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Short-Term Behavioural Responses of Wintering Waterbirds to Marine Activity: Appendix 2

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Appendix 2

Literature Review

BTO Research Report No. 695

Quantifying the Sensitivity of Waterbird Species during the Non-Breeding Season to Marine Activities in Orkney and the Western Isles

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Report of work carried out by the British Trust for Ornithology
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Summary

Special Protection Areas (SPAs) are a network of protected sites established under the EC Birds Directive (2009/147/EC), for the conservation of rare or vulnerable birds and regularly occurring migratory species. Scottish Natural Heritage (SNH) and Joint Nature Conservation Committee (JNCC) have recommended a further suite of SPAs to Scottish Government (SG) for the protection of inshore aggregations of wintering divers, grebes and seaduck, collectively referred to as waterbirds, in Scottish coastal waters, including Orkney and the Western Isles.

A range of licensed marine activities occur in this region including; renewable energy generation, oil and gas extraction, fisheries, shellfish harvesting, and navigational dredging. These activities have the potential to affect qualifying features of the proposed SPAs (pSPAs) through a number of pressures including disturbance, displacement, habitat loss, barrier effects, collision, pollution, prey toxic contamination, species depletion, sedimentation, increased turbidity and by-catch.

The purpose of this review is to collate and critically assess the evidence of impacts during the non-breeding season from licensed marine activities to species that are qualifying features of the Orkney and Western Isles pSPAs[1]. For each activity, we review the pressures operating, the methods used to assess impacts to target species, provide a synthesis of the evidence for impacts to target species and identify key knowledge gaps relating to the activity, or individual pressures.

Our review identified strong evidence that disturbance and displacement may be key pressures that impact waterbird populations in the non-breeding season. These pressures are, to varying degrees, associated with all of the licensed marine activities covered by this review. However, in assessing the impact of these pressures, studies have focussed on immediate impacts, for example the loss of foraging habitat, rather than longer-term impacts, like changes to overwinter survival, which may have a more significant effect at a population level. In relation to disturbance there were gaps in knowledge for several of the target species notably Goldeneye, Black-throated and Great Northern Divers, Slavonian Grebe and Black

[1] Common Eider *Somateria mollissima*, Long-tailed Duck *Clangula hyemalis,* Velvet Scoter *Melanitta fusca*, Common Goldeneye *Bucephala clangula*, Red-breasted Merganser *Mergus serrator*, Red-throated Diver *Gavia stellata*, Black-throated Diver *Gavia arctica*, Great Northern Diver *Gavia Immer*, European Shag *Phalacrocorax aristotellis and* Slavonian Grebe *Podiceps auritus*. Black Guillemot *Cepphus grylle*, is not a qualifying feature, but is included as it occurs in large numbers in the region.

Guillemot, with the evidence for these species largely drawn from reviews and expert opinion.

1. Introduction

This report presents the results of work carried out for Marine Scotland under external commission. The work was funded through the Scottish Government's Contract Research Fund. Under the Birds Directive (EC Directive on the conservation of wild birds – 2009/147/EC), a co-ordinated network of protected areas have been set up, for the conservation of wild bird species, known as Special Protected Areas (SPAs)[2]. Although the terrestrial network is considered to be well established, further work is required to set up a complete network of marine SPAs. There are four types of marine SPAs currently recognised: marine extensions to breeding seabird colonies; inshore aggregations of non-breeding water fowl; aggregations of seabirds; and other types of marine SPAs (to allow for sites which do not fall under the other categories). To date, 31 marine extensions to seabird colony SPAs have been classified in Scotland.

Scottish Natural Heritage (SNH) and Joint Nature Conservation Committee (JNCC) have recommended a further suite of SPAs for marine birds to Scottish Government (SG)[3]. Proposed SPAs (pSPAs) for inshore aggregations of wintering divers, grebes and seaduck have been identified for the following areas: Outer Firth of Forth and St Andrews Bay Complex; Pentland Firth; Seas off Foula; Seas off St Kilda; Solway Firth; Bluemull and Colgrave Sounds; Coll and Tiree; East Mainland Coast; Moray Firth; **North Orkney**; Rum; **Scapa Flow**; Sound of Gigha; **West Coast of the Outer Hebrides**; Ythan Estuary, Sands of Forvie and Meikle Loch (see Figure 1). Collectively these are argued to represent the main concentrations and range of the species in Scottish coastal waters but the target areas for this project have been identified by SG as Orkney and the Western Isles, as shown in bold above.

