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Smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands

D 5.6 – Desk-based scoping study of the potential impacts associated with the Renewable Energy Systems within ROBINSON

Lead partner: Environmental Research Institute (ERI)

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Executive summary

I. The Horizon 2020 project ROBINSON aims to drive forward the decarbonisation of industrialised islands by reducing fossil fuel consumption by developing, installing and integrating a number of new renewable energy devices. As a consequence of these new pieces of infrastructure, there is the potential for ecological impacts that may be both positive and negative.

II. To investigate the likely types of impact, their scale and the affected organisms, we used a combination of flexible, transferable methods so that they are applicable to multiple locations. We conducted a desk-based scoping study comprising a Driver-Pressure-State-Impact-Response (DPSIR) framework to identify the potential impact chains, followed by a Weight of Evidence (WoE) analysis to ascertain the likely cause-and-effect relationships, and finally created a Receptor Sensitivity Index (RSI) to identify the most vulnerable or responsive species on Eigerøy.

III. The DPSIR refined many potential linkages down to three primary impact chains, which we then investigated using the WoE analysis. The WoE showed support, consistency and relevance for all three impact chains, concerning the potential ecological effects of the proposed wind turbine, AD-BES unit, and elevated noise levels as the result of additional infrastructure. The RSI highlighted species with declining populations nationally, regionally and globally, as well as stable species which have a large percentage of their population resident in Norway.

IV. Locally, a lack of consistent, standardised data on species presence, movements and behaviour mean that the scale and strength of their responses are uncertain. The WoE analysis highlights the importance of habitat requirements of species in dictating such responses to novel infrastructure, which means it is important to collect and map species data on Eigerøy.

V. We recommend standardised data collection, focusing on those taxa thought to be most vulnerable, such as seaducks, and migrating birds and bats. Obtaining comprehensive baseline ecological data is vital, and a combination of methods that can achieve this for multiple taxa should be used, particularly to direct more targeted single genus/species study further down the line.

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List of abbreviations

BACI	Before-After-Control-Impact
BARI	Before-After-Reference-Impact
DPSIR	Driver-Pressure-State-Impact-Response
IWF	Inside wind farm
LNG	Liquified Natural Gas
MBACI	Multiple Before-After-Control-Impact locations (can include multiple impact, or multiple control locations and replication through time)
OWF	Outside wind farm
RED	Renewable Energy Device
RSI	Receptor Sensitivity Index
SAV	Submerged aquatic vegetation
SWT	Small Wind Turbine
WoE	Weight of Evidence
WWTP	Wastewater Treatment Plant

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Introduction

The H2020 project '*smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands'* (ROBINSON) aims to decarbonise industrialised islands through the integration of multiple differing renewable energy devices (REDs), tied together by a smart management system.

Objective 6 of ROBINSON aims to 'demonstrate a significant positive impact on human health and the environment'. Work Package 5 supports this objective through life cycle analyses (LCA – T5.1) and ecological impact analysis (T5.4, which includes this deliverable). The ROBINSON project will reduce island reliance on fossil fuel consumption and therefore should reduce harmful greenhouse gas emissions, aiming to reduce CO_2 emissions by 20% at the end of the project in 2024. Other positive environmental impacts include the conversion of wastewater, specifically from Prima Protein, the island's largest energy consumer, to biogas and digestate through an anaerobic digestion system, which diverts organic waste from being discharged into Egersund harbour. Prima Protein, a large producer of fishmeal and oil, was constructed in 2019 and since then has used LNG to power the majority of its operations.

T5.4 focuses on identifying and quantifying potential impacts of the ROBINSON system. Whilst the positive impact of the reduction of fossil fuel emissions is clear, the construction of new infrastructure means that there is the potential for negative environmental impact, which will vary according to the specific location and type of equipment being installed. The demonstration island of Eigerøy (Norway), as well as the two 'follower' islands of Crete (Greece) and the Western Isles (Scotland), vary in their energy needs, their geographical locations and their dominant industries meaning that the REDs employed will differ in each case.

This deliverable takes the form of a desk-based ecological impact study, firstly assessing what potential impact chains exist through a Driver-Pressure-State-Impact-Response (DPSIR) framework (Section 1), uses a Weight of Evidence (WoE) framework (Section 2) to estimate the likely impact of these chains, and finally undertakes a Receptor Sensitivity Index (RSI; Section 3) to identify the taxa most at risk or most likely to experience positive change. The scope of this deliverable does not allow us to investigate all possible effects of all possible combinations of components; therefore, only three key impact chains will be discussed, and their potential impact estimated. The methods used herein have been chosen for their ability to be applied to multiple different scenarios i.e., the islands within ROBINSON, and their ability to work with limited data, as in many cases remote, less-

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populated islands do not have detailed data collected over the long term on species presence, abundance nor density that may help to predict ecological impacts.

Section 1

1.1 Driver-Pressure-State-Impact-Response framework

Considering a multi-stressor system such as the ROBINSON project, means that there are myriad linkages, or pathways, between the stressor and the receptor, complicating an assessment of ecological impacts. Such a system necessitates a method that can reduce the number of linkages investigated, by prioritizing those stressor-receptor relationships identified to be the most likely, the most serious, or the most widespread, for example (Judd, Backhaus and Goodsir, 2015; Brignon *et al.*, 2022). A DPSIR framework is flexible, transferrable to any ecosystem or situation and used widely for on- and off-shore REDs, as well as other socio-ecological scenarios (Lewison *et al.*, 2016; Monk *et al.*, 2019). Following this framework allows the researcher to move sequentially through the pathways, beginning with the potential stressors (the causal factors; here, for ROBINSON, these are the components of the integrated system), their associated pressures (any event or "agent" produced by the source - Judd, Backhaus and Goodsir, 2015; including chemical, physical or biological changes - Perujo *et al.*, 2021), and associated receptors (taxa and/or habitats present in the area); then moving on to how they might be impacted (both positively and negatively), and finally, what the outcomes might be.

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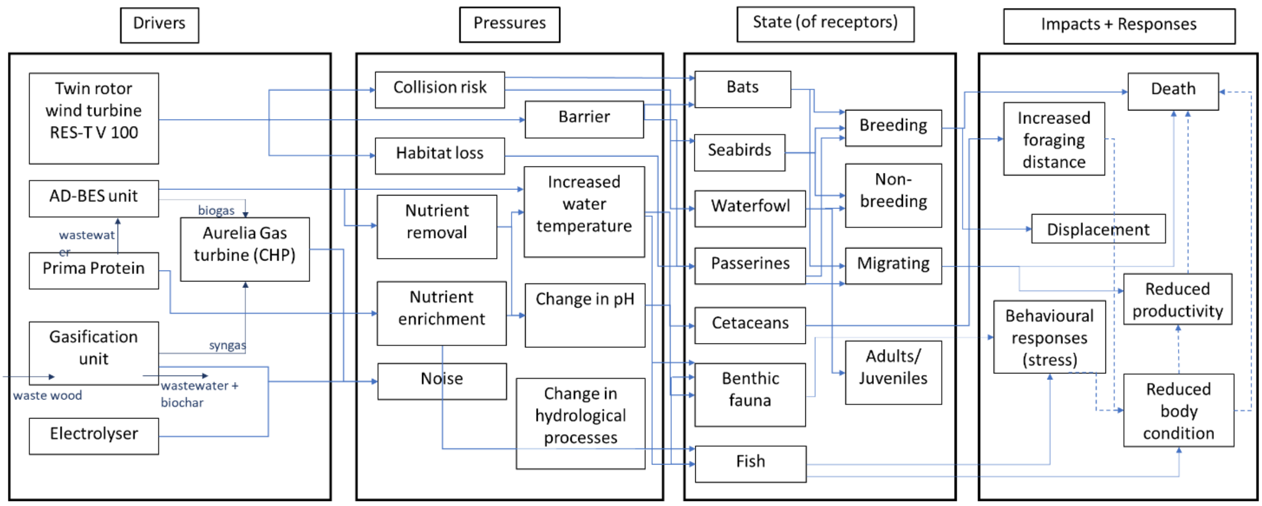

Figure 1: Conceptual DPSIR framework presenting the potential ecological impacts of the ROBINSON project.

We produced a conceptual framework for the ROBINSON system (Figure 1), containing all identified linkages and pathways. Limited capacity and information availability, as well as recognition that as the ROBINSON project targets industrialised islands rather than pristine wilderness, meant we prioritised three main pathways (Figure 2).

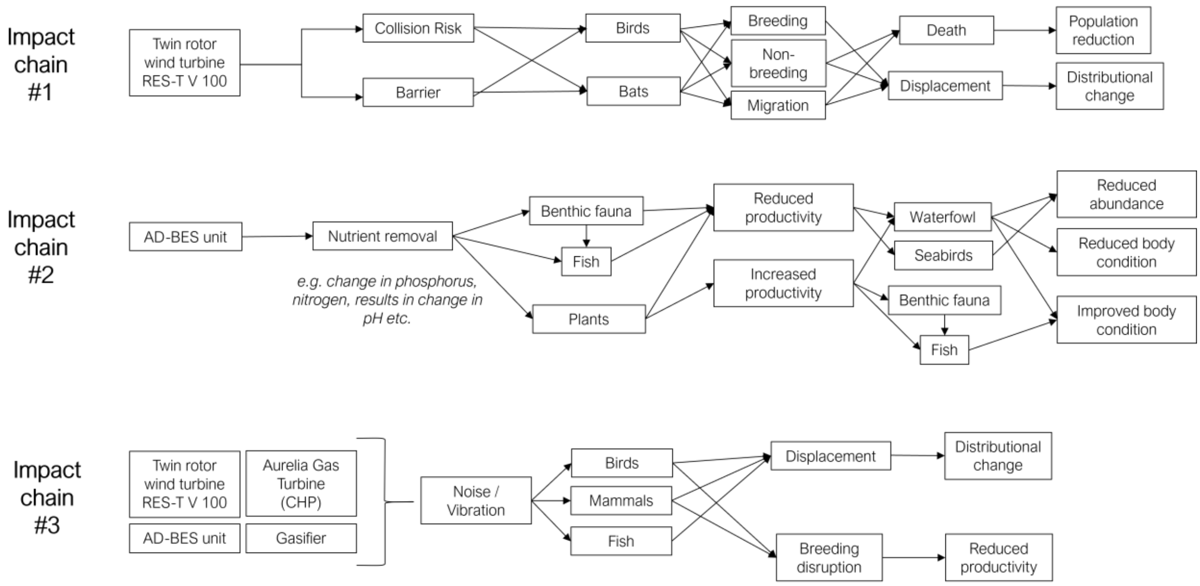

Figure 2: Selected impact chains for further investigation using the Weight-of-Evidence approach.

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1.2 Selected Impact chains

Our highlighted impact chains were chosen through literature review and discussion, and represent the relationships most likely to occur, given either the sensitivity of the taxa involved, or the nature of the component being installed as part of the project.

