most frequently recorded score in all instances, both for all spatiotemporal variables combined and for each spatiotemporal variable in turn, whilst medium is the most frequent score accorded to the second highest number of species. The small number of outliers are illustrative of the broader trend. Two species, lesser black-backed gull and great black-backed gull (tied with Insufficient Evidence and medium resistance) record high resistance as the most frequent result in the non-breeding season. Two species, razorbill and roseate tern, record low resistance as the most frequent result at the colony during the breeding season. In addition, when removing Insufficient Evidence, arctic tern, eider and common gull also have a most frequent assessment of low resistance at the colony. Kittiwake, when Insufficient Evidence is discounted, has low resistance as the highest frequency result for all spatiotemporal variables. It appears that species are most vulnerable to the impact of pressures at the colony and least vulnerable during the non-breeding season. This is as expected from the results in the pressures section but the smaller sample size of UoA per species appears to mask the results, so they are more equivocal.

Table 13: Number of Species Exhibiting Given Resistance Scores at the Highest Frequency

Spatiotemporal variable	Number of species				
	Insufficient evidence	High	Medium	Low	None
Overall	22	0	14	0	0
Breeding	16	0	15	0	0
Colony	14	0	11	2	0
Non-breeding	20	2	11	0	0

When considering the different feeding guilds, all guilds have Insufficient Evidence as the most frequent result when tallying UoA. All guilds have medium resistance as the second most frequent result of assessments. As such, identifying trends requires an alternate approach, ranking the guilds according to the frequency of resistance scores. These results are shown in **Table 14**.

Table 14: Percentage of Units of Assessment Assessed as High and Low / No Resistance including Comparative Ranking for Feeding Guilds

Phylogenetic group	High resistance (% of UoA)	Rank	Low / No resistance (% of UoA)	Rank
Surface feeders	25.2	1	26.6	4
Water column feeders	16.6	2	28.4	3
Water column / benthic feeders	6.6	4	36.3	1
Benthic feeders	11.9	3	30.5	2

As can be seen from **Table 14**, surface feeding species exhibit the lowest frequency of low resistance assessments and the highest frequency of high resistance assessments. Conversely, water column and benthic feeding species exhibit the highest frequency of low resistance assessments and the lowest frequency of high resistance assessments. Surface feeding seabirds thus exhibit the highest level of resistance to the range of pressures assessed and water column and benthic feeding species the lowest. Water column feeding species are ranked second highest on resistance followed by benthic feeding species in third. There is less than a 10% spread of scores for low resistance assessments between the four guilds but this is more pronounced for high resistance assessments, with over 18% between the highest and lowest rank guilds. Phylogenetic groupings were also considered but the results aligned with those of the feeding guilds and are not presented.

Resilience

As with the overall table for resistance by species (**Table A 4**), the wider trends from the full resilience by species table (**Table A 5**) are difficult to interpret, particularly with the sample size for an individual species or variable being low. In **Table 15** the number of species exhibiting a level of resilience most frequently is presented. Low resilience was the most frequently recorded score in all instances, both for all spatiotemporal variables combined and for each spatiotemporal in turn whilst medium is the most frequent score accorded to the second highest number of species. No species was assessed as high resilience most frequently. Seven species (red-throated and great northern diver, slavonian and black-necked grebe, eider, common scoter and red-breasted merganser) were assessed as medium resilience most frequently either overall or for a specific spatiotemporal variable. These species are all waterfowl with a relatively high reproductive rate and shorter lifespan when compared to the other species included within the report.

Table 15: Number of Species Exhibiting Given Resilience Scores at the Highest Frequency. Percentage of scores as a total of those which had sufficient evidence to assess (insufficient evidence excluded) are shown in parentheses. Scores in bold indicate peak results for each variable.

Spatiotemporal variable	Number of species			
	Insufficient evidence	High	Medium	Low
Overall	6	0 (0.0%)	6 (20.7%)	**23 (79.3%)**
Breeding	3	0 (0.0%)	3 (12.0%)	**22 (88.0%)**
Colony	3	0 (0.0%)	4 (17.4%)	**19 (82.6%)**
Non-breeding	5	0 (0.0%)	7 (24.1%)	**22 (75.9%)**

Table 16: Number of Units of Assessment Scored at a Resilience Level for Feeding Guilds. Percentage of scores as a total of those which had sufficient evidence to assess (insufficient evidence excluded) are shown in parentheses. Scores in bold indicate peak results for each guild.