Under the Habitat Regulations (The Conservation of Habitats and Species (Amendment) Regulations 2012), in instances where licenced marine activities can potentially negatively affect qualifying species of SPAs, there is a requirement for a Habitats Regulations Appraisal(HRA) to be carried out[4]. Guidance has been produced by Royal Society for the Protection of Birds (RSPB) specifically for marine planners on how to use bird data in the development of marine plans (RSPB 2012)

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[2] http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm
[3] http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/proposed-marine-spas/
[4] http://www.gov.scot/Resource/0039/00392525.pdf

but it can potentially also be used to inform HRAs. Not only does the guidance identify a range of direct and indirect impacts of human activity on birds in the marine environment, they have also derived a sensitivity matrix which provides a species specific score to a range of pressures associated with these human activities for both the non-breeding and breeding periods. Similarly at the scoping stage, SG's Feature Activity Sensitivity Tool (FEAST) can be used to determine the potential sensitivity of features (including species and habitats) to a range of potential activities and their corresponding pressures[5]. This tool is updated regularly to ensure that it is based upon the best available evidence and SNH are currently providing information on a number of the wintering waterbird species. At present both the tool and RSPB's guidance (and other such similar studies e.g. Furness et al. 2013) can only provide information on the sensitivity of the feature of interest and do not incorporate the severity of impact to birds' fitness. The level of information given also tends to be fairly generic and hence key aspects required for the assessment process cannot be taken into account (e.g. the type of technology involved, location including high energy sites versus low energy sites, scale of activity and any population level effects).

Under the European Marine Strategy Framework Directive (MSFD) the UK is committed to the preparation of national strategies in order to manage its seas in order to achieve or maintain Good Environmental Status (GES) by 2020[6]. One of the key requirements is the establishment of a comprehensive set of environmental targets and associated indicators which can be used to assess whether GES has been achieved, as defined by 11 high-level qualitative descriptors. Three of which are relevant to marine birds: species distribution (1.1), which is assessed by indicators of distributional range (1.1.1) and pattern (1.1.2); population size (1.2), which is assessed by indicators of population abundance (1.2.1); and population condition (1.3), which is assessed by indicators of demographic characteristics (1.3.1). For these reasons, it is important to identify areas where licensed marine activities may have a detrimental impact on marine bird populations, and what implications this may have under the MSFD.

A range of licensed activities occur in Orkney and the Western Isles including; renewable energy generation, oil and gas extraction, fishing with mobile and static gears, shellfish harvesting, navigational dredging and recreational activities, for example boating. These activities have the potential to affect qualifying features of the pSPAs through a number of impacts including, but not limited to; disturbance,

[5] http://www.marine.scotland.gov.uk/FEAST/
[6] http://www.gov.scot/Topics/marine/seamanagement/msfd

displacement, habitat loss, collision, pollution, prey species depletion and bycatch. As part of the National Marine Plan for Scotland[7], there is an aim to ensure that these activities do not have negative impacts on the marine environment. Whilst the impact of many of these activities on breeding birds has been extensively studied and reviewed (e.g. Furness & Tasker 2000; Garthe & Huppop 2004), their impact on birds during the non-breeding seasons is much less well understood.

The Orkney and Western Isles pSPAs include as qualifying features nine species outside of the breeding season. These are presented (in BOU order) in Table 1. Black Guillemot *Cepphus grylle*, whilst not a qualifying feature of these sites, also occurs in substantial numbers. These species will be referred to throughout as "target species". Non breeding red-throated diver were incorrectly identified in the original tender by MSS as a qualifying species for all three SPAs at the draft stage and were included in this literature review accordingly. They have been retained on the grounds of potentially providing some insight into how divers in general may behave at sea in the winter.

Table 1

Qualifying features for Orkney & Western Isles pSPAs outside the breeding season.

		Qualifying feauture for SPAs		
Common name	**Latin names**	**North Orkney**	**Scapa Flow**	**West coast of the outer Hebrides**
Common Eider	*Somateria mollissima*	✓	✓	✓
Long-tailed Duck	*Clangula hyemalis*	✓	✓	✓
Velvet Scoter	*Melanitta fusca*	✓		
Common Goldeneye	*Bucephala clangula*		✓	
Red-breasted Merganser	*Mergus serrator*	✓	✓	✓
Black-throated Diver	*Gavia arctica*		✓	✓
Great Northern Diver	*Gavia Immer*	✓	✓	✓
European Shag	*Phalacrocorax aristotellis*	✓	✓	
Slavonian Grebe	*Podiceps auritus*	✓	✓	✓

[7] http://www.gov.scot/Resource/0047/00475466.pdf

1.1 Objective and Scope

This report will, therefore, aim to provide a better understanding of the sensitivity of the target species to licenced marine activities outside of the breeding season by identifying underlying pressures they exert and the likely parameters, relating to the bird, which are impacted. This will be achieved through reviewing existing studies on the effects on target species from licensed activities (or appropriate surrogates where such information does not exist). The information gathered will form the basis for any recommendations for the most appropriate methods (e.g. VPs, boat surveys, visual aerial surveys, digital aerial surveys) and analytical framework for the collection and analyses of bird data to inform the sensitivity of bird species to licenced marine activities in Orkney and the Western Isles.