Impact chain 1: The first pathway considered relates to the consequences of installation of a small horizontal-axis wind turbine (SWT; planned hub height 22.6m, total height 29.2m), which was planned for the western side of the Egersund harbour area, on an elevated section of land. Although it is uncertain as to whether the turbine will now be installed, we considered it worthy of assessment given the likelihood of a SWT being installed elsewhere and to ensure that evidence is available if the decision is taken to go ahead. There is a substantial amount of research into the effects of wind turbines on wildlife, particularly birds and bats (Kunz *et al.*, 2007; Marques *et al.*, 2014), which are at risk from collision risk with either the rotor blades or the tower, displacement as a result of habitat loss, through noise disturbance or when the wind turbine(s) acts as a barrier (Dai *et al.*, 2015). Although understanding of the potential impacts exists, studies often relate to large / full size wind turbines, where tower heights are often more than double the height of the proposed turbine on Eigerøy; fewer studies exist on SWTs, even though in 2014 there were 900,000 SWTs installed worldwide (Minderman *et al.*, 2012, 2017). Collision still exists as a risk for SWTs, often because they are constructed close to buildings or natural features such as woodlands or hedgerows (Minderman *et al.*, 2012), although data collected by Minderman et al., (2015) suggests that mortality rate is very low, and that habitat variables are unlikely to significantly influence the probability of birds and bats colliding.

Preliminary information available on the wind turbine specifications suggests that the tower would be a lattice-type structure, rather than the more common monopole. Lattice towers are suggested to be more lethal to birds, particularly birds of prey as they use the lattice structure as a perch (Orloff and Flannery, 1992; Hunt and Watson, 2016; although see Dürr and Rasran, 2017, who found no additional risk of lattice towers to birds). On Eigerøy, the wind turbine was to be placed in an elevated position, close to distinctive coastal features including the strait between the island and the mainland. Of particular interest is how birds and bats move in this location, as it is known that species of both taxa use coastlines to navigate whilst on migration (Alerstam and Pettersson, 1977; Gorman *et al.*, 2021). Although migration is likely to be the time of greatest concentration of bats and birds passing through Eigerøy, breeding and wintering birds and bats are also potentially at risk not only from direct collision, but also from disturbance and/or displacement due to the

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presence of the turbine close to desired foraging or nesting areas (Tanskanen, 2012; Reusch *et al.*, 2022).

Impact chain 2: Pathway 2 concerns the impacts of the anaerobic digestion unit, which aims to remove a proportion of the wastewater emitted by Prima Protein. The waste already undergoes a primary treatment before entering the harbour, which does reduce the high nitrogen, phosphorus and suspended solids content but the wastewater would benefit from an additional step – i.e., anaerobic digestion – in order to further reduce harmful contents. The water in the wider Dalane area, which includes Egersund harbour has been tested in several different locations (Naess, Trannum and Borgersen, 2021); overall, the harbour was found to be in poor condition, with high levels of metal and organic compounds, and high numbers pollution-tolerant species including mussels *Kurtiella bidentata* and polychaete worms *Capitella capitata*.

Anaerobic digestion promotes the degradation of organic waste materials into biogas, which can then be used to generate electricity and/or heat (Lusk *et al.*, 1996). It is used on a wide range of organic and industrial waste products, including agricultural sludge and, as with the ROBINSON project, fish processing waste (Angelidaki, Ellegaard and Ahring, 2003), whose high lipid content presents it an ideal candidate for production of energy from waste (Eiroa *et al.*, 2012). It is reported that anaerobic digestion can remove 80-90% of the organic matter from fish processing wastewater, which would undoubtedly improve local water quality (Chowdhury, Viraraghavan and Srinivasan, 2010). In contrast, the high nitrogen and phosphorus content of the wastewater can drive growth and productivity of vegetation and benthic fauna locally, therefore, the removal of the high organic loading could in fact reduce marine primary productivity and thus the local biodiversity (Laursen and Møller, 2014; Morelli *et al.*, 2021). We caution that this impact chain is likely to be complex and potentially non-linear, owing to many indirect as well as direct effects.

Impact chain 3: The final highlighted pathway concerns noise emissions from the newly installed equipment. It is likely that several new mechanical elements will join already present industry, and whilst the additional noise emissions may not be as high as the industry currently at Egersund harbour (e.g., Prima Protein itself), it is possible that the additional elements will act cumulatively (Pine, Jeffs and Radford, 2014), and impact on both birds and mammals in the locale. Development of some of the REDs is still taking place, which means there is little information available at this stage on the amplitude of the noise (and/or vibrations) from these installations.

Noise emissions can influence the distribution and abundance, as well as the productivity and survival of a number of species, both terrestrial and marine (Pine, Radford

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and Jeffs, 2015), yet a lack of data on background/ ambient noise and the relative change in this with construction and operation of machinery prohibits extensive analysis (Hawkins, Pembroke and Popper, 2015). Variation due to sound source, species involved and environment (shallow, coastal waters versus deep ocean for example) all influence behavioural and physiological responses (Cox *et al.*, 2018). Responses to an increase in noise can occur at a number of frequencies, and at low amplitude, with studies reporting altered behaviour and stress levels at amplitudes as low as 35dBA (Bunkley and Barber, 2015).

1.3 Weight of Evidence analysis

Following the identification of what we considered to be the most likely impact chains, we began a Weight of Evidence (WoE) analysis (Nichols *et al.*, 2011; Norris *et al.*, 2012; Monk *et al.*, 2019). The WoE process uses a systematic literature review, data extraction and subsequently a weighting of these data (by result and study quality), in order to then assess how likely the hypothesised chains are to materialise given the location and taxa, and what the magnitude of the effects might be. The WoE recognises that ecosystems are complex and that there might be more than one outcome from a set of circumstances dependent on the taxa involved or the location, such that individual studies cannot infer cause and effect, requiring pooling of all available data (Nichols *et al.*, 2011). This analysis method is very relevant to the ROBINSON project; due to the novelty of the different system components and the lack of ecological data collected in the area, we need to draw experience from elsewhere and attempt to quantify uncertainty within and amongst the different impact chains.

The WoE process presents a clear, logical workflow, in order to gather data in a standardised manner (Figure 3). This makes it applicable to any number of stressors, pressures and receptors, making it a very flexible and broad assessment tool. WoE has been used to explore the impact of a particular process on a specific taxon (Greet, Angus Webb and Cousens, 2011), a single species retrospectively to identify causes of decline (Burkhardt-Holm and Scheurer, 2007) and the integration of multiple stressors to an ecosystem (Lowell, Culp and Dubé, 2000; Monk *et al.*, 2019).

WoE also encourages specificity, by refining the questions and hypotheses to produce relevant cause and effect relationships that can then be searched for (see Figure 3; step 4). Once the hypotheses and questions to explore have been identified, a thorough literature search should be conducted, with all search terms documented, the number of studies which are found using these terms, the number that are subsequently identified as

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relevant (using title, abstract, keywords; Norris *et al.*, 2012) and from which data are extracted.

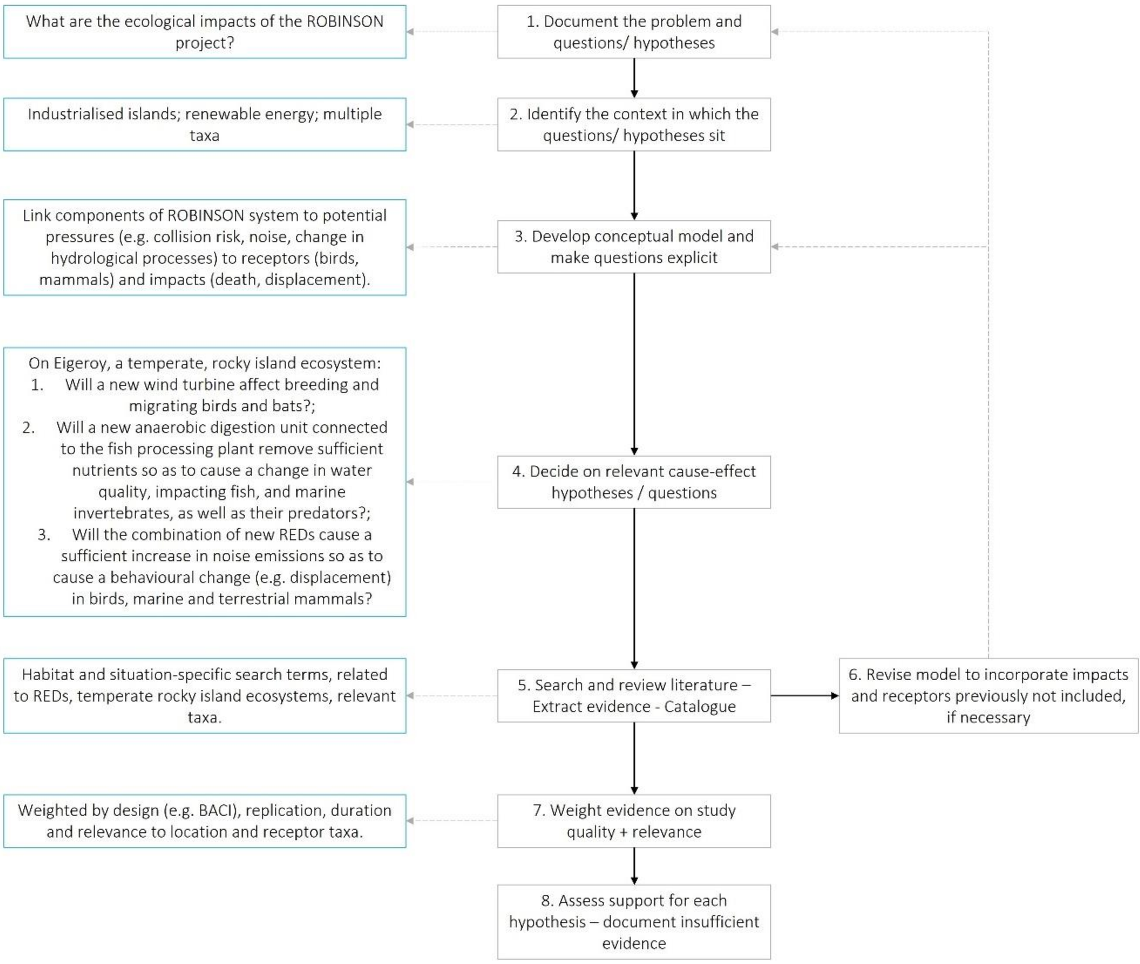

Figure 3: Weight of Evidence workflow including study-specific examples (blue boxes).