Feeding guilds	Number of Units of Assessment			
	Insufficient evidence	High	Medium	Low
Surface feeders	363	314 (27.2%)	113 (9.8%)	**729 (63.0%)**
Water column feeders	206	168 (29.5%)	32 (5.6%)	**369 (64.9%)**
Water column / benthic feeders	135	51 (21.5%)	**170 (71.7%)**	16 (6.8%)
Benthic feeders	40	40 (34.8%)	**73 (63.5%)**	2 (1.7%)

Table 16 which splits the results by guild. The guilds are split between seabirds (surface-feeders and water column feeders) and waterfowl (benthic feeders and water column / benthic feeders) and the results reflect this. Both seabird guilds come out with higher frequency of UoA assessed as low resilience while both waterfowl guilds come out with medium resilience as the highest frequency assessment result. Between the waterfowl guilds, higher resilience is shown by benthic feeding species (98.3% high or medium resilience) when compared with water column / benthic feeders (waterfowl) (93.2%), but the sample size is relatively small. The difference between the seabird guilds is less notable with 37% of surface feeding species assessments at high or medium resilience compared to 35.1% for water column feeding species.

5. Conclusion and recommendations

The overall aim of the project was to provide Natural England with up-to-date, evidence-based, auditable, and transparent assessments of the sensitivity of a range of waterfowl and seabird species to a range of human-related environmental pressures suitable for the development of vulnerability assessments to inform an ESCaRP. This report documents how this was achieved.

Two methods (Pérez-Domínguez and others 2016, Rogerson and others 2021) were reviewed and compared to derive a scientifically robust method that was appropriate and applicable for the purposes of determining sensitivity of seabirds listed within the ESCaRP (see section 2.4). Although the two methods followed a largely similar approach, differences were noted around the consideration of spatiotemporal effects (e.g., breeding season and location), the pathway of impact (displacement or mortality effects), the criteria used to score resilience, the level of precaution built into the sensitivity matrix, and differences in some of the benchmarks used to measure the intensity of the pressure being considered.

To allow a greater consistency of advice provided by Natural England, and to enable the results of this work to be used beyond the ESCaRP, the decision was made by Natural England to base the method as much as possible on that of Pérez-Domínguez and others (2016), but to take on board recommendations made by APEM of how the method could be improved for application to the ESCaRP.

Recommendations that were made and incorporated into the new method included changing resilience scoring to reduce the number of categories and a change in the recovery time-period used (see section 2.6). Reducing the number of categories allowed for an increased accuracy in scoring, while the change in time criteria allowed this method to be better aligned with others, such as that used by Natural England to assess sensitivity of benthic habitats and species (Tyler-Walters and others 2018). The derivation of a new, less precautionary sensitivity matrix was adopted, to enable a greater granularity of results, that would be more useful in considering relative vulnerability of seabird species within the ESCaRP. A small number of pressure definitions and benchmarks were modified, to improve clarity (and hence improve consistency) in their application to seabirds. Although the preference was for quantified benchmarks, in some cases benchmarks were changed to be qualitative. This was the case where the initial benchmarks had been produced with other species in mind and were considered to be less applicable to the activities that were likely to result in the pressure when it affected birds. For example, the benchmark relating to the pressure ‘collision below water’ in Pérez-Domínguez and others (2016) referred to a percentage of tidal volume passing through a tidal barrage. The decision was made to change this to a qualitative benchmark, which would be applicable to a wider range of activities that could impact birds, and which was more likely to be reflected in the evidence used to inform the assessments.

Further recommendations that were adopted related to guidance on interpreting evidence, and on increasing clarity of documentation.

One final methodological decision, recommended by Natural England, and which reflected the approach used by Rogerson and others (2021), was to include two new pressures to address indirect impacts of other pressures on prey resource or availability of supporting habitats, and a third pressure to assess impacts caused by native predators or competitors.

A review of the results of the sensitivity assessment allowed some appraisal of the new method to be made.

The results of the assessment process generally suggest that bird species exhibit highest resistance to pressures when applied at the benchmark level during the non-breeding season and resistance decreases during the breeding season, particularly at the colony. Although Pérez-Domínguez and others (2016) assumed that resistance to displacement would be lower than to mortality effects (due to avoidance behaviours being likely to cause a greater population decline over a short time period), this study showed that resistance to displacement was generally found to be higher than to the mortality pathway, although this may be an artefact that breeding birds are tied to a discrete area and are thus less able to exhibit displacement over mortality. Very few of the assessments (six) led to an assessment of resistance as none. This warrants consideration of whether this category is useful to determine resistance or whether refinement of the criteria for each resistance category is required.

Further observations regarding the resistance assessments include noting that the agreed benchmark for Water flow changes (pressure H3) was bimodal and not directional, relating to change of flow rate not an increase in flow rate, and thus consideration of both increase and decrease was required when making an assessment. This made assessment of this pressure unfeasible at the benchmark level as outcomes to the available evidence were likely to be offset by the corresponding change in flow in the other direction such as a positive effect of less energetic spend in a lower flow would also equate to an equivalent effect of greater energetic spend in a higher flow. One way to mitigate this would be to split the pressure into two, increase and decrease of water flow.