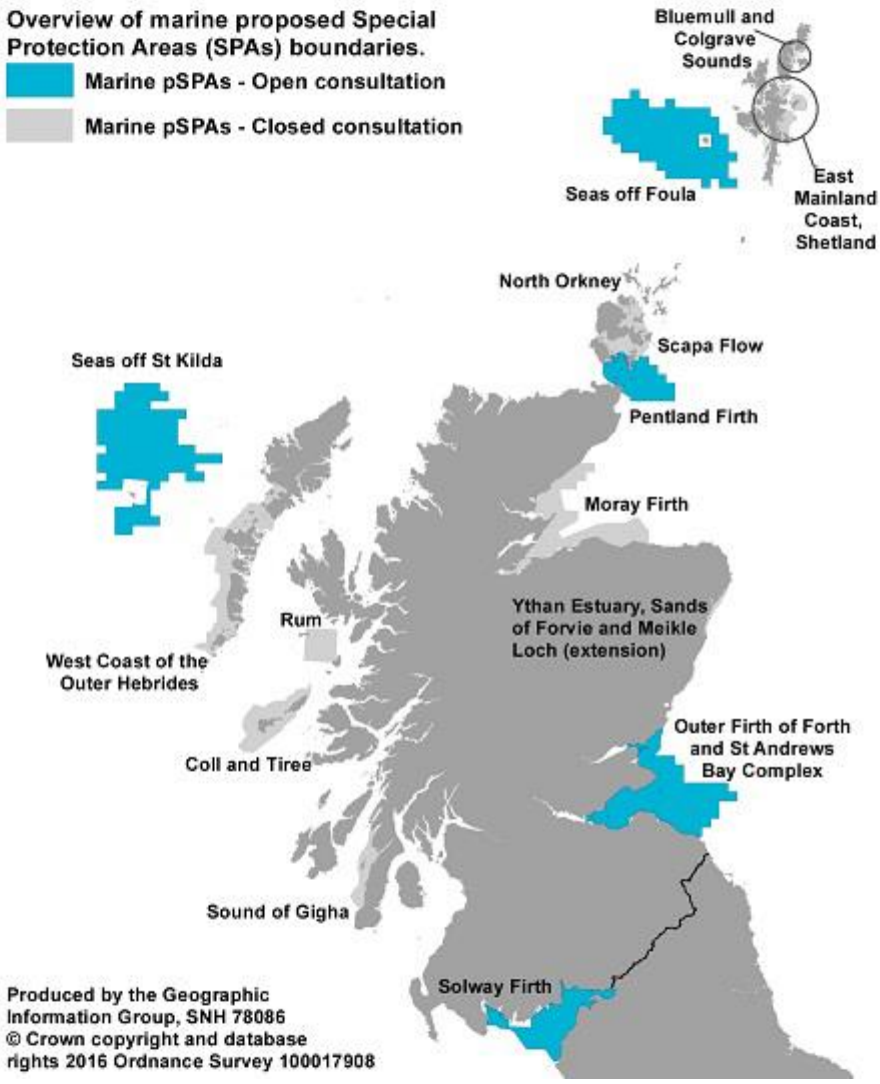

Figure 1: Map of all Scottish marine proposed Special Protection Areas and the stage of the consultation process (dated January 2017).

2. Methods

We conducted literature searches in Web of Science and Google Scholar to identify peer-reviewed and grey literature. Firstly, references relevant to target species were identified using common names and scientific names as search terms. In the case of Velvet scoter, we included references on White-winged scoter (*Melanitta fusca deglandi*) as it is a separate race of the same species. For species for which the initial search identified 100+ references, the initial search was narrowed using species name + disturb*.

Secondly, references relevant to licensed activities were identified using the following search terms:

- Renewable* AND *bird
- Oil and gas AND *bird
- *Fishing AND *bird
- Shellfish* AND *bird
- Fish farm* AND *bird (also fishfarm* and fish-farm)
- Dredg* AND *bird
- Recreation AND *bird
- Wave AND *bird
- Tidal AND *bird
- Wind farm* AND bird (also windfarm* and wind-farm*)
- Ship* and *bird
- Boat* and *bird

In cases where the initial search identified more than 100 references "AND marine" was added to search term.