Search criteria have been documented (Table 1) to allow for replicability across follower islands. Criteria should be specific to the stressor, location and receptor taxa, but in the event that very few studies are returned from such a restricted set of keywords, the search criteria can be broadened; for example, when implementing the search for evidence on impact chain 1 (see Figure 2), we searched for papers on birds and bats separately for clarity, yet initial search criteria returned only 6 papers, none of which were actually relevant. We removed specificity in the location (i.e., the ‘coast* OR island’ term), which led to the return of 134 papers, yet still only 6 were relevant.

Relevant studies are then weighted according to their study design in two categories; *type*: for example, is it a comparison of before and after a change, a comparison of control vs impact, or a full Before-After-Control-Impact (BACI) study; and *replication*: namely, how

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many impact units are involved, and how many control units? More of both types of units give the study more power and inference (Nichols *et al.*, 2011). Whilst Norris *et al.* (2012), and Nichols *et al.* (2011) do not formally weight study relevance (e.g., geographical location, taxa, habitat), we have chosen to in this project, because ecological responses among taxa – even among genera and species – can vary widely (Monk *et al.*, 2019). The weights given to each of the categories are specified in Table 2.

Table 1: Search criteria for each of the 3 main impact chains and two associated subdivisions.

Impact chain	Criteria	Number of papers sourced	Number used for WoE
1a	(**Topic**) wind turbine *OR* wind energy *AND* (**Topic**) collision *OR* barrier *OR* displacement *OR* disturbance *AND* (**Topic**) coast* *OR* island *AND* (**Topic**) impact* *OR* behaviour* *OR* response* *OR* change* *AND* (**Topic**) bird* *OR* avian*	N = 58	12
1b	As above but substitute (**Topic**) bird* *OR* avian* for (**Topic**) bat* *OR* Chiroptera*	N = 40 Remove^ (**Topic**) coast* *OR* island; N = 134	6
2a	(**Topic**) wastewater *OR* waste* *OR* nutrient* *AND* (**Topic**) reduction *OR* removal *AND* (**Topic**) AD *OR* AD-BES *OR* BES *OR* anaerobic *OR* bio-electrochemical *OR* bioelectrochemical *OR* digest* *AND* (**Topic**) coast* *OR* island* *OR* headland *AND* (**Topic**) invertebrate* *OR* fish* *OR* mollusc* *OR* bird* *OR* avian *OR* mammal* *OR* communit* *OR* assemblage *AND* (**Topic**) impact* *OR* behaviour *OR* response *OR* change	N = 109	15
2b	(**Topic**) heat* *OR* hot water *OR* therm* *AND* (**Topic**) bird* *OR* avian* *OR* mammal* *OR* benthic *OR* fish* *OR* communit* OR assemblage AND (**Topic**) pH *OR* temperature *AND* (**Topic**) coast* *OR* island* *OR* headland *OR* harbour *AND* (**Topic**) impact* *OR* behaviour *OR* response *OR* change *OR* effect AND (**Topic**) temperate OR baltic	N = 245	8
3	(**Topic**) noise* *OR* sound *OR* *acoustic *AND* (**Topic**) renewable* *OR* energy* *OR* machinery *OR* equipment *AND* (**Topic**) coast* *OR* island *OR* harbour *AND* (**Topic**) bird* *OR* avian* *OR* mammal* *OR* vert* *OR* cetac* *OR* fish *AND* (**Topic**) impact *OR* behaviour *OR* response *OR* change	N = 76 Remove^ (**Topic**) coast* *OR* island *OR* harbour; N = 3523	20

^ Terms removed from search criteria - not from selection criteria

New lines of evidence may appear during the systematic review, for example groups of species not previous considered or a less well-known effect, and these can be incorporated into the conceptual model (see Figure 3, step 6). For example, during the month 18 meeting with the ROBINSON partners, the issue of not only nutrient removal (Impact chain #2 – see Figure 2), but also an increase in temperature was raised. This was subsequently incorporated into our search criteria (Table 1, section 2b).

Once the evidence has been recorded and weighted, an overall conclusion should be drawn for each cause-and-effect (here meaning pressure-impact) question, according to the weighting. Norris *et al*. 2012 applied a 20-point threshold to each of three criteria: Evidence

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of response, Evidence of dose-response and Consistency of association; when measured against these criteria, hypotheses and impact chains can be described as well-supported, inconsistent (studies show evidence both *for* and *against* the hypothesis), or insufficient (no evidence at all; Nichols *et al*. 2011). For better applicability to ROBINSON, because of the addition of two extra rating columns in stage 1 (Table 2(a)) we have changed the threshold to 30 points, to reflect the additional points that could be gained. In stage 2, we have also included an additional 'Relevance to current scenario' category. Here we felt that we needed to incorporate a specific criterion relating to relevance because of the breadth of studies produced on certain topics.

The Weight of Evidence catalogue including calculations is included in Appendix I.

Table 2: Study weighting criteria and combination strategy to identify support for hypotheses.

(a) Stage 1: Weight each study according to 6 criteria

(1) Study design	Weight	**(2) N. impact locations**	Weight	**(3) N. control locations**	Weight	**(4) N. *gradient* impact locations**	Weight	**(5) Relevance of taxa**	Weight	**(6) Relevance of location**	Weight
After impact only	1	1	0	0	0	3	0	Familial	1	Different habitat, different continent	0
Control *v* impact (no before) OR Before *v* after (no control)	2	2	2	1	2	4	2	Congeneric	2	Similar habitat, different continent/ Different habitat, same continent	1
Gradient response model	3	3+	3	2+	3	5	3	Conspecific	3	Similar habitat type, same continent	2
BACI/BARI/MBACI	4					6+	4			Similar habitat type, same country	3

(b) Stage 2: Sum study weights - address following critera to assess support for hypotheses

Criteria	**Calculation:**	**Threshold**
(1) Evidence of **response**	Number of low quality studies* showing response **+** Number of high quality studies* showing response	30
(2) **Consistency** of association	N. low quality studies NOT supporting hypothesis N. high quality studies NOT supporting hypothesis	30
(3) **Relevance** to current scenario	N. low quality studies with relevance >2 N. high quality studies with relevance >2	30

* *low quality studies = <7; high quality studies = ≥7*

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1.4 Receptor Sensitivity Index

Having identified potential groups of receptors in subsections 1.1 & 1.2, we sought to compile information on which species are present in the area surrounding Egersund harbour, throughout the year, in order to further explore the likelihood of species being impacted by ROBINSON. It is important to not just consider breeding species, but also those species which may move through during the autumn migratory period. Not all species will be impacted equally due to varying behaviour and habitat preferences, as well as current conservation status (Garthe and Hüppop, 2004; Benjamins, Masden and Collu, 2020), and it is important to account for this variation in vulnerability (Reece and Noss, 2014).

To identify which species are recorded as being present in the region, which indicates which receptors are realistically likely to be affected by the ROBINSON system, we began by sourcing data from the Global Biodiversity Information Facility (GBIF), which collates a number of different national datasets. However, data on all taxa in this geographic area were sporadic and did not provide more than an indication of occurrence (i.e., presence only data). No standardised breeding bird survey takes place locally, although in the wider Rogaland region there are breeding bird data for 2020/2021, which we have used to supplement the sporadic GBIF data where possible. A previous environmental survey (Norconsult, 2014) highlights several bird species as being of management interest in the area, which supported some of the opportunistic data we located. These were Peregrine falcon (*Falco peregrinus*), Great black-backed gull (*Larus marinus*), Common gull (*Larus canus*), Common scoter (*Melanitta nigra*), Velvet scoter (*Melanitta fusca*) and Common guillemot (*Uria aalge*), however the report gives no indication of whether these are breeding species or otherwise. There are also no other data apart from on GBIF available on mammal distribution in the area.

Because of the lack of comprehensive information on the status of different species in the Eigerøy area we decided to build a sensitivity index for the different taxa in the region, guided by the methods of Bradbury *et al.*, (2014) and Benjamins, Masden and Collu (2020), which both advocate using grey literature and species assessments to build an understanding of how likely species are to be impacted. We started with the data gathered from GBIF, using the last 12 years of records (from 2010 onwards as records are more numerous and regularly recorded). We then scored species according to the following criteria:

a. Number of years recorded as present in area [/12; 1-3 years = 1 point, 4-8 years = 2 points, 9-13 years = 3points]

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b. Recorded as present in the county (Rogaland) [Yes = 2, No evidence (NE) = 1, No = 0)

c. Norwegian Red List status [LC = 1, NT = 2, EN = 3, VU = 4, CR = 5]

d. European Red List status [LC = 1, NT = 2, EN = 3, VU = 4, CR = 5]

e. Global Red List status [LC = 1, NT = 2, EN = 3, VU = 4, CR = 5]

f. % of European population present in Norway [<1% = 1, 1-5% = 2, 5-25% = 3, 25-50% = 4, >50% = 5]

g. % of global population present in Norway [<1% = 1, 1-5% = 2, 5-25% = 3, 25-50% = 4, >50% = 5]

h. Adult survival rate [≤60% = 1; 61-70% = 2; 71-80% = 3; 81-90% = 4; >90% = 5]

i. Habitat preference [from 1= very flexible, including urban areas, to 5 = specialist, restricted to one or two habitat types].

We restricted the species scored initially to those both recorded on Eigerøy (more points allocated to species recorded regularly as well as those with evidence of breeding, which are therefore more likely to be affected), and those present on the Norwegian Red List (**c**) as either Near threatened, Vulnerable, Endangered or Critical; *OR* as Least Concern, but with >5% of the European population present in Norway (**f**). Information on the percentages of populations present in Norway was taken from the Norwegian Red List dataset. Species in these categories were then scored further on their vulnerability at a global level (**g**), as well as demographic characteristics (**h.** adult survival) and on habitat preferences (**i**). This was to identify those species both vulnerable to impacts such as collision and displacement which can lead to reduced adult survival, and those species which might be particularly reliant on the rocky coastal habitats present on Eigerøy. Data on evidence of breeding were acquired using the Norwegian Breeding Bird Atlas and the Atlas of European Mammals. Adult survival rate data were taken from Garthe & Huppop (2004; seabirds only), from the British Trust for Ornithology's Birdfacts database (these data are sourced from individual studies undertaken around the globe), from individual studies sourced online, or - where a species-specific survival rate has not been calculated - from congeneric species. Additional habitat information for marine mammals was taken from the North Atlantic Marine Mammal Commission (NAMMCO). The source of the data is noted in the full sensitivity index table (Appendix II).

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Our approach takes into consideration the fact that these records are opportunistic, and therefore does not allocate weight alone to numbers recorded and the duration over which they have been logged. We have also incorporated national and international threat-levels, as well as the amount of the European and global populations present in Norway, along with demographic information, which provides a more realistic assessment of species that are more likely to be affected either positively or negatively. It also highlights which species or groups of species should be surveyed before and after the installation of the selected REDs. Scores from each of the categories were then summed to produce an overall sensitivity score (a summary of the most common and highest scoring species and their scores found in Section 2, Table 4).