Introduction of other substances, was difficult to assess as aside from specific references to exogenous substances, this pressure had few specifics and as such a limited evidence base, as the majority of research found during the literature search for this pressure, using the search terms outlined in **Appendix 2,** related to pollutants and contaminants considered within the other pressures. In addition to the introduction of other substances, five further pressures, reduction in availability, extent, or quality of supporting habitats (L3), the uncontrolled increase of native / competitor species (B7), wave exposure changes (H5), the introduction of light (O4) and above water noise (O7) had particularly underdeveloped evidence bases, and it is anticipated that considerable change to assessment results may occur when further research in these areas is published. Two pressures that were assessed more widely had generally low confidence in their confidence scores for resistance, the introduction or spread of invasive non-native species (B3) and underwater noise changes (O3).

As with the FeAST update (Rogerson and others 2021), all resistance assessments for emergence regime changes (H4) had insufficient evidence to assess, and this pressure cannot be determined to have direct effects on seabird species. It is therefore recommended that this pressure is not considered to have direct effect on the birds considered within this assessment.

Resilience assessments remained tied tightly to life-history traits as there was a lack of evidence to allow for consideration of species-, pressure-, or pathway-specific impacts. One instance where resilience evidence was available was when displacement of colonies in Manx shearwater and roseate tern would occur at the benchmark level. Both species showed a delayed recolonisation of former breeding areas due to the requirement for a large floating population of non-breeding adults to be present within the environment to form a founder population. This decreased the level of resilience of UoA using the displacement pathway for these species and allowed inferences about impacts on the resilience of congeners.

As each species assessed had relatively few UoA, determining patterns for individual species from the data was more difficult but kittiwake was notable as being assessed as low resistance for all three spatiotemporal variables. Other species, razorbill, common gull, eider, roseate tern and arctic tern, were also assessed most frequently as low resistance at the breeding colony. Seabirds generally showed higher resistance than waterfowl with skuas and gulls exhibiting particularly high levels of resistance and divers and grebes assessed as having low resistance. This tallies with the life-history of these species as seabirds breed more slowly and live longer than waterfowl and thus to maintain a viable population would need to exhibit greater resistance. This is reflected in the resilience scores which were higher for waterfowl in comparison with seabirds and thus are assessed as being able to return to areas more rapidly when a pressure is released. Overall, these results support the expected outcome, and provide confidence that the method is suitable for distinguishing between relative sensitivity of seabirds.

Further refinements of the method by production of spatiotemporal specific evidence bases or reducing the reliance on expert judgement in assessment, with particular reference to resilience scoring for the displacement pathway, are desirable. Further avenues for developing pressure assessments for seabirds include referencing the spatial or population scales of the assessments so that these may be considered when undertaking a location-specific assessment or designing a mechanism for incorporating in-combination or cumulative effects which are unlikely to be purely additive in nature. A specific recommendation of this report is that the pressure Water flow (H3) is subdivided into two further pressures, Increase in water flow (H3i) and Decrease in water flow (H3d). This would reflect the approach used for pressures related to temperature and salinity changes, and would allow specific benchmarks and thus resistance assessments to be carried out.

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7. Appendices

Appendix 1: Pressures and species lists

Table A 1: Seabird sensitivity review species list

Species	Scientific name	Family	Guild
Common eider	*Somateria mollissima*	Anatidae	Benthic feeders
Common scoter	*Melanitta nigra*	Anatidae	Benthic feeders
Long-tailed duck	*Clangula hyemalis*	Anatidae	Benthic feeders
Red-breasted merganser	*Mergus serrator*	Anatidae	Water column / benthic feeders
Slavonian grebe	*Podiceps auritus*	Podicipedidae	Water column / benthic feeders
Black-necked grebe	*Podiceps nigricollis*	Podicipedidae	Water column / benthic feeders
Black-legged kittiwake	*Rissa tridactyla*	Laridae	Surface feeders
Black-headed gull	*Chroicocephalus ridibundus*	Laridae	Surface feeders
Little gull	*Hydrocoloeus minutus*	Laridae	Surface feeders
Mediterranean gull	*Ichthyaetus melanocephalus*	Laridae	Surface feeders
Common gull	*Larus canus*	Laridae	Surface feeders
Great black-backed gull	*Larus marinus*	Laridae	Surface feeders
Herring gull	*Larus argentatus*	Laridae	Surface feeders
Yellow-legged gull	*Larus michahellis*	Laridae	Surface feeders

Species	Scientific name	Family	Guild
Lesser black-backed gull	*Larus fuscus*	Laridae	Surface feeders
Sandwich tern	*Thalasseus sandvichensis*	Laridae	Surface feeders
Little tern	*Sternula albifrons*	Laridae	Surface feeders
Roseate tern	*Sterna dougallii*	Laridae	Surface feeders
Common tern	*Sterna hirundo*	Laridae	Surface feeders
Arctic tern	*Sterna paradisaea*	Laridae	Surface feeders
Great skua	*Stercorarius skua*	Stercorariidae	Surface feeders
Arctic skua	*Storcorarius parasiticus*	Stercorariidae	Surface feeders
Common guillemot	*Uria aalge*	Alcidae	Water column feeders
Razorbill	*Alca torda*	Alcidae	Water column feeders
Black guillemot	*Cepphus grille*	Alcidae	Water column feeders
Atlantic puffin	*Fratercula arctic*	Alcidae	Water column feeders
Red-throated diver	*Gavia stellata*	Gaviidae	Water column / benthic feeders
Black-throated diver	*Gavia arctica*	Gaviidae	Water column / benthic feeders
Great northern diver	*Gavia immer*	Gaviidae	Water column / benthic feeders
European storm petrel	*Hydrobates pelagicus*	Hydrobatidae	Surface feeders
Northern fulmar	*Fulmarus glacialis*	Procellariidae	Surface feeders