Thirdly, references relevant to pressures/impacts and ecological processes were identified using the following search terms:

- Disturb* AND *bird
- Habituat* AND *bird
- Displace* AND *bird
- Habitat loss AND *bird
- Habitat degrad* AND *bird
- Collision AND *bird (also collid* AND *bird)
- Pollution AND *bird

- Contaminat AND *bird
- Sedimentation AND *bird
- Prey deplet* AND *bird
- Bycatch AND *bird
- Barrier effect* AND *bird

As with other searches, in cases where the initial search identified more than 100 references "AND marine" was added to search term. References that were judged to be relevant from their titles were included in a Mendeley reference library and Excel spreadsheet. References were marked as not relevant if they:

- Discussed marine activities or pressures, but not impacts to target species;
- Studies were conducted during the breeding season and the impact measured was specific to breeding season (e.g. productivity, chick growth rates, etc.). However, breeding season studies were included if the impacts discussed could have similar effects in the non-breeding season.

In the case of reviews or reports citing primary literature from other sources, the primary source was used when possible. However, if the primary source was not available online, or not in English, the information was extracted from the secondary source, noting the primary source and secondary sources (e.g. Stripniece et al 2008 (cited in Žydelis et al 2009)). In some cases (e.g. Cook and Burton 2010), reviews were treated as primary sources if the impacts to birds were deduced or asserted by the review author. This was justified to be appropriate in the absence of relevant primary literature for particular activities (e.g. dredging) or pressures.

2.1 Clarification of Terminology

We use the following terms throughout the review:

Activity	Refers to licensed marine activities (e.g. wind farms, fisheries, etc.)
Pressure	Mechanism through which the activity is affecting birds (e.g. habitat loss, increased sedimentation etc.). Note that pressures include mechanisms which can be observed directly (e.g. habitat loss, increased sedimentation etc.) as well as mechanisms that can only be measured indirectly via the birds' behavioural response (e.g. displacement effects which are observed as changes in birds abundance and/or distribution).
Parameter	The aspects of the birds' ecology that can be measured to assess impact (e.g. changes in demographic rates).

Impact	The result of the pressure on the birds and/or their population (e.g. reduced survival).
Magnitude	The degree of impact is the pressure having on the studied population. This has been classified as LOW, MODERATE or HIGH based on criteria defined separately for each activity.
Displacement	A functional habitat loss at a site (e.g. in terms of foraging or other behaviours such as maintenance) as a consequence of an activity. This effect may be transient (e.g. minutes or hours) or longer-term (e.g. days weeks or months).
Barrier effects	A behavioural evasive response shown by birds in response to an activity resulting in extended distances being travelled in order to avoid the site of the activity (e. birds in flight passing around a wind farm but also could extend to birds swimming under water around wave or tidal devices)
Pollution	An event which affects an individual externally (e.g. oiling)
Contamination	An event which affects an individual internally (e.g. ingesting heavy metals

2.2 Structure of Review

We have structured this review by individual marine licenced activity, including the evidence for all potential pressures relevant to that particular activity. The licensed marine activities included in the review, along with pressures they can potentially exert on target species in the non-breeding season are listed in Table 2. The potential parameters that can be used to assess the impacts to target species from each of the pressures in the non-breeding season are listed in Table 3.

For each activity, we review the pressures operating, the methods used to assess impacts to target species, and provide a synthesis of the evidence for impacts to target species. For each activity, we include a table listing the pressure that is operating on the birds along with the quality of evidence used to assess the impact and the magnitude of the impact which are defined below:

1. Quality of evidence is classified as POOR, MODERATE or GOOD. The criteria used to define quality of evidence varied slightly for each activity, and are defined separately within each activity section. This variation is unavoidable as there are methodological considerations specific to the type of study used to study pressures resulting from different activities. In general terms, quality of evidence was classified POOR if findings were based on

expert opinion, anecdotal data or analysis with a low statistical power, MODERATE if they were based on expert opinion supported by robust data collection and or data collected following standard survey methodologies, and GOOD if data were collected using standardised survey methodologies and analysed with appropriate techniques.

2. The classification of magnitude of impact was also difficult to standardise across activities for the reasons stated above, and the definition of criteria are again provided within each activity section.

The quality of evidence and magnitude columns in the tables are coloured according to a traffic light colour scheme – whereby for quality of evidence, red indicates POOR quality and green indicates GOOD quality and for magnitude red indicates HIGH impact and green indicates LOW impact.

Finally we go onto to look at the key knowledge gaps relating to the activity, or individual pressures. We summarise the information collected for each pressure by considering the weight of evidence for the magnitude of its impact. For example, where there are four studies, if three rate the impact of the pressure as high, we assess the impact of the pressure as high overall. Where studies give conflicting information, we give priority to those in which the quality of evidence was assessed as being highest.

Table 2

The licensed marine activities covered in this review and the pressures they exert on non-breeding waterbirds. Pressures that are measured indirectly by behavioural responses, rather than directly are highlighted in grey.