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Section 2

2.1 Results from the Weight of Evidence analysis

Using the different sets of search criteria, we identified 61 papers that were relevant (Table 1) and subsequently used 58 of these in the WoE analysis (Table 3). Support was found for a response when assessing all impact chains, as all scores are >30. However, for each impact chain there was some level of inconsistency, primarily inconclusive evidence (i.e., both a response and no response perhaps from different species or in different seasons), although it was only for impact chain 1(a) that the level of inconsistency met the threshold of 30 and was thus deemed to be overall inconclusive.

All impact chains scored highly on relevance, owing partly to our suitable initial search criteria and to a number of studies collecting data on species with a wide European, or even global, distribution. Each impact chain will be discussed individually, with the main conclusions, strengths and weaknesses.

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Table 3: Summary of weight of evidence analysis assessment. Scores of low (<7 points) and high (>7 points) quality studies are summed and assessed against a threshold of 30 points to judge whether there is support for a response, evidence of consistency and evidence of relevance.

Assessment category	Impact chain	Study Quality Num. Low	Num. High	Sum
Evidence of Response	1a	5	5	70
	1b	1	3	30
	2a	5	9	116
	2b	1	5	43
	3	9	10	143
Evidence of Consistency	1a	3	4	45
	1b	0	2	13
	2a	0	2	22
	2b	1	0	6
	3	1	1	15
Evidence of Relevance	1a	3	7	94
	1b	1	1	43
	2a	0	3	128
	2b	0	4	30
	3	5	6	97
Conclusion		**Response**	**Consistency**	**Relevance**
Inconsistent support	1a	H	L	H
Consistent support	1b	H	H	H
Consistent support	2a	H	H	H
Consistent support	2b	H	H	H
Consistent support	3	H	H	H

2.1.1 Impact chain 1

More studies than not within our WoE analysis supported an impact of wind turbines on behaviour including collision risk, although it was heavily dependent on the species investigated as well as location and type of turbine. For example, White-tailed eagles (*Haliaeetus albicilla*) in rocky coastal areas of Norway do not seem to modify their behaviour around wind turbines, particularly where the habitat is suitable for them, which leads to an increased risk of collision and thus mortality (Dahl *et al.*, 2012, 2013). This concurs with a study in northern Japan whereby raptors interacting with turbines placed on coastal cliffs accounted for a significant number of fatalities (Kitano and Shiraki, 2013). However, studies based in coastal wetland areas in China report that waterfowl and some terns and gull species do modify their flight height, therefore reducing collision (Zhao *et al.*, 2020).

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Although these studies are primarily concerned with large turbines (>50 metres in height), which contrasts the SWT suggested for Eigerøy, the habitat type surrounding the turbines clearly has an influence on the likelihood of species using the area around turbines, and thus potentially on collision risk.

Only one study specifically looks at the interactions of birds with an SWT (Morris and Stumpe, 2015), which was installed in the centre of a small island off the coast of the USA. The authors suggest that most species avoided the rotor blades although were aware of some anecdotal collisions. More studies looked at SWTs in relation to bat collisions than for birds; Minderman *et al.*, (2012, 2015) found that selective avoidance of SWTs occurred when running at high wind speeds, and lower activity of a few bat species within a wide area (to 100m) surrounding the turbine. As with birds, there was a strong influence of habitat, and siting the turbine close to a waterbody or known roost increased the number of bat passes near to the turbines, suggesting pre-installation surveys are necessary. This may particularly be the case for coastal areas, along which species are known to migrate and could mean that much higher numbers of birds and bats interact with the wind turbine in quite a short period of time.

Overall, there is a great deal of uncertainty, owing to the paucity of studies looking at SWTs, birds and bats, and it is likely that the specific location for installation will influence interactions.

2.1.2 Impact chain 2

For the anaerobic digestor-related impact chain, initial search terms used in the WoE analysis were too restrictive, meaning that very few results were retrieved from the literature. After adjusting the terms in order to provide sufficient specificity without being too prescriptive, we retrieved 109 papers, 15 of which were suitable for assessing the impacts of anaerobic digestion on fish processing wastewater (Figure 3). Although the studies were not all necessarily fish processing plant specific, the studies all concentrated on reduction of wastewater emissions, and, crucially, on a reduction in nutrients and contaminants e.g., nitrogen, phosphorus and copper.

Overwhelmingly, the WoE analysis showed that reductions of nutrients through wastewater removal caused changes in species richness, abundance and trophic structure of benthic fauna, particularly macroinvertebrates and fish, as well as the extent and quality of submerged aquatic vegetation (SAV). Reduction in total nitrogen, phosphorus and suspended solids, which was documented in multiple studies, was significantly linked to a

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reduction in primary production within the coastal and estuarine environments studied (Philippart *et al.*, 2007; Ruhl and Rybicki, 2010; Taylor *et al.*, 2020). This change in primary production then influenced the whole trophic structure; a reduction in macroalgae and phytoplankton led to declines in filter feeding invertebrates such as mussels (*Mytilus* sp.) and clams (*Nucula annulata*), causing an overall decline in underwater biomass (Craig, 1994; Riemann *et al.*, 2016; Taylor *et al.*, 2020). Moving to the top of the food chain, the decline in these invertebrates, particularly mussels, has been linked to a decline in breeding eider (*Somateria mollissima*; Laursen and Møller, 2014; Morelli *et al.*, 2021).

However, the reduction in biomass in certain filter feeding invertebrates is mirrored by a concurrent increase in overall biodiversity and a shift towards less pollution tolerant, sentinel species of both SAV and benthic invertebrates, reflecting a recovery in the ecosystem (Bellan *et al.*, 1999; Rybicki and Landwehr, 2007). Two studies linked an increase in SAV abundance to an increase in waterfowl abundance and a change in the composition of this upper trophic level (Philippart *et al.*, 2007; Rybicki and Landwehr, 2007), indicating a healthier environment. Therefore, although a decrease of overall bird numbers might occur initially, the resultant community shift and diversification that cleaner waters and vegetation regrowth would encourage, signifies a positive change.

The second part of impact chain 2 (2b – Figure 3) related to a potential impact of temperature, given that the water will be warmed having been through the AD-BES. The impacts of increased water temperature vary significantly with taxa and temperature, causing shifts in phytoplankton and benthic macroinvertebrate community structure (Lin, Zou and Huang, 2018). It might be expected on a large scale for there to be knock-on effects on fish community structure, recruitment and species composition (Sandström, Neuman and Thoresson, 1995), yet the WoE analysis shows low support for any one set of outcomes because of the variation amongst location and species.

2.1.3 Impact chain 3

The final impact chain concerned the effect of additional noise in the area local to the Prima Protein fish processing plant. Although the area is already industrialised with a number of warehouses and associated noise, the cumulative effects of any additional noise are uncertain, particularly because the amount of noise produced by each additional component is, in most cases, unquantified. As a result, our search criteria for the noise impact chain reflected the need to account for a wide range of different noise sources (both terrestrial and marine, from gas compressor operation to tidal turbine noise), as well as wide variation in noise level i.e., frequency and amplitude. We explicitly did not include noise from

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construction activities, e.g. pile driving of turbine bases, because the noise is often intermittent and short-lived (Tougaard *et al.*, 2012), whereas it is expected that the new ROBINSON elements to produce more continuous noise outputs and to be of lower amplitude.

Most of the studies we extracted data from as part of the WoE showed support for a response to increased noise levels in a variety of taxa. The difficulties in measuring responses to altered noise conditions in the field of marine invertebrates such as Shore crabs (*Carcinus maenas*), Norway lobsters (*Nephrops norvegicus*) and Manila clams (*Ruditapes philippinarum*), mean that there are a number of experimental studies, i.e., lab-based, used for this impact chain (Solan *et al.*, 2016; Aimon *et al.*, 2021). Whilst these do not entirely replicate field conditions, they mostly consider European species so are relevant to ROBINSON in that respect; they also demonstrate a number of different stress-related responses (Simpson, Purser and Radford, 2015; Aimon *et al.*, 2021) as well as changes in behaviour that might induce changes in ecosystem function (Solan *et al.*, 2016).

Both birds and bats exposed to additional noise through field-based and housed experiments displayed disrupted foraging behaviours (Finch, Schofield and Mathews, 2020; Allen *et al.*, 2021) and stress responses, including reduced breeding success (Injaian, Poon and Patricelli, 2018; Rosa and Koper, 2022) and increased corticosterone (Kleist *et al.*, 2018). These responses occur at low levels of noise; owls were less successful at detecting prey when traffic noise was played at 45dBA (Senzaki *et al.*, 2016) and sparrow numbers decreased in response to gas field noise played at between 39.8 – 58 dBA in both narrow- and broadband (ambient background noise varied 30.6 - 37dBA; Cinto Mejia, McClure and Barber, 2019). Even birds considered not naïve to background noise such as in Grunst *et al.*, (2021) demonstrated disrupted sleeping behaviour when exposed to playback of traffic noise of around 70-80dBA. This demonstrates that even small increases in noise can induce behavioural or physiological changes in multiple taxa, which should be borne in mind when introducing several new components into an already industrialised environment.

2.2 Results from the Receptor Sensitivity Analysis

The dataset of records retrieved from GBIF contained 203 species of multiple taxa, the vast majority of which were birds (full scoring sheet in Appendix II). Records of a number of mammal species included Harbour seal (*Phoca vitulina*), European badger (*Meles meles*) and Red squirrel (*Scirus vulgaris*), alongside several invertebrate families, particularly anemones. We totalled all records for each species and counted the number of years in

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which the species was recorded. Table 4 lists the species with the highest scores that were recorded in five or more years (out of a possible 13).

Of these recorded species, 41 were assessed as being Near Threatened (NT), Vulnerable (VU), Endangered (EN) or Critical (CR), and 32 were assessed as being Least Concern (LC) but have >5% of their population in Norway. This gives a total of 73 species which were assessed further, by sourcing an adult survival rate and details of their habitat requirements/ preferences. By giving increased weight to species with higher adult survival rates and more restricted habitat requirements, we aimed to highlight species that may be more susceptible to removal of habitat and disruption to breeding success or population numbers.

The opportunistic nature of the GBIF data encouraged us to think more widely about which taxa should be taken into consideration given the habitat present and the activities likely being undertaken through ROBINSON, as species may have been present but not recorded. For example, there are no GBIF records of grey seal (*Halichoerus grypus*) and Harbour porpoise (*Phocoena phocoena*), yet these species are distributed widely around the Norwegian coastline, and we would expect to find them on and around Eigerøy because of their coastal habitat use. As a result, we included them in our sensitivity assessment. There is also a distinct lack of bat records throughout the GBIF data, which we treated in the same way as the two marine mammals mentioned above. We selected bats present in the area (identified using the Atlas of European Mammals) and assessed them in the same way as the other species (i.e., using red list status and habitat requirements).