Species	Scientific name	Family	Guild
Manx shearwater	*Puffinus puffinus*	Procellariidae	Water column feeders
Balearic shearwater	*Puffinus mauretanicus*	Procellariidae	Water column feeders
Northern gannet	*Morus bassanus*	Sulidae	Water column feeders
Great cormorant	*Phalacrocorax carbo*	Phalacrocoracidae	Water column feeders
European shag	*Phalacrocorax aristotelis*	Phalacrocoracidae	Water column feeders

Table A 2: Seabird sensitivity review pressures, benchmarks and effect pathways

Pressure code	Pressure name	Pressure benchmark	Effect pathway
L3	Reduction in availability, extent, or quality of supporting habitat	Reduction in habitat availability, extent or quality.	Displacement, mortality
B1	Visual Disturbance	The daily duration of transient visual cues exceeds 10% of the period of site occupancy by the feature.	Displacement, mortality
B2	Genetic modification and translocation of indigenous species	Translocation/displacement outside of a geographic area; introduction of farm/hatchery-reared individuals outside of geographic area from which adult stock derives.	No direct effects
B3	Introduction or spread of invasive non-indigenous species (INIS)	A significant pathway exists for introduction or spread of one or more non-indigenous invasive species; OR there is a potential for the introduction of highly invasive/impact species.	Displacement, mortality
B4	Introduction of microbial pathogens	The introduction of relevant microbial pathogens to an area where they are currently not present (e.g. avian influenza virus,	Mortality

Pressure code	Pressure name	Pressure benchmark	Effect pathway
		viral haemorrhagic septicaemia virus, etc.)	
B5	Removal of target species	Deliberate removal of the species by humans through e.g. hunting, culling, harvesting, the removal/ destruction of nests/ eggs etc.	Mortality
B6	Removal of non-target species	Unintentional, direct removal or harvesting of the species through e.g. bycatch and entanglement or through misidentification, including the removal or destruction of misidentified eggs/ nest.	Mortality
B7	Uncontrolled increase of native competitor/predator species	A significant pathway exists for native competitor or predator species to exude a pressure due to uncontrolled levels or predation or competition in the absence of exclusion or control; OR there is a potential for native competitor or predator species to exude such a pressure due to change in the exclusion and control of these species.	Displacement, mortality
B8	Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities	Reduction in food availability or quality of food.	Displacement, mortality
D1	Habitat structure changes – removal of substratum (extraction)	Extraction of sediment to 30cm; OR removal of >10% area/volume of biologically relevant structures (including water column habitat and biogenic forming structures).	No direct effects
D2	Penetration and/or disturbance of the substratum below the	Structural damage of >10% area/volume of biologically relevant structures (including water column	No direct effects

Pressure code	Pressure name	Pressure benchmark	Effect pathway
	surface of the seabed, including abrasion	habitat and biogenic forming structures).	
D3	Changes in suspended solids (water clarity)	A change in one rank on the WFD (Water Framework Directive) scale, e.g. from clear to intermediate for one year. (Ranks are mean suspended particulate matter in units of mg/c: >300 - very turbid; 100-300 - medium turbidity; 10-100 - intermediate; <10 - clear).	Displacement
D4	Smothering and siltation rate changes (heavy)	Up to 30cm of fine material added to the seabed in a single event.	No direct effects
D5	Smothering and siltation rate changes (light)	Up to 5cm of fine material added to the seabed in a single event.	No direct effects
D6	Abrasion/disturbance of the substrate on the surface of the seabed	Structural damage of >10% area/volume of biologically relevant structures (including biogenic forming structures).	No direct effects
H1d	Temperature decrease	A short-term 5°C change in temp over species habitat areas, or 2°C for one year or more.	No direct effects
H1i	Temperature increase	A short-term 5°C change in temp over species habitat areas, or 2°C for one year or more.	No direct effects
H2d	Salinity decrease	Decrease in salinity by 4-10 units a year.	No direct effects
H2i	Salinity increase	An increase in salinity from 35 to 38 units over species essential habitat areas.	No direct effects
H3	Water flow (tidal current) changes, including sediment transport considerations	A change in peak mean spring tide / riverine bed flow velocity of between 0.1 m/s to 0.2 m/s.	Displacement