	Displacement/ Attraction	Habitat Loss	Disturbance	Barrier Effects	Prey Species Depletion	Sedimentation	Increased turbidity	Toxic Contamination	Pollution	Collision	Bycatch
Renewable energy generation (wind farms)	*	*	*	*	*					*	
Renewable energy generation (wave and tidal)	*	*	*		*					*	
Hydrocarbons – oil and gas extraction	*	*	*		*			*	*		
Fisheries	*	*	*		*				*		*
Shellfishing	*	*	*		*	*	*	*			
Fish farms	*	*	*		*				*		
Navigational dredging/aggregate extraction	*	*	*		*	*	*	*	*		
Shipping/boating	*	*	*						*		
Recreation	*	*	*						*		

Table 3

The range of parameters that can be measured to assess the potential sensitivity to impacts from each pressure to waterbirds in the non-breeding season. These parameters may reflect aspects of a species ecology which relate to sensitivity to a particular impact, or the characteristics of a site which may reflect how a species will respond to any impact. Pressures that measured by behavioural responses, rather than directly are highlighted in grey.

	Displacement/ Attraction	Habitat Loss	Barrier Effects	Disturbance	Prey Species Depletion	Sedimentation	Increased Turbidity	Toxic Contamination	Pollution	Collision	Bycatch
Wintering Home Range[1]	*	*	*		*	*	*	*	*		
Habitat Specialisation[2]	*	*		*		*	*		*		
Availability of Alternative Habitat[3]	*	*		*		*	*		*		
Dietary Specialisation[4]		*			*	*	*	*			
Availability of Alternative Prey[5]		*			*	*	*	*			
Foraging Habitat[2]		*				*	*				*
Response Initiation Distance[6]			*	*						*	*

	Displacement/ Attraction	Habitat Loss	Barrier Effects	Disturbance	Prey Species Depletion	Sedimentation	Increased Turbidity	Toxic Contamination	Pollution	Collision	Bycatch
Vigilance Behaviour[7]				*							
Length of Time to Return[8]				*							
Foraging Mode[9]						*	*			*	*
Diving Depth[10]						*	*			*	*
Time Spent Underwater[11]						*	*			*	*
Trophic Status[12]								*			
Adult Survival Rate[13]								*	*	*	*
Generation Time[13]								*	*	*	*
Type of Pollution[14]								*	*		

	Displacement/ Attraction	Habitat Loss	Barrier Effects	Disturbance	Prey Species Depletion	Sedimentation	Increased Turbidity	Toxic Contamination	Pollution	Collision	Bycatch
Probability of Exposure to Pollution[15]								*	*		
Attraction to Boats[16]								*	*		*

[1]Do individuals cover a wide area over winter, for example, as measured using tracking data; [2]Are species restricted to a specific habitat type, for example, as measured using species distribution models; [3]If species are restricted to a particular habitat, is it locally widespread or restricted?; [4]Do dietary studies indicate a strong preference for a particular prey type (e.g. benthic prey); [5]Are locally common alternative prey available?; [6]Distance at which birds are disturbed by boat traffic etc.; [7]For example, the proportion of time birds spend alert in comparison to foraging etc.; [8]Length of time it takes birds to return to an area following a disturbance; [9]For example, plunge divers vs pursuit foragers, some foraging modes may pose greater risk in combination with certain activities than others; [10]Maximum diving depth may indicate probability of exposure to a given activity; [11]Increased time underwater may increase risk of exposure to a managed activity; [12]The potential for contaminants (e.g. heavy metals, Persistent Organic Pollutants) to bio-accumulate means top predators may be at greater risk from exposure than other species; [13]k-selected species with high survival rates and long generation times are generally believed to be more sensitive to pressures which result in additional adult mortality; [14]Different types of pollutant may have an acute or chronic impact on a species, e.g. marine plastics vs. food waste; [15] For example, are birds more likely to aggregate in areas where exposure to pollution is high, e.g. shipping lanes; [16]Are birds attracted to boats, e.g. seabirds foraging on fisheries discards.

3. Impacts of Marine Licensed Activities on Wintering Waterbirds

3.1 Renewable Energy Generation (Wind Farms)

3.1.1 Literature Summary

We identified 26 papers and reports relevant to the impact of wind farms on the key study species. Given the relatively young age of the industry, these reports only date back as far as 2001, with 11 of them coming from the past five years. Of these papers, 21 were reports or papers which quantified the impact of wind farms on the target species and the remaining five were reviews which synthesised data from elsewhere and drew on expert opinion in order to assess the sensitivity of the target species to wind farms. These studies largely originated from the southern part of the North Sea, in particular from operational offshore wind farms such as Nysted, Horns Rev and Egmond aan Zee (e.g. Krijgsveld et al., 2011; Petersen, Christensen, & Kahlert, 2006). However, data were also identified relating to operation offshore wind farms in the UK including Robin Rigg, Gunfleet Sands and Kentish Flats (e.g. GoBe Consultants Ltd., 2012; Natural Power, 2013; Percival, 2010). There were no studies from the region of interest (Orkney and the Western Isles) due to the lack of planned, consented or constructed offshore wind farms in these areas.