Unsurprisingly, many of the species included in our sensitivity index are coastal inhabitants, including Eider (*Somateria mollissima*), Guillemot (*Uria aalge*), Razorbill (*Alca torda*), Velvet scoter (*Melanitta fusca*), Common gull (*Larus canus*), Cormorant (*Phalacrocorax carbo*), and Long-tailed duck (*Clangula hyemalis*). There are also many less geographically- and habitat-restricted species which have experienced severe national and international declines such as the Herring gull (*Larus argentatus*) and Black-headed gull (*Chroicocephalus ridibundus*). Species listed of Least Concern, yet with high percentages of the European and/or global population present in Norway include Fieldfare (*Turdus pilaris*), Meadow pipit (*Anthus pratensis*) and White-tailed eagle (*Haliaeetus albicilla*), all of which have been regularly recorded in Eigerøy over the past decade.

Whilst we have summarised the most frequently recorded species in Table 4, we have fully scored all species recorded less frequently, which include a number of vulnerable species including Fulmar (*Fulmarus glacialis*), Sand martin (*Riparia riparia*), Kittiwake (*Rissa tridactyla*) and Curlew (*Numenius arquata*). As with the lack of mammal records, the paucity

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of records for these particular species, which we would expect in an area such as Eigerøy, are not necessarily reflective of a genuine lack of presence. All four of these species score highly because of habitat restrictions and population vulnerability.

Table 4: Summary of highest scoring receptors (i.e., species) as judged by the sensitivity index scoring. For full table with details on key criteria, see Appendix II.

Species	Common name	Total
Somateria mollissima	Eider /ærfugl	26
Uria aalge	Guillemot/lomvi	25
Anthus pratensis	Meadow pipit/ heipiplerke	24
Acanthis flammea	Common redpoll/gråsisik	23
Larus argentatus	Herring gull/gråmåke	22
Fulica atra	Coot/sothøne	22
Melanitta fusca	Velvet scoter/ svartbak	21
Ficedula hypoleuca	Pied flycatcher/svarthvit fluesnapper	21
Alca torda	Razorbill/alke	21
Larus canus	Common gull/fiskemåke	20
Phalacrocorax carbo	Cormorant/storskarv	20
Poecile montanus	Willow tit/granmeis	20
Aythya marila	Scaup/bergand	20
Tachybaptus ruficollis	Little grebe/dvergdykker	19
Spinus spinus	Siskin/grønnsisik	19
Haliaeetus albicilla	White tailed Eagle/havørn	19
Clangula hyemalis	Long-tailed duck/havelle	19
Turdus pilaris	Fieldfare/gråtrost	18
Gallinula chloropus	Moorhen/sivhøne	18
Cinclus cinclus	Dipper/fossekall	18
Phylloscopus trochilus	Willow warbler/løvsanger	18
Cuculus canorus	Cuckoo/gjøk	18
Fringilla montifringilla	Brambling/bjørkefink	17
Melanitta nigra	Common scoter/svartand	17
Loxia curvirostra	Crossbill/grankorsnebb	17
Chloris chloris	Greenfinch /grønnfink	16
Emberiza citrinella	Yellowhammer/gulspurv	16
Chroicocephalus ridibundus	Black-headed gull/hettemåke	16
Anser anser	Greylag goose/grågås	16
Apus apus	Swift/tårnseiler	15
Accipiter gentilis	Goshawk/hønsehauk	15
Sturnus vulgaris	Starling/stær	14
Streptopelia decaocto	Collared dove/tyrkerdue	14
Larus fuscus	Lesser black-backed gull/sildemåke	14
Gavia stellata	Red-throated diver/smålom	13
Passer domesticus	House sparrow /gråspurv	11

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Section 3

3.1 Potential ecological effects of ROBINSON

We have used a DPSIR framework, WoE analysis and RSI to identify the potential ecological effects of the ROBINSON system. We used an initial DPSIR framework to provide an articulation of the pressures, resultant stressors, receptors and outcomes, in order to streamline a thorough WoE analysis. The RSI was built using available local data and information from the wider literature, to identify which receptors may be most impacted. The DPSIR enabled construction of the more likely impact chains as a result of ROBINSON. As information on the specifics of the components of ROBINSON were lacking, we used best-available knowledge and communication with partners to prioritise those components most likely to induce change in the environment. The uncertainty regarding the outputs of the components did not affect the WoE analysis, which although relatively restrictive in its search terms in order to focus the analysis, did incorporate a variety of studies, recognising that ecological evidence is sparse and that many studies can contribute in some form (Norris *et al.*, 2012).

All three of our impact chains demonstrated cause-and-effect relationships between potential drivers/pressures and receptors, although the strength and scale of the impacts were in some cases uncertain. Whilst many of the examples were from different countries or habitat types, as well as congenerics and confamilials, if robustly conducted these studies held some weight of evidence to support a change in status. The only impact chain to demonstrate inconsistency in the responses of receptors to a pressure was that concerning the wind turbine. The size of the wind turbine is clearly relevant, as is the location in which it is sited. The small wind turbine proposed for Eigerøy is likely to be quieter and be perceived as less of a barrier to flying species. However, it is being sited in a prominent coastal location, with a rocky undulating surrounding landscape where it might interact with locally breeding and migrating birds and bats (see section 2.1.1).

Habitat requirements, alongside conservation status, were the main drivers of higher receptor sensitivity indices. Often, habitat-restricted species are more likely to be of conservation concern as they are reliant on a limited amount of resources, such that any habitat loss or development is likely to impact them more (Staude, Navarro and Pereira, 2020). Groups of species such as sea ducks and some marine mammals, make use of both the terrestrial and marine environment in a narrow coastal zone for much of the year, which means that developments in this zone are likely to impact these groups more than others. Specifically, on Eigerøy, some of these groups may be present in large numbers at many

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points throughout the year and behaviours may differ among these points (Jarrett *et al.*, 2018), so any impacts may not be restricted just to one season. Because of the lack of data on species presence and their associated behaviours, it is currently unclear how much species numbers change throughout the year, particularly in terms of breeding locations and during migration, when a spatially and temporally concentrated rise in abundance of multiple species might occur.

3.2 Potential for cumulative or combined effects

Whilst the components of ROBINSON individually are unlikely to cause major impacts to the environment, there is the potential for the components to act in combination, thus increasing their impact. Impact chain 3 introduced this, by exploring the effect of noise increases of varying amplitudes to show that only small increases in noise levels can induce changes, even where individuals are not naïve to noise, in animal behaviour and biology. It is also the case that the components are being introduced to an already industrialised area, so is not damaging pristine wilderness or natural greenspace. Conversely, this means that the components are going to be interacting with already installed infrastructure such as roads and traffic, Prima Protein and Egersund harbour.

There is therefore the potential for the new components to increase cumulative impacts in the local area on Eigerøy that are difficult to assess at this stage but should be taken into account for the following phases of the project. Lonsdale *et al.*, (2020) and Segner, Schmitt-Jansen and Sabater (2014) suggest mapping the receptors as a priority, concentrating on their properties and the likelihood of exposure, rather than the properties of the drivers or pressures and what outcomes may follow, in order to better understand the cumulative aspect of any development project.

3.3 Future ecological impact assessment for the ROBINSON islands

The next phase of ROBINSON T5.4 involves collecting ecological data from the demonstrator island of Eigerøy, where selected components will be installed and connected using a smart energy management system. This provides a unique opportunity to gather data on taxa behaviour within the Eigerøy area before and after installation. Our analyses have highlighted species which may be more vulnerable or at least more responsive to change in the local environment, and those components which are most likely to affect such species. Understanding the distribution and movements of birds and bats around the coastline of the local area will be important particularly for the wind turbine, whereby

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topography influences wind currents and thus species interactions with the renewable energy device (Alerstam and Pettersson, 1977; Liechti, 2006).

Methods of ecological effect assessment should be prioritised that can be easily standardised and preferably automated to some extent. These should be employed in key locations to provide unbiased data gathering, and to collect data over a longer period of time to improve power and reduce the chance of type II errors (Fairweather, 1991). There is an increasing number of Eulerian data collection methods that can help to translate our weight of evidence analyses and receptor sensitivity indices to in-the-field evidence (Largey *et al.*, 2021), such as radar and ornithodolite surveys, as well as low-cost acoustic devices (Hill *et al.*, 2018). However, as data are lacking from this area, it is currently uncertain how long data collection would need to continue, or how many locations may be needed, in order to reach an appropriately thorough level to be able to detect any changes in the local environment (positive or negative) as a result of ROBINSON (Lloyd-Jones *et al.*, 2022). Ideally, a combination of surveillance and targeted monitoring could be conducted, in order to assess the species assemblage, as well as presence and movements of highlighted vulnerable species, to develop a more comprehensive understanding of the distribution, behaviour and responses of multiple taxa (Sparrow *et al.*, 2020).

Conclusions

Our combination of transferable, flexible, desk-based methods has highlighted potential ecological effects of ROBINSON on multiple taxa thought or known to be present in the area on and around Eigerøy. We have gathered evidence of impacts and used a combination of opportunistically collected citizen science data along with species information from the literature to produce an assessment of the most likely effects. ROBINSON aims to aid the decarbonisation of industrialised islands, reducing the reliance on fossil fuels through the installation of a number of REDs, the specific combination of which will differ among the demonstration islands, which also differ in their size, climate, topography and habitat types. Our analysis presents likely cause-and-effect relationships between the changes the ROBINSON elements may induce, and species of multiple taxa present in the area. Of particular interest are breeding and wintering sea ducks, which occur in large numbers in spatially restricted environment, as well as migrating birds and bats which may pass through in concentrated time periods and larger groups.

It is clear that further data are needed and that knowledge gaps are present owing to the uncertainty surrounding the components, the species that are present and the potential for cumulative effects as a result of the industrial nature of the island. We recommend

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concurrent broad and targeted monitoring methods, to collect baseline data in the area as well as species-specific data, with a particular focus on birds. We recommend collecting such data with an emphasis on achieving sufficient power to detect changes; sufficiently comprehensive monitoring can be performed with standardised, low-cost techniques and devices, to direct more targeted monitoring where required, in relation to any of the specific impact chains identified.