Pressure code	Pressure name	Pressure benchmark	Effect pathway
H4	Emergence regime changes, including tidal level change	Intertidal species and habitats not uniquely defined by intertidal zone: A one hour change in the time covered or not covered by the sea for a period of one year. Intertidal species and habitats (and landscapes) defined by intertidal zone: An increase in relative sea level or decrease in high water level of 1 mm for one year over a shoreline length >1 km	Displacement
H5	Wave exposure change	A change in nearshore significant wave height of >3% but <5%.	Displacement
L1	Physical loss (to land or freshwater habitat)	Permanent loss of existing saline habitat within a site.	No direct effects
L2sed	Physical change (to another sediment type)	Change in one Folk class for two years or >10% habitat type change within site.	No direct effects
L2sb	Physical change (to another seabed type)	Change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa.	No direct effects
O1	Litter	The introduction of manmade objects able to cause physical harm	Mortality
O2	Electromagnetic changes	The introduction of a local electric field of 1 V/m-or a local magnetic field of 10 µT within a site.	No direct effects
O3	Underwater noise changes	Anthropogenic sound sources exceed levels that elicit a response from an individual (e.g., moving	Displacement

Pressure code	Pressure name	Pressure benchmark	Effect pathway
		away, cessation of feeding) or that causes auditory injury, for over 10% of the period of site occupancy by the feature.	
O4	Introduction of light	A change of 0.1 Lux in diffuse irradiation during period of site occupancy by the feature; >3 distant strobe and point light sources visible over a 90° azimuth arc.	Displacement, mortality
O5	Barrier to species movement	Disruption to >10% of local population affected by permanent or temporary lack of continuity of parts of the commuting or migration corridor causing complete obstruction or an increase in travel distance around barriers to species movement.	Displacement
O6a	Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)	The introduction of structures or devices that introduce aerial collision risk in areas used by features.	Mortality
O6b	Collision BELOW water with static or moving objects not naturally found in the marine environment	The introduction of structures or devices that introduce underwater collision risk in areas used by features.	Mortality
O7	Above water noise	Anthropogenic sound sources exceed levels that elicit a response from an individual (e.g., moving away, cessation of feeding) or that causes auditory injury, for over 10% of the period of site occupancy by the feature.	Displacement

Pressure code	Pressure name	Pressure benchmark	Effect pathway
O8	Vibration	Particle motion equivalent for MSFD indicator levels (SEL or peak SPL) exceeded in areas used by features.	Displacement
P1	Transition elements & organo-metal (e.g. TBT) contamination	Non-compliance with all average annual Environmental Quality Standards, or conformance with Probable Effect levels, Environment Assessment Criteria, Effects Range - Low.	Mortality
P2	Hydrocarbon and PAH contamination	The non-compliance with any Annual Average Environmental Quality Standard (AA EQS), non-conformance with any Permissible Exposure Limits (PELs), Environmental Assessment Criteria (EACs) or Effects Range Low (ER-Ls) within a site.	Mortality
P3	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	The non-compliance with any AA EQS, non-conformance with PELs, EACs, ER-Ls within site.	Mortality
P4	Introduction of other substances (solid, liquid or gas)	The presence of exogenous substances (including oil films and slicks) in areas used by features.	Mortality
P5	Radionuclide contamination	An increase in radionuclides of 10 µGy/h above background levels within site.	Mortality
P6	Nutrient enrichment	Non-compliance with Water Framework Directive (WFD) criteria for good status within a site.	No direct effects
P7	Organic enrichment	A deposit of 100 gC/m2/yr or more.	No direct effects
P8	Deoxygenation	Non-compliance with WFD criteria for good status within site.	No direct effects

Appendix 2: Literature search keywords

Table A 3: Literature search keywords

Pressure name	Keywords
Reduction in availability, extent, or quality of supporting habitat	Habitat availability, habitat quality, habitat extent.
Visual Disturbance	Visual disturb, human, boat, recreation, tourism, vehicle.
Introduction or spread of invasive non-indigenous species (INIS)	Non-indigenous, non-native, mink, squirrel, rat, stoat, cat, mouse, mice, invasive, alien.
Introduction of microbial pathogens	Bird flu, disease, virus, parasite, bacteria, H5N1, infection, botulism, land-fill, influenza.
Removal of target species	Harvest, egg collection, persecution, cull, hunt, trap, exploit.
Removal of non-target species	Bycatch, drown, net, entangle, windfarm, renewable, static gear, seine, aquaculture.
Uncontrolled increase of native competitor/predator species	Corvids, fox, rat, gull*, competition, native predators, predation. *gull omitted during literature searches for gull species.
Reduction in the quantity or quality of available food due to direct removal of food resources by anthropogenic activities	Prey availability, prey quality, prey, food availability.
Changes in suspended solids (water clarity)	Water clarity.
Water flow (tidal current) changes, including sediment transport considerations	Water flow, water current, hydrological energy.
Emergence regime changes, including tidal level change	Regime change.
Wave exposure change	Wave, roost, artificial reefs.