3.1.2 Pressures

The wind farm pressures considered in these studies were collision, displacement, barrier effects and disturbance. Of these, **displacement** (12 studies) and **barrier effects** (seven studies) have been the most widely investigated in relation to the key study species. We identified two studies which assessed the sensitivity of wintering waterbirds to **disturbance** from marine traffic associated with offshore wind farms (e.g. maintenance vessels) using data from Scotland and Sweden (Pettersson 2005; Natural Power 2013) and a final study which could be used to assess the potential sensitivity of wintering waterbirds to **collision** by considering their flight heights in relation to wind turbines using data drawn from across the North Sea region (Johnston *et al.* 2014). **Habitat loss** is often considered as an impact in relation to onshore wind farms. It has not been considered here due to the difficulty in distinguishing it from the impacts of displacement and disturbance as reflected by the lack of studies on habitat loss in the context of offshore wind farms. However, estimates of displacement rates, which encompass all changes in the bird numbers pre- and post-construction, will incorporate habitat loss.

3.1.3 Methods for Quantifying Impact

Studies of displacement typically statistically compare densities and/or distributions of birds pre- and post-wind farm construction using data collected using boat or aerial survey data. Of the two approaches for data collection, aerial survey, and particularly digital aerial survey post 2012 (due to improvements in the quality of the images), is believed to give the most reliable estimate of bird populations. This is due to it being less prone to disturbance and attraction effects than boat surveys and is carried out over a shorter time period meaning that it offers a more realistic snapshot of the bird population in the study area at any given time (Buckland et al., 2012; Johnston *et al.*, 2014). However, many studies of displacement suffer from problems relating to experimental design meaning that it can be difficult to draw conclusions about the reliability of the results presented – notably for the early developments in the UK (Marine Management Organisation 2014). For the purposes of this review, low quality studies are those which rely on anecdotal data and/or expert opinion, moderate quality studies are those which use standardised survey methodology (e.g. boat/aerial surveys following the methodology of Camphuysen *et al.* (2004)) but with no further analysis, and high quality studies are those which combine standardised survey methodology with robust analytical techniques in order to assess the impact of displacement (e.g. Before – After Gradient design combined with density surface modelling techniques).

Barrier effects have been assessed using radar and/or visual observations of bird flight paths in and around operational wind farms (e.g. Krijgsveld et al., 2011.; Petersen et al, 2006). There are advantages and disadvantages to each approach. Whilst radar can give a highly detailed record of flight tracks, unless it is combined with visual observations, or in an area where tracks are likely to reflect a single species or group, it is not possible to know the species, or number of birds, each track relates to. For the purposes of this review, low quality studies are those which rely on anecdotal data and/or expert opinion, given the limitations of each approach, moderate quality studies are those which rely on visual or radar observations and high quality studies are those which use both visual and radar observations.

In relation to collision, there are no published data on collision rates with offshore wind farms and it is, therefore, impossible to ascertain the frequency at which such events occur. Johnston et al., (2014) modelled the flight height distribution of birds observed during boat-based surveys as a proxy for the likelihood of risk of collision. This study was based on a large dataset covering a wide geographic scale (boat based surveys carried out at 32 offshore wind farms in the pre-construction period. However, as it compared relative risk based on the heights at which birds fly, rather than directly quantifying collision rates, for the purposes of this review, it was assessed as being of moderate quality.

In relation to disturbance, Pettersson (2005) and Natural Power (2013) noted interaction between waterfowl and boats. However, these observations were not the primary purpose of these studies and were largely anecdotal. Consequently, the quality of this evidence is assessed as low.

For each pressure, the magnitude of the impacts is assessed relative to the population concerned or impacts on other species where appropriate. For example, the proportion of birds flying at heights which place them at risk of collision ranged from 2-35 % (Johnston et al., 2014). Consequently, where species flight heights occurred at the upper limit of this range the magnitude of collision risk was assessed as high. In contrast, the proportion of birds displaced from a wind farm could be up to 100%. Consequently, where at least 75% of birds were displaced, or the authors noted (but didn't quantify) a particularly strong displacement effect, the magnitude of the impact of displacement was assessed as high.