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Appendix I Weight of Evidence analysis data sheet

Impact chain	Article title	Authors	Year	Location	Organism(s)	Stressor	Measure (e.g. behaviour/ density/ abundance)	Support for hypothesis	Design type	Num. Impact Units	Num. Control Units	Species relevance	Location relevance	Summed score	Summed relevance
1a	Response of waterbird abundance and flight behavior to a coastal wind farm on the East Asian-Australasian Flyway | SpringerLink	Bai et al.	2021	Taiwan	Waterbirds	WT	Abundance. Flight behaviour.	+/-	4	0	2	1	0	7	1
1a	Habitat utilization in white-tailed eagles (Haliaeetus albicilla) and the displacement impact of the Smøla wind-power plant - May - 2013 - Wildlife Society Bulletin - Wiley Online Library	May et al	2013	Norway	White tailed eagle	WT	Habitat use	+	1	0	2	3	3	9	6
1a	White-tailed eagles (Haliaeetus albicilla) at the Smøla wind-power plant, Central Norway, lack behavioral flight responses to wind turbines - Dahl - 2013 - Wildlife Society Bulletin - Wiley Online Library	Dahl et al	2013	Norway	White tailed eagle	WT	Flight activity, behaviour and altitude.	-	2	0	2	3	3	10	6
1a	Effect of wind farms on wintering ducks at an important wintering ground in China along the East Asian–Australasian Flyway - Zhao - 2020 - Ecology and Evolution - Wiley Online Library	Zhao et al	2020	China	Ducks	WT	Abundance	+	2	0	2	2	0	6	2
1a	Effect of wind farms on wintering ducks at an important wintering ground in China along the East Asian-Australasian Flyway	Zhao et al	2020	China	Eastern spot billed duck (ESBD), Mallard	WT	Behaviour	++	1	0	2	2	0	5	2
1a	Abundance and behavior of little egrets (Egretta garzetta) near an onshore wind farm in Chongming Dongtan, China - ScienceDirect	Xu et al	2020	China	Little Egrets	WT	Behaviour and abundance	-	1	0	2	0	0	3	0
1a	Risk evaluation of onshore wind farms in relation to wild duck (Anatidae) movements in the Yangtze River Mouth, China - Zhao - 2022 - IET Renewable Power Generation - Wiley Online Library	Zhao et al	2022	China	Ducks	WT	Flight height.	++	2	0	2	2	0	6	2
1a	Reduced breeding success in white-tailed eagles at Smøla windfarm, western Norway, is caused by mortality and displacement - ScienceDirect	Dahl	2012	Norway	WTE	WT	Breeding success	++	4	0	2	3	3	12	6
1a	Limited Impact of a Small Residential Wind Turbine on Birds on an Off-Shore Island in Maine	Morris & Stumpe	2015	USA	Gulls (Herring and L. Black. Backed)	SWT	Mortality and behaviour	--	1	0	0	3	1	5	4

Impact chain	Article title	Authors	Year	Location	Organism(s)	Stressor	Measure (e.g. behaviour/ density/ abundance)	Support for hypothesis	Design type	Num. Impact Units	Num. Control Units	Species relevance	Location relevance	Summed score	Summed relevance
1a	Effects of wind farms on the nest distribution of magpie (Pica pica) in agroforestry systems of Chongming Island, China - ScienceDirect	Song et al	2021	China	Magpie	WT	Nest density variables.	+	2	0	2	0	0	4	0
1a	Impact on breeding birds of a semi-offshore island-based windmill park in Åland, Northern Baltic Sea | Ornis Svecica (lu.se)	Tanskanen	2012	Aland, Finland	Whole bird assemblage	WT	Numbers, Nest counts, Carcasses	-	2	0	2	3	2	9	5
1a	NINA Report 620	Bevanger et al	2016	Smøla, Norway	Willow ptarmigan	WT	Ptarmigan density; chick production	-	2	0	2	0	3	7	3
1a	NINA Report 620	Bevanger et al	2016	Smøla, Norway	Willow ptarmigan	WT	Habitat selection, movements, collision, avoidance, survival.	-	1	0	0	0	3	4	3
1a	NINA Report 620	Bevanger et al	2016	Smøla, Norway	Waders and passerines	WT	Distribution	+	1	0	2	2	3	8	5
1a	NINA Report 620	Bevanger et al	2016	Smøla, Norway	White tailed eagle	WT	Mortality + Flight activity	+	1	0	2	3	3	9	6
1a	Estimation of bird fatalities at wind farms with complex topography and vegetation in Hokkaido, Japan - Kitano - 2013 - Wildlife Society Bulletin - Wiley Online Library	Kitano & Shiraki	2013	Hokkaido	Whole bird assemblage	WT	Collisions/mortality	+	1	0	0	2	1	4	3
1b	Coastal onshore wind turbines lead to habitat loss for bats in Northern Germany	Reusch et al	2022	Germany	Common noctule bats	WT	Flight behaviour	+	1	0	0	3	1	5	4
1b	Experimental Evidence for the Effect of Small Wind Turbine Proximity and Operation on Bird and Bat Activity | PLOS ONE	Minderman et al	2012	Scotland and N England	Birds and Bats	SWT	Activity	+	1	3	0	2	1	7	3
1b	Effect of wind turbine curtailment on bird and bat fatalities	Smallwood and Bell	2020	California, USA	Birds and Bats	WT	Fatalities; Passage rates.	+	4	2	2	2	0	10	2
1b	Three-dimensional analysis of bat flight paths around small wind turbines suggests no major collision risk or behavioral changes | SpringerLink	Hochradel et al	2022	Germany	Bats	SWT	Acoustic activity; 3D activity	-	1	0	2	2	1	6	3
1b	Collision risk of bats with small wind turbines: Worst-case scenarios near roosts, commuting and hunting structures | PLOS ONE	Hartmann et al	2021	Germany	Bats	SWT	Movement with thermal camera	-	1	3	0	2	1	7	3
1b	Landscape-scale effects of single- and multiple small wind turbines on bat activity - Minderman - 2017 - Animal Conservation - Wiley Online Library	Minderman et al	2016	UK	Bats	SWT	Bat activity - Num. bat passes.	+	1	3	0	3	1	8	4

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Impact chain	Article title	Authors	Year	Location	Organism(s)	Stressor	Measure (e.g. behaviour/ density/ abundance)	Support for hypothesis	Design type	Num. Impact Units	Num. Control Units	Species relevance	Location relevance	Summed score	Summed relevance
2a	Growth Rates for Quahogs (Mercenaria mercenaria) in a Reduced Nitrogen Environment in Narragansett Bay, RI (bioone.org)	Robinson et al.	2020	USA, Long Island/ Cape Cod	Quahog (*M mercenaria*)	Wastewater N	Growth rate	-	3	6	0	0	1	10	1
2a	Benthic macroinvertebrate community response to environmental changes over 7 decades in an urbanized estuary in the northeastern US.	Pelletier et al	2021	USA, Long Island/ Cape Cod	Macro-invertebrates	Wastewater N	Diversity and competition	+	3	6	0	2	1	12	3
2a	Recovery of Danish Coastal Ecosystems After Reductions in Nutrient Loading: A Holistic Ecosystem Approach	Riemann et al	2016	Denmark	Benthic vegetation + Macrofauna	N and P	Macroalgal cover. Macrofaunal biomass.	++	3	6	0	2	1	12	3
2a	Wastewater input reductions reverse historic hypereutrophication of Boston Harbor, USA	Taylor et al	2020	Boston harbour	Phytoplankton, seagrass	Wastewater	Phytoplankton biomass	+	3	6	0	2	1	12	3
2a	Growth of the bivalve Nucula annulata in nutrient-enriched environments on JSTOR	Craig	1994	Narragansett bay, Rhode Island	*Nucula annulata*	Nutrients	Growth w nutrient gradient; abundance of size groups.	+	3	2	2	2	1	10	3
2a	How the Distribution of Anthropogenic Nitrogen Has Changed in Narragansett Bay (RI, USA) Following Major Reductions in Nutrient Loads | SpringerLink	Oczkowski	2018	Narragansett bay, Rhode Island	Macroalgae and Hard clams (*M mercenaria*)	Dissolved N	Stable isotopes (N and C) in clam tissue	-	3	6	0	2	1	12	3
2a	Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region	Lefcheck et al	2018	Chesapeake Bay, USA	SAV - submerged aquatic vegetation	Nutrients (fertiliser / manure)	SAV area and density	++	3	6	0	1	1	11	2
2a	Long-term reductions in anthropogenic nutrients link to improvements in Chesapeake Bay habitat	Ruhl & Rybicki	2010	Chesapeake Bay, USA	SAV	Nutrients incl WWTP.	Community composition	++	3	6	0	2	1	12	3
2a	Long-term changes in abundance and diversity of macrophyte and waterfowlpopulations in an estuary with exotic macrophytes and improving water quality	Rybicki & Landwehr	2007	Chesapeake Bay, USA	Waterfowl & SAV	Nutrients	SAV cover and spp abundance, waterfowl abund.	++	3	0	0	3	0	6	3
2a	Eiders, nutrients and eagles: Bottom-up and top-down population dynamics in a marine bird	Morelli et al	2021	Wadden Sea	Eider	Nutrients	Amount of nutrients; Size of mussel stock; Breeding success eider.	++	1	0	0	3	2	6	5

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Impact chain	Article title	Authors	Year	Location	Organism(s)	Stressor	Measure (e.g. behaviour/ density/ abundance)	Support for hypothesis	Design type	Num. Impact Units	Num. Control Units	Species relevance	Location relevance	Summed score	Summed relevance
2a	Long-Term Changes in Nutrients and Mussel Stocks Are Related to Numbers of Breeding Eiders Somateria mollissima at a Large Baltic Colony	Laursen & Moller	2014	Christiansø island, Baltic Sea	Eider	Nutrients	TN concentration (ug/l), num eider nests.	+	3	0	0	3	3	9	6
2a	Impacts of Nutrient Reduction on Coastal Communities | SpringerLink	Philippart et al	2007	Wadden Sea	Phytoplankton Birds	Nutrients	Phytoplankton sp composition; Chl-a concentrations	++	3	0	0	3	2	8	5
2a	A change in phytoplankton community index with water quality improvement in Tolo Harbour, Hong Kong	Lei et al	2018	Tolo harbour, HK	Phytoplankton	Total N	Phytoplankton abundance	+	3	0	0	2	0	5	2
2a	Response of a seagrass fish assemblage to improved wastewater treatment	Ourgaud et al	2015	Marseille, France	Fish	Wastewater	Species richness; Density; Biomass; Trophic structure.	++	4	0	2	1	1	8	2
2a	Benthic Ecosystem Changes Associated with Wastewater Treatment at Marseille: Implications for the Protection and Restoration of the Mediterranean Coastal Shelf Ecosystems	Bellan et al	1999	Marseille, France	Benthic fauna	Nutrients	Species diversity	+	3	0	0	1	1	5	2
2b	On the influence of hot-water discharges on phytoplankton communities from a coastal zone of the Gulf of Mexico.	Martinez-Arroyo	1999	Veracruz, Gulf of Mexico	Phytoplankton	Thermal effluent	Physico-chmical variables; O2, temp, salinity. Shannons div. Chl a.	-	3	2	0	1	0	6	1
2b	Effects of the thermal discharge from an offshore power plant on plankton and macrobenthic communities in subtropical China	Lin et al	2018	›wer Plant, Fujia	Zooplankton; Macrobenthos	Thermal effluent	Water temp with Chl a concentrations. Plankton and macrobenthic community composition.	+	2	0	0	1	0	3	1
2b	The response of phytoplkankton to incr temp in the Loviisa archipelago Gulf of Finland	Ilus & Keskitalo	2008	Gulf of Finland	Phytoplankton	Thermal effluent	Biomass, Composition	+	2	0	2	1	2	7	3
2b	Phytoplankton community organization and succession by sea warming: A case study in thermal discharge area of the northern coastal seawater of China	Dong et al 2021	2021	Bohai Sea, China	Phytoplankton	Thermal effluent	conductivity. Nutrient concentrations. Phytoplankton and chl-a analyses.	+	3	6	0	1	0	10	1
2b	Warming alters the body shape of European perch Perca fluviatilis	Rowinski et al	2015	Forsmark, Baltic sea	Perch	Thermal effluent	Body size and shape	+	2	0	2	1	2	7	3