Pressure name	Keywords
Litter	Litter, waste, plastic, ghost, debris, microplastic, ingestion, entanglement.
Underwater noise changes	Noise, decibel.
Introduction of light	Light, boat, lighthouse.
Barrier to species movement	Barrier, windfarm, renewable, dredging, tidal energy, wave energy.
Collision ABOVE water with static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)	Windfarm, renewable, collision.
Collision BELOW water with static or moving objects not naturally found in the marine environment	Wave energy, tidal.
Above water noise	Noise, decibel, vehicles, tourism, construction.
Vibration	Vibration, drilling, trawling.
Transition elements & organo-metal (e.g. TBT) contamination	Mercury, chromium, copper, metal, transition elements, organometal.
Hydrocarbon and PAH contamination	Oil, pollution, hydrocarbon.
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	Organochlorine, pesticide, antifoulant, pharmaceutical.
Introduction of other substances (solid, liquid or gas)	Exogenous substances, inorganic.
Radionuclide contamination	Radionuclide, contamination.

Appendix 3: Additional summary tables

Table A 4: Frequency of resistance scores by species including spatiotemporal variables

Species code	Species name	Spatiotemporal variable	IE	H	M	L	N
A001_nb	Red-throated diver	Non-breeding	**12**	1	7	11	0
A002_nb	Black-throated diver	Non-breeding	6	2	**15**	8	0
A003_nb	Great northern diver	Non-breeding	9	2	**12**	8	0
A007_b	Slavonian grebe	Breeding	12	0	**14**	5	0
A007_c	Slavonian grebe	Colony	**12**	0	**12**	7	0
A007_nb	Slavonian grebe	Non-breeding	**16**	0	10	5	0
A008_b	Black-necked grebe	Breeding	**15**	1	7	8	0
A008_c	Black-necked grebe	Colony	**15**	1	7	8	0
A008_nb	Black-necked grebe	Non-breeding	**13**	2	9	7	0
A009_b	Fulmar	Breeding	**10**	8	8	5	0
A009_c	Fulmar	Colony	**10**	3	**10**	8	0
A009_nb	Fulmar	Non-breeding	**10**	8	8	5	0
A013_b	Manx shearwater	Breeding	**15**	4	9	3	0
A013_c	Manx shearwater	Colony	**16**	2	6	7	0
A013_nb	Manx shearwater	Non-breeding	**15**	5	9	2	0
A014_b	Storm petrel	Breeding	6	3	**17**	5	0
A014_c	Storm petrel	Colony	6	5	**13**	7	0
A016_b	Gannet	Breeding	**14**	1	11	5	0

Species code	Species name	Spatiotemporal variable	IE	H	M	L	N
A016_c	Gannet	Colony	**14**	2	10	5	0
A016_nb	Gannet	Non-breeding	**14**	2	11	4	0
A017_b	Cormorant	Breeding	**13**	3	7	8	0
A017_c	Cormorant	Colony	**13**	3	9	6	0
A017_nb	Cormorant	Non-breeding	**13**	3	8	7	0
A018_b	Shag	Breeding	**13**	2	11	5	0
A018_c	Shag	Colony	**13**	4	9	5	0
A018_nb	Shag	Non-breeding	**13**	3	11	4	0
A063_b	Eider	Breeding	**22**	1	5	3	0
A063_c	Eider	Colony	**18**	1	5	7	0
A063_nb	Eider	Non-breeding	**20**	2	6	3	0
A064_nb	Long-tailed duck	Non-breeding	**19**	2	8	2	0
A065_nb	Common scoter	Non-breeding	**17**	1	10	3	0
A069_b	Red-breasted merganser	Breeding	12	0	**15**	4	0
A069_c	Red-breasted merganser	Colony	**12**	4	9	6	0
A069_nb	Red-breasted merganser	Non-breeding	**12**	2	**12**	5	0
A173_b	Arctic skua	Breeding	**12**	4	11	4	0
A173_nb	Arctic skua	Non-breeding	**12**	8	7	4	0
A175_b	Great skua	Breeding	10	7	**14**	0	0

Species code	Species name	Spatiotemporal variable	IE	H	M	L	N
A175_nb	Great skua	Non-breeding	10	7	**13**	1	0
A176_b	Mediterranean gull	Breeding	**13**	4	8	6	0
A176_c	Mediterranean gull	Colony	**13**	1	9	8	0
A176_nb	Mediterranean gull	Non-breeding	**14**	8	6	3	0
A177_nb	Little gull	Non-breeding	**12**	6	9	4	0
A179_b	Black-headed gull	Breeding	**19**	2	7	3	0
A179_c	Black-headed gull	Colony	**19**	2	6	4	0
A179_nb	Black-headed gull	Non-breeding	**21**	2	6	2	0
A182_b	Common Gull	Breeding	**14**	10	5	2	0
A182_c	Common Gull	Colony	**13**	6	3	8	1
A182_nb	Common Gull	Non-breeding	**14**	10	4	3	0
A183_b	Lesser black-backed gull	Breeding	8	**9**	**9**	5	0
A183_c	Lesser black-backed gull	Colony	8	5	**13**	5	0
A183_nb	Lesser black-backed gull	Non-breeding	8	**10**	8	5	0
A184_b	Herring gull	Breeding	7	7	**15**	2	0
A184_c	Herring gull	Colony	7	4	**12**	8	0
A184_nb	Herring gull	Non-breeding	7	9	**13**	2	0
A187_b	Great black-backed gull	Breeding	9	7	**12**	3	0