3.1.4 Synthesis of Evidence for Impacts

Studies assessing the impact of pressures associated with offshore wind farms on target species in the non-breeding season are listed in Table 4. The studies we identified suggested that Red-breasted Mergansers, Long-tailed Duck, Common Eider and Diver spp all showed significant reductions in density or abundance within wind farm areas across multiple sites and in multiple years. This suggests that these species may be sensitive to displacement from key areas of habitat by the presence of a wind farm. This finding is consistent with previous expert opinion on the likely impact of offshore wind farms on these species (Garthe & Huppop 2004; Furness & Wade 2012; Langston 2010) which based assessment of potential sensitivity to displacement on flexibility of habitat use and sensitivity to loss of habitat. Of the remaining target species, Slavonian Grebe, Velvet Scoter and Common Goldeneye were assessed to have a low to moderate sensitivity to displacement based on the expert opinion presented in these reviews. In contrast to the other species, the review of Dierschke *et al.*, (2016) concluded that European Shag was strongly attracted to offshore wind farms.

The studies we identified indicate that divers and seaduck (Velvet scoter, Common Eider and Long-tailed Duck) consistently perceive wind farms as a barrier, with a significant proportion of birds not entering the wind farm and a deflection in flight paths evident at distances of at least 1.5 km, as recorded by radar (Petersen et al.

2006). Based on the expert opinion presented in the reviews we identified (Garthe & Huppop 2004; Langston 2010; Furness & Wade 2012), the remaining target species were all considered to have a moderate sensitivity to barrier effects.

The models presented in (Johnston et al. 2014) indicated that Black-throated and Red-throated Diver and European Shag all fly at heights which are unlikely to place them at risk of collision. Whilst a higher proportion of Common Eider was found to fly at heights placing them at risk of collision, there was significant uncertainty surrounding the estimates for this species. The remaining target species were all assessed to be at low risk of collision by expert opinion (Garthe & Huppop 2004; Langston 2010; Furness & Wade 2012).

We identified anecdotal evidence to suggest that Long-tailed Duck and Red-breasted Merganser may be sensitive to disturbance by boat traffic (Pettersson 2005; Natural Power 2013). Evidence based on expert opinion suggests that the remaining target species may also have a moderate to high sensitivity to disturbance by boat/helicopter traffic (Furness *et al.* 2013; Garthe & Huppop, 2004).

3.1.5 Conclusions and Knowledge Gaps

In relation to offshore wind farms, the majority of evidence we identified with which to assess pressures on wintering waterbirds was assessed as being of low-moderate quality, highlighting the significant uncertainty surrounding likely effects on wintering waterbird populations. The majority of studies focussed on displacement and barrier effects and, with the exception of European Shag, the impact of these pressures was generally of a high magnitude. The combined impacts of barrier effects and displacement in response to offshore wind farms may lead to functional habitat loss, if birds are displaced from preferred habitat, and increased energy expenditure, if birds have to travel further to find suitable habitat and/or avoid entering a wind farm as they perceive it as a barrier. There was limited evidence about the impact of disturbance associated with offshore wind farms on wintering waterbirds. However, this evidence suggested that birds may be disturbed over significant distances, again, potentially increasing energy expenditure and displacing birds from preferred habitat. In general, the heights at which these species fly, place them at a low risk of collision.