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Impact chain	Article title	Authors	Year	Location	Organism(s)	Stressor	Measure (e.g. behaviour/ density/ abundance)	Support for hypothesis	Design type	Num. Impact Units	Num. Control Units	Species relevance	Location relevance	Summed score	Summed relevance
2b	The impacts of the Ignalina Nuclear Power Plant effluent on fishes in Lithuania	Astrauskas et al	1998	Ignalina nuclear plant, Druksiai lake.	Fishes	Thermal effluent	Size, species composition	+	2	0	2	2	2	8	4
2b	Effects of temperature on life history variables in perch - Sandström - 1995 - Journal of Fish Biology - Wiley Online Library	Sandstrom et al	1995	Forsmark, Baltic sea	Fishes; benthic fauna	Thermal effluent	Relative abundance, Population structure; Fish growth and condition variables.	++	2	0	2	2	2	8	4
3	Anthropogenic underwater vibrations are sensed and stressful for the shore crab (Carcinus maenas)	Aimon et al	2021	Devon, UK	Shore crabs	Vibration	Antennae beat rate, activity, oxygen consumption.	++	2	3	3	3	2	13	5
3	Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties	Solan et al	2016	Poole, Dorset (clams), Scotland (Nephrops).	Manila clam, Decapod crustaceans Nephops norvegicus, Ophiuroid brittlestars.	Vibration	Organism physiology, metabolic processes, and ecosystem process (bioturb, bioirrig).	++	2	3	3	3	2	13	5
3	Anthropogenic noise compromises antipredator behaviour in European eels - Simpson - 2015 - Global Change Biology - Wiley Online Library	Simpson et al	2015	UK	European eels	Noise	Startle response	++	2	3	3	3	2	13	5
3	Finding a home in the noise: cross-modal impact of anthropogenic vibration on animal search behaviour	Roberts & Laidre	2019	Gulf of Maine, USA	Acadian hermit crab	Vibration	Numbers	++	4	0	0	2	1	7	3
3	How anthropogenic noise affects foraging	Luo et al	2015	Kiel, DE	Daubentons bats	Noise	Success rate during foraging	+	2	0	0	3	1	6	4
3	Noise distracts foraging bats	Allen et al	2021	Idaho, USA	Parti-coloured bat	Noise	Foraging behaviour	++	2	0	0	1	0	3	1
3	Variable and consistent traffic noise negatively affect the sleep behavior of a free-living songbird	Grunst et al	2021	Wilrijk, Belgium	Great tit (*Parus major*)	Noise	Sleep behaviour	+	2	0	0	3	1	6	4
3	Noise Reduces Foraging Efficiency in Pallid Bats (Antrozous pallidus)	Bunkley & Barber	2015	Idaho, USA	Parti-coloured bat	Noise	Foraging behaviour	+	2	0	0	1	0	3	1
3	Traffic noise playback reduces the activity and feeding behaviour of free-living bats	Finch et al 2020	2020	Devon, UK	Bat spp.	Noise	Foraging behaviour	++	4	3	3	3	0	13	3
3	Traffic noise reduces foraging efficiency in wild owls	Senzaki et al	2016	Hokkaido	Owls	Noise	Prey detectability	+	1	2	0	3	0	6	3
3	Chronic anthropogenic noise disrupts glucocorticoid signaling and has multiple effects on fitness in an avian community	Kleist et al	2018	New Mexico	Ash-throated flycatcher, Western/ Mountain Bluebirds	Noise	Stress, condition	++	2	3	3	1	0	9	1

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Impact chain	Article title	Authors	Year	Location	Organism(s)	Stressor	Measure (e.g. behaviour/ density/ abundance)	Support for hypothesis	Design type	Num. Impact Units	Num. Control Units	Species relevance	Location relevance	Summed score	Summed relevance
3	Effects of experimental anthropogenic noise on avian settlement patterns and reproductive success	Injaian et al	2018	California, USA	Tree swallows	Noise	Settlement, nesting success	++	2	1	0	0	0	3	0
3	Impacts of oil well drilling and operating noise on abundance and productivity of grassland songbirds	Rosa and Koper	2021	Prairies	Grassland bird spp	Noise	Abundance; Nesting success; Nestling condition	++	2	3	3	0	0	8	0
3	Experimental playback of natural gas compressor noise reduces incubation time and hatching success in two secondary cavity-nesting bird species	Williams et al	2021	Pennsylvania, USA	Eastern Bluebirds / Tree Swallows	Noise	Behaviour, Nest success	+	2	3	3	0	0	8	0
3	Bats increase vocal amplitude and decrease vocal complexity to mitigate noise interference during social communication	Jiang et al	2019	Heilongjiang province, China	Asian particoloured bats	Noise	Vocalization analysis	+	2	0	0	1	0	3	1
3	The song of Skylarks Alauda arvensis indicates the deterioration of an acoustic environment resulting from wind farm start-up	Szymanski et al	2017	Margonin, Poland	Skylarks	Noise	Vocalization analysis	+	2	0	2	3	1	8	4
3	Large-scale manipulation of the acoustic environment can alter the abundance of breeding birds: Evidence from a phantom natural gas field	Mejia et al	2019	USA, Idaho	Birds spp.	Noise	Abundance	+-	2	3	3	1	0	9	1
3	High rates of vessel noise disrupt foraging in wild harbour porpoises (Phocoena phocoena)	Wisniewska et al	2018	Denmark	Harbour porpoise	Noise	Behaviour	+-	1	0	0	3	2	6	5
3	Behavioural reactions of free-ranging porpoises and seals to the noise of a simulated 2 MW windpower generator	Koschinski et al	2003	Vancouver isl., Canada	Harbour porpoise	Noise	Behaviour	++	2	0	0	3	1	6	4

Key to numbers: **Design type**: 1 = After impact only study; 2 = Before v after (no reference/control) /Control v impact only (no before data); 3 = Gradient response; 4= BACI/BARI/BACIP. **Num. impact units**: 1 unit = 0; 2 = 2; >2 =3. **Num. control units**: 0 units = 0; 1 = 2; 2+ = 3. **Species relevance**: 1 = familial relationship; 2 = congeneric; 3 = conspecific. **Location relevance:** 0 = Different habitat, different continent; 1 = Similar habitat, different continent/ Different habitat, same continent; 2 = Similar habitat type, same continent; 3 = Similar habitat type, same country.

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Appendix II Full Receptor Sensitivity Index