Species code	Species name	Spatiotemporal variable	IE	H	M	L	N
A187_c	Great black-backed gull	Colony	9	6	**10**	6	0
A187_nb	Great black-backed gull	Non-breeding	**9**	**9**	**9**	4	0
A188_b	Kittiwake	Breeding	**9**	6	6	9	1
A188_c	Kittiwake	Colony	**10**	3	6	11	1
A188_nb	Kittiwake	Non-breeding	**10**	6	8	7	0
A191_b	Sandwich tern	Breeding	6	3	**17**	5	0
A191_c	Sandwich tern	Colony	6	2	**14**	9	0
A191_nb	Sandwich tern	Non-breeding	8	6	**14**	3	0
A192_b	Roseate tern	Breeding	10	1	**13**	7	0
A192_c	Roseate tern	Colony	10	4	2	**15**	0
A192_nb	Roseate tern	Non-breeding	**11**	7	7	6	0
A193_b	Common tern	Breeding	6	3	**12**	10	0
A193_c	Common tern	Colony	6	3	**13**	9	0
A193_nb	Common tern	Non-breeding	6	8	**11**	6	0
A194_b	Arctic tern	Breeding	12	1	**13**	5	0
A194_c	Arctic tern	Colony	**12**	1	8	10	0
A194_nb	Arctic tern	Non-breeding	**13**	4	10	4	0
A195_b	Little tern	Breeding	6	3	**16**	6	0
A195_c	Little tern	Colony	6	2	**12**	11	0

Species code	Species name	Spatiotemporal variable	IE	H	M	L	N
A195_nb	Little tern	Non-breeding	6	3	**15**	7	0
A199_b	Guillemot	Breeding	10	0	**16**	5	0
A199_c	Guillemot	Colony	9	1	**13**	8	0
A199_nb	Guillemot	Non-breeding	11	6	**12**	2	0
A200_b	Razorbill	Breeding	7	1	**12**	11	0
A200_c	Razorbill	Colony	8	2	8	**13**	0
A200_nb	Razorbill	Non-breeding	7	2	**17**	5	0
A202_b	Black guillemot	Breeding	**14**	3	10	4	0
A202_c	Black guillemot	Colony	**14**	5	6	3	3
A202_nb	Black guillemot	Non-breeding	**14**	5	8	4	0
A204_b	Puffin	Breeding	7	3	**17**	4	0
A204_c	Puffin	Colony	7	6	**14**	4	0
A204_nb	Puffin	Non-breeding	8	6	**14**	3	0
A384_nb	Balearic shearwater	Non-breeding	**10**	6	8	7	0
A604_b	Yellow-legged gull	Breeding	**12**	7	10	2	0
A604_c	Yellow-legged gull	Colony	**10**	9	8	4	0
A604_nb	Yellow-legged gull	Non-breeding	**12**	6	`	1	0

Table A 5: Frequency of resilience scores

Species code	Species name	Spatiotemporal variable	IE	H	M	L
A001_nb	Red-throated diver	Non-breeding	12	4	**15**	0
A002_nb	Black-throated diver	Non-breeding	4	11	0	**16**
A003_nb	Great northern diver	Non-breeding	9	3	**19**	0
A007_b	Slavonian grebe	Breeding	12	2	**17**	0
A007_c	Slavonian grebe	Colony	12	1	**18**	0
A007_nb	Slavonian grebe	Non-breeding	14	2	**15**	0
A008_b	Black-necked grebe	Breeding	**15**	4	12	0
A008_c	Black-necked grebe	Colony	15	0	**16**	0
A008_nb	Black-necked grebe	Non-breeding	13	7	**11**	0
A009_b	Fulmar	Breeding	10	8	0	**13**
A009_c	Fulmar	Colony	10	2	6	**13**
A009_nb	Fulmar	Non-breeding	10	8	0	**13**
A013_b	Manx shearwater	Breeding	**15**	4	2	10
A013_c	Manx shearwater	Colony	**15**	2	2	12
A013_nb	Manx shearwater	Non-breeding	**14**	7	0	10
A014_b	Storm petrel	Breeding	5	10	1	**15**
A014_c	Storm petrel	Colony	5	7	4	**15**
A016_b	Gannet	Breeding	13	4	0	**14**
A016_c	Gannet	Colony	**14**	3	1	13