Table 4

Studies assessing the impact of pressures associated with offshore wind farms on wintering waterbirds. The strength of the methodologies for each study are assessed as being POOR (based on expert opinion, anecdotal data or analysis with a low statistical power), MODERATE (expert opinion supported by robust data collection and or data collected following standard survey methodologies, e.g. standard boat/aerial survey methodologies described by Camphuysen *et al.* 2004, with no further analysis) or GOOD (data collected using standard survey methodologies and analysed with appropriate techniques, e.g. distance corrected population estimates). N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper. The magnitude of the impact was assessed as LOW if studies noted no significant change from the baseline pre-construction population or if the proportion of birds affected was less than 10% of the total number present, HIGH if studies noted the effect as being particularly strong, or if more than 75% of birds present were affected and MODERATE if between 10 and 75% of the total birds present or the effect was described as significant but not strong. Note that in many cases only a qualitative, rather than quantitative assessment was made. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of Evidence**	**Magnitude**
Common Eider	Larsen & Guillemette 2007	Displacement	% birds landing close to wind farm	GOOD	MODERATE
Common Eider	Dierschke et al. 2016	*Displacement*	*Change in populations pre and post construction*	*GOOD*	*LOW*
Common Eider	*Garthe & Huppop, 2004*	*Displacement*	*Habitat use flexibility*	*POOR*	*HIGH*
Common Eider	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*LOW*
Common Eider	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*MODERATE*	*LOW*
Common Eider	Johnston et al. 2014	Collision	% birds at collision risk height	MODERATE	MODERATE
Common Eider	*Garthe & Huppop, 2004*	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*POOR*	*LOW*
Common Eider	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Common Eider	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of Evidence**	**Magnitude**
Common Eider	Nilsson & Green 2011	Displacement	Comparison of distribution pre/post construction	GOOD	HIGH
Common Eider[1]	Petersen et al. 2006	Displacement	Comparison of distribution pre/post construction	GOOD	LOW
Common Eider[1]	Petersen et al. 2006	Displacement	Comparison of distribution pre/post construction	GOOD	MODERATE
Common Eider	Rothery et al. 2009	Displacement	Change in populations pre and post construction	POOR	LOW
Common Eider	Masden et al. 2009	Barrier Effects	Minimum distance to wind farm	MODERATE	HIGH
Common Eider	Pettersson 2005	Barrier Effects	Distance at which birds change flight direction	POOR	HIGH
Common Eider	*Garthe & Huppop, 2004*	*Disturbance*	Relative sensitivity to boat/aerial traffic	*POOR*	*MODERATE*
Common Eider	Furness & Wade 2012	*Disturbance*	*Relative sensitivity to boat/aerial traffic & response distance to boat*	*MODERATE*	*MODERATE*
Common Eider & Common Scoter	Percival 2001	Displacement	Change in populations pre and post construction	MODERATE	HIGH
Common Eider & Common Scoter	Percival 2001	Barrier Effects	Distance at which birds change flight direction	MODERATE	HIGH
Long-Tailed Duck	Pettersson 2005	Disturbance	Response distance to boat traffic	POOR	HIGH
Long-Tailed Duck	Dierschke et al. 2016	*Displacement*	*Change in populations pre and post construction*	*GOOD*	*HIGH*
Long-Tailed Duck	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*MODERATE*
Long-Tailed Duck	Nilsson & Green 2011	Displacement	Comparison of distribution pre/post construction	GOOD	HIGH

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of Evidence**	**Magnitude**
Long-Tailed Duck	Petersen et al. 2006	Displacement	Comparison of distribution pre/post construction	GOOD	MODERATE
Long-Tailed Duck	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*MODERATE*	*LOW*
Long-Tailed Duck	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Long-Tailed Duck	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Long-Tailed Duck	Furness & Wade 2012	*Disturbance*	*Relative sensitivity to boat/aerial traffic & response distance to boat*	*MODERATE*	*MODERATE*
Velvet Scoter	*Garthe & Huppop, 2004*	*Displacement*	*Habitat use flexibility*	*POOR*	*HIGH*
Velvet Scoter	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*MODERATE*
Velvet Scoter	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*MODERATE*	*LOW*
Velvet Scoter	*Garthe & Huppop, 2004*	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*POOR*	*LOW*
Velvet Scoter	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Velvet Scoter	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Velvet Scoter	*Garthe & Huppop, 2004*	*Disturbance*	*Relative sensitivity to boat/aerial traffic*	*POOR*	*HIGH*
Seaduck spp.	Krijgsveld et al., 2011	Barrier Effects	% tracks entering wind farm	MODERATE	MODERATE
Red-Breasted Merganser	Pettersson 2005	Disturbance	Response distance to boat traffic	POOR	MODERATE
Red-Breasted Merganser	Dierschke et al. 2016	*Displacement*	*Change in populations pre and post construction*	*GOOD*	*HIGH*
Red-Breasted Merganser	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*LOW*

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
Red-Breasted Merganser	Nilsson & Green 2011	Displacement	Comparison of distribution pre/post construction	GOOD	HIGH
Red-Breasted Merganser	Petersen et al. 2006	Displacement	Comparison of distribution pre/post construction	GOOD	LOW
Red-Breasted Merganser	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Red-Breasted Merganser	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Common Goldeneye	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*LOW*
Common Goldeneye	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Common Goldeneye	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Common Goldeneye	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*MODERATE*	*LOW*
Waterfowl	Desholm & Kahlert 2005	Barrier Effects	% birds entering wind farm	MODERATE	HIGH
Waterfowl	Pettersson 2005	Barrier Effects	Distance at which birds change flight direction	MODERATE	HIGH
Waterfowl	Petersen et al. 2006	Barrier Effects	Comparison of track density pre/post construction & distance at which birds change flight direction	GOOD	HIGH
Duck spp.	Krijgsveld et al., 2011	Barrier Effects	% tracks entering wind farm	MODERATE	MODERATE
Red-Breasted Merganser	Pettersson 2005	Disturbance	Response distance to boat traffic	POOR	MODERATE
Red-Breasted Merganser	Dierschke et al. 2016	*Displacement*	*Change in populations pre and post construction*	*GOOD*	*HIGH*
Red-Breasted Merganser	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*LOW*

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
Red-Breasted Merganser	Nilsson & Green 2011	Displacement	Comparison of distribution pre/post construction	GOOD	HIGH
Red-Breasted