	Recorded in Eigeroy		Breeding in Rogaland		Red-list status						Population metrics								
Species	**Number of years**	*Score*	**Y/N/NE**	*Score*	**Norway**	*Score*	**Europe**	*Score*	**Global**	*Score*	**% European pop**	*Score*	**% Global pop**	*Score*	**Adult survival**	*Score*	**Habitat preference**	*Score*	**Total**
Larus argentatus	13	3	Y	2	VU	3	NT	2	LC	1	5 - 25 %	3	1 - 5 %	2	0.93	5	Coastal, Urban, Farmland, Wetland	1	22
Somateria mollissima	13	3	NE	1	VU	3	VU	3	NT	2	5 - 25 %	3	5 - 25 %	3	0.895	4	Coastal, Marine, Tundra	4	26
Passer domesticus	13	3	N	0	NT	2	LC	1	LC	1	< 1 %	1	< 1 %	1	0.609	1	Urban, Farmland, Grassland, Coast	1	11
Chloris chloris	13	3	Y	2	VU	3	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.443	1	Urban, Farmland, Forest	2	16
Larus canus	13	3	N	0	VU	3	LC	1	LC	1	5 - 25 %	3	5 - 25 %	3	0.8	3	Coastal, Marine, Wetland	3	20
Sturnus vulgaris	13	3	Y	2	NT	2	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.687	2	Urban, Farmland, Grassland, Coast, Scrub	1	15
Phalacrocorax carbo	13	3	NE	1	NT	2	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.84	4	Coastal, Marine, Wetland	3	20
Streptopelia decaocto	13	3	NE	1	NT	2	LC	1	LC	1	< 1 %	1	< 1 %	1	0.642	2	Grassland, Urban, Scrub, Farmland	2	14
Emberiza citrinella	13	3	Y	2	VU	3	LC	1	LC	1	< 1 %	1	< 1 %	1	0.536	1	Farmland, Grassland, Forest, Scrub	3	16
Tachybaptus ruficollis	13	3	NE	1	EN	4	LC	1	LC	1	< 1 %	1	< 1 %	1	0.6	1	Freshwater, Coastal, Wetland, Artificial Water	3	16
Turdus pilaris	13	3	Y	2	LC	1	LC	1	LC	1	25 - 50 %	4	1 - 5 %	2	0.41	1	Farmland, Forest, Scrub, Grassland	1	16
Spinus spinus	13	3	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.461	1	Forest, Urban, Farmland	2	15
Fringilla montifringilla	13	3	N	0	LC	1	LC	1	LC	1	25 - 50 %	4	1 - 5 %	2	0.589*	2	Forest, Farmland, Scrub	2	16
Haliaeetus albicilla	13	3	N	0	LC	1	LC	1	LC	1	> 50 %	5	25 - 50 %	4	0.84^	5	Coastal, Estuarine, Artificial Water, Wetland, Forest	2	22
Melanitta nigra	12	3	N	0	VU	3	LC	1	LC	1	< 1 %	1	< 1 %	1	0.783	3	Wetland, Coastal, Marine, Tundra, Freshwater	4	17
Melanitta fusca	12	3	NE	1	VU	3	VU	3	VU	3	1 - 5 %	2	< 1 %	1	0.77	3	Wetland, Coastal, Marine, Tundra, Freshwater, Estuarine	4	23
Poecile montanus	12	3	Y	2	VU	3	-	-	LC	1	5 - 25 %	3	< 1 %	1	0.63	2	Forest, Wetland, Scrub	3	18
Chroicocephalus ridibundus	12	3	N	0	CR	5	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.825	4	Artificial Water, Coastal, Farmland, Urban, Estuarine	1	18
Acanthis flammea	12	3	Y	2	LC	1	LC	1	LC	1	25 - 50 %	4	1 - 5 %	2	0.425*	4	Forest, Scrub, Urban, Farmland	2	20
Larus fuscus	12	3	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.913	5	Coastal, Marine, Wetland, Artificial Water, Farmland, Urban	1	17
Gavia stellata	11	3	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.84	4	Coastal, Estuarine, Marine, Wetland, Tundra	4	18
Aythya marila	10	3	NE	1	EN	4	VU	3	LC	1	1 - 5 %	2	< 1 %	1	0.48	1	Estuarine, Coastal, Wetland, Freshwater	3	19
Uria aalge	10	3	NE	1	CR	5	NT	2	LC	1	1 - 5 %	2	< 1 %	1	0.885	4	Coastal, Marine, Cliffs	5	24
Fulica atra	10	3	NE	1	VU	3	NT	2	LC	1	< 1 %	1	< 1 %	1	0.7	2	Wetland, Freshwater, Artificial Water, Coastal	1	15
Loxia curvirostra	10	3	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.463	1	Forest, Scrub	4	17
Apus apus	9	3	Y	2	NT	2	LC	1	LC	1	< 1 %	1	< 1 %	1	0.76	3	Urban, Wetland, Coastal	3	17
Gallinula chloropus	9	3	NE	1	VU	3	LC	1	LC	1	< 1 %	1	< 1 %	1	0.623	2	Wetland, Freshwater, Artificial Water, Coastal	1	14
Anser anser	9	3	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.83	3	Wetland, Coastal, Farmland, Grassland, Artificial Water	1	15
Accipiter gentilis	8	2	N	0	VU	3	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.83	4	Forest, Scrub, Urban, Farmland	1	15
Cinclus cinclus	8	2	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.54	1	Freshwater, Wetland, Cliffs	4	15
Phylloscopus trochilus	8	2	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.46	1	Forest, Scrub, Wetland, Grassland	3	16
Clangula hyemalis	7	2	N	0	NT	2	VU	3	VU	3	5 - 25 %	3	< 1 %	1	0.74	3	Coastal, Wetland, Marine, Tundra	4	21
Ficedula hypoleuca	7	2	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.36	1	Forest, Farmland, Grassland, Urban	2	15
Cuculus canorus	6	2	Y	2	NT	2	LC	1	LC	1	< 1 %	1	< 1 %	1	0.799	3	Forest, Scrub, Farmland, Wetland	2	15
Anthus pratensis	6	2	Y	2	LC	1	LC	1	LC	1	25 - 50 %	4	25 - 50 %	4	0.543	1	Grassland, Wetland, Scrub, Farmland, Coastal, Tundra	2	18
Alca torda	5	2	NE	1	VU	3	NT	2	LC	1	5 - 25 %	3	5 - 25 %	3	0.905	5	Coastal, Marine, Cliffs	5	25
Fulmarus glacialis	4	2	NE	1	EN	4	EN	4	LC	1	< 1 %	1	< 1 %	1	0.986	5	Coastal, Marine, Cliffs	5	24
Haematopus ostralegus	4	2	Y	2	NT	2	VU	3	NT	2	5 - 25 %	3	5 - 25 %	3	0.88	4	Coastal, Wetland, Estuarine, Farmland	3	24
Erinaceus europaeus	4	2	NE	1	NT	2	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.83	4	Urban, Grassland, Farmland, Forest	1	17
Linaria flavirostris	4	2	Y	2	LC	1	LC	1	LC	1	> 50 %	5	< 1 %	1	0.41	1	Grassland, Scrub, Tundra	3	17
Turdus torquatus	4	2	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.42	1	Forest, Grassland, Tundra, Scrub	3	14
Lyrurus tetrix	4	2	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.72	3	Forest, Grassland, Tundra, Scrub	4	19
Delichon urbicum	3	1	N	0	NT	2	LC	1	LC	1	< 1 %	1	< 1 %	1	0.41	1	Urban, Wetland, Freshwater, Coastal, Farmland, Artificial Water	2	10
Riparia riparia	3	1	NE	1	VU	3	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.3	1	Wetland, Coastal, Freshwater, Bare earth, Artificial water	3	14
Vanellus vanellus	3	1	Y	2	CR	5	VU	3	NT	2	1 - 5 %	2	< 1 %	1	0.705	2	Wetland, Coastal, Estuarine, Farmland	3	21
Sterna hirundo	3	1	NE	1	EN	4	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.88	4	Coastal, Marine, Wetland, Artificial Water	4	19

Species	Recorded in Eigeroy Number of years	Score	Breeding in Rogaland Y/N/NE	Score	Red-list status Norway	Score	Europe	Score	Global	Score	Population metrics % European pop	Score	% Global pop	Score	Adult survival	Score	Habitat preference	Score	Total
Pandion haliaetus	3	1	N	0	VU	3	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.765^	3	Coastal, Wetland, Artificial Water, Freshwater, Estuarine	3	15
Podiceps auritus	3	1	NE	1	VU	3	NT	2	VU	3	5 - 25 %	3	1 - 5 %	2	0.79	4	Wetland, Estuarine, Coastal, Freshwater, Artificial Water	2	21
Aquila chrysaetos	3	1	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.95	5	Forest, Cliffs, Grassland, Coastal, Tundra	2	15
Emberiza schoeniclus	3	1	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.54	1	Wetland, Grassland, Farmland, Scrub	2	13
Gavia arctica	3	1	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.85	4	Estuarine, Coastal, Wetland, Freshwater	4	18
Cepphus grylle	2	1	NE	1	NT	2	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.87	4	Coastal, Marine, Cliffs	5	20
Rissa tridactyla	2	1	NE	1	EN	4	VU	3	VU	3	5 - 25 %	3	1 - 5 %	2	0.81	4	Coastal, Marine, Cliffs	5	26
Tringa totanus	2	1	Y	2	NT	2	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.74	3	Wetland, Coastal, Estuarine, Freshwater	3	18
Glaucidium passerinum	2	1	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.75*	3	Forest, Scrub, Wetland	3	14
Motacilla flava	2	1	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.533	1	Wetland, Grassland, Farmland, Freshwater, Artificial Water	2	11
Tringa nebularia	2	1	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.536*	1	Wetland, Estuarine, Coastal, Freshwater, Artificial Water	3	13
Tringa ochropus	2	1	N	0	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.536*	1	Wetland, Freshwater, Artificial Water, Forest	3	12
Numenius arquata	1	1	Y	2	EN	4	VU	3	NT	2	1 - 5 %	2	< 1 %	1	0.89	4	Coastal, Wetland, Estuarine, Farmland, Grassland	2	21
Bubo bubo	1	1	NE	1	EN	4	LC	1	LC	1	1 - 5 %	2	< 1 %	1	0.776	3	Forest, Scrub, Grassland	2	16
Carpodacus erythrinus	1	1	NE	1	NT	2	LC	1	LC	1	< 1 %	1	< 1 %	1	0.61	2	Scrub, Forest, Grassland, Freshwater	2	12
Circus cyaneus	1	1	NE	1	EN	4	NT	2	LC	1	< 1 %	1	< 1 %	1	0.778	3	Tundra, Wetland, Forest, Scrub, Grassland	3	17
Corvus frugilegus	1	1	NE	1	VU	3	LC	1	LC	1	< 1 %	1	< 1 %	1	0.79	3	Urban, Farmland, Forest, Grassland	1	13
Pluvialis apricaria	1	1	N	0	NT	2	LC	1	LC	1	25 - 50 %	4	5 - 25 %	3	0.73	3	Tundra, Coastal, Wetland	3	18
Asio flammeus	1	1	N	0	LC	1	LC	1	LC	1	25 - 50 %	4	< 1 %	1	0.64	2	Farmland, Forest, Scrub, Grassland, Wetland	2	13
Surnia ulula	1	1	NE	1	LC	1	LC	1	LC	1	5 - 25 %	3	< 1 %	1	0.6	1	Forest, Grassland, Tundra, Scrub, Wetland	2	12
Anthus trivialis	1	1	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.42	1	Forest, Grassland, Farmland, Scrub	3	15
Buteo lagopus	1	1	N	0	LC	1	LC	1	LC	1	> 50 %	5	1 - 5 %	2	0.715^	3	Forest, Farmland, Wetland, Cliffs	3	17
Calidris maritima	1	1	NE	1	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.795	3	Coastal, Wetland, Estuarine, Artificial Water	3	16
Phoca vitulina	1	1	Y	2	LC	1	LC	1	LC	1	5 - 25 %	3	1 - 5 %	2	0.92	5	Coastal, Marine	4	20
Anthus petrosus	1	1	NE	1	LC	1	LC	1	LC	1	> 50 %	5	> 50 %	5	0.42*	1	Coastal, Cliffs, Wetland	4	20
Not recorded but should be present																			
Halichoerus grypus	-	-	-	-	VU	3	LC	1	LC	1	1 - 5 %	2	1 - 5 %	2	0.95	5	Coastal, Marine	4	18
Phocoena phocoena	-	-	-	-	LC	1	DD	0	LC	1	25 - 50 %	4	1 - 5 %	2	0.95	5	Coastal, Marine	4	17
Lagenorhynchus albirostris	-	-	-	-	LC	1	LC	1	LC	1	25 - 50 %	4	5 - 25%	3	NE	-	Marine, Coastal	5	15
Lagenorhynchus acutus	-	-	-	-	LC	1	LC	1	LC	1	> 50 %	5	25 - 50 %	4	NE	-	Marine, Coastal	5	17
Myotis daubentonii	-	-	-	-	LC	1	LC	1	LC	1	1-5%	2	<1%	1	0.82^	4	Wetland, Scrub, Forest, Cliffs, Artificial water	3	13
Eptesicus nilssonii	-	-	-	-	VU	3	LC	1	LC	1	5-25%	3	1-5%	2	0.79*	3	Forest, Wetlands, Farmland, Urban, Coastal	2	15

Full Receptor Sensitivity Index. As documented in section 1.4 species are scored according to the following categories: Number of years recorded as present in area (1-3 years = 1 point, 4-8 years = 2, 9-13 years = 3); Recorded as present in the region (Rogaland: Yes = 2, No evidence (NE) = 1, No = 0); Norwegian Red List status (LC = 1, NT = 2, EN = 3, VU = 4, CR = 5); European Red List status (LC = 1, NT = 2, EN = 3, VU = 4, CR = 5); Global Red List status (LC = 1, NT = 2, EN = 3, VU = 4, CR = 5); % of European population present in Norway (<1% = 1, 1-5% = 2, 5-25% = 3, 25-50% = 4, >50% = 5); % of global population present in Norway (<1% = 1, 1-5% = 2, 5-25% = 3, 25-50% = 4, >50% = 5); Adult survival rate (≤60% = 1; 61-70% = 2; 71-80% = 3; 81-90% = 4; >90% = 5); Habitat preference (from 1= very flexible, including urban areas, to 5 = specialist, restricted to one or two habitat types).

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