Species code	Species name	Spatiotemporal variable	IE	H	M	L
A016_nb	Gannet	Non-breeding	**14**	4	0	13
A017_b	Cormorant	Breeding	7	8	0	**16**
A017_c	Cormorant	Colony	7	8	0	**16**
A017_nb	Cormorant	Non-breeding	6	8	0	**17**
A018_b	Shag	Breeding	4	10	0	**17**
A018_c	Shag	Colony	5	8	1	**17**
A018_nb	Shag	Non-breeding	5	9	0	**17**
A063_b	Eider	Breeding	3	11	**17**	0
A063_c	Eider	Colony	2	10	**17**	2
A063_nb	Eider	Non-breeding	3	11	**17**	0
A064_nb	Long-tailed duck	Non-breeding	**19**	4	8	0
A065_nb	Common scoter	Non-breeding	13	4	**14**	0
A069_b	Red-breasted merganser	Breeding	10	6	**15**	0
A069_c	Red-breasted merganser	Colony	9	5	**17**	0
A069_nb	Red-breasted merganser	Non-breeding	10	6	**15**	0
A173_b	Arctic skua	Breeding	1	13	0	**17**
A173_nb	Arctic skua	Non-breeding	1	13	0	**17**
A175_b	Great skua	Breeding	10	6	2	**13**
A175_nb	Great skua	Non-breeding	10	7	1	**13**

Species code	Species name	Spatiotemporal variable	IE	H	M	L
A176_b	Mediterranean gull	Breeding	**13**	7	0	11
A176_c	Mediterranean gull	Colony	**13**	6	0	12
A176_nb	Mediterranean gull	Non-breeding	**13**	7	0	11
A177_nb	Little gull	Non-breeding	**12**	4	4	11
A179_b	Black-headed gull	Breeding	11	3	0	**17**
A179_c	Black-headed gull	Colony	9	4	0	**18**
A179_nb	Black-headed gull	Non-breeding	10	4	0	**17**
A182_b	Common Gull	Breeding	4	9	1	**17**
A182_c	Common Gull	Colony	4	8	2	**17**
A182_nb	Common Gull	Non-breeding	4	7	3	**17**
A183_b	Lesser black-backed gull	Breeding	6	10	0	**15**
A183_c	Lesser black-backed gull	Colony	6	8	2	**15**
A183_nb	Lesser black-backed gull	Non-breeding	6	10	0	**15**
A184_b	Herring gull	Breeding	7	5	5	**14**
A184_c	Herring gull	Colony	7	4	6	**14**
A184_nb	Herring gull	Non-breeding	7	9	1	**14**
A187_b	Great black-backed gull	Breeding	9	8	0	**14**
A187_c	Great black-backed gull	Colony	7	9	0	**15**

Species code	Species name	Spatiotemporal variable	IE	H	M	L
A187_nb	Great black-backed gull	Non-breeding	8	9	0	**14**
A188_b	Kittiwake	Breeding	5	6	4	**16**
A188_c	Kittiwake	Colony	7	4	5	**15**
A188_nb	Kittiwake	Non-breeding	5	5	4	**17**
A191_b	Sandwich tern	Breeding	6	2	8	**15**
A191_c	Sandwich tern	Colony	6	1	8	**16**
A191_nb	Sandwich tern	Non-breeding	8	2	7	**14**
A192_b	Roseate tern	Breeding	10	7	1	**13**
A192_c	Roseate tern	Colony	10	4	2	**15**
A192_nb	Roseate tern	Non-breeding	11	8	0	**12**
A193_b	Common tern	Breeding	5	4	5	**17**
A193_c	Common tern	Colony	5	4	4	**18**
A193_nb	Common tern	Non-breeding	5	7	3	**16**
A194_b	Arctic tern	Breeding	11	5	2	**13**
A194_c	Arctic tern	Colony	11	1	5	**14**
A194_nb	Arctic tern	Non-breeding	11	6	2	**12**
A195_b	Little tern	Breeding	6	6	4	**15**
A195_c	Little tern	Colony	5	5	3	**18**
A195_nb	Little tern	Non-breeding	6	7	3	**15**

Species code	Species name	Spatiotemporal variable	IE	H	M	L
A199_b	Guillemot	Breeding	7	7	2	**15**
A199_c	Guillemot	Colony	5	7	2	**17**
A199_nb	Guillemot	Non-breeding	6	8	1	**16**
A200_b	Razorbill	Breeding	7	9	1	**14**
A200_c	Razorbill	Colony	8	4	4	**15**
A200_nb	Razorbill	Non-breeding	7	10	0	**14**
A202_b	Black guillemot	Breeding	7	5	3	**16**
A202_c	Black guillemot	Colony	3	7	5	**16**
A202_nb	Black guillemot	Non-breeding	5	8	2	**16**
A204_b	Puffin	Breeding	7	6	3	**15**
A204_c	Puffin	Colony	7	7	2	**15**
A204_nb	Puffin	Non-breeding	8	7	1	**15**
A384_nb	Balearic shearwater	Non-breeding	10	8	0	**13**
A604_b	Yellow-legged gull	Breeding	4	9	1	**17**
A604_c	Yellow-legged gull	Colony	4	6	4	**17**
A604_nb	Yellow-legged gull	Non-breeding	4	10	0	**17**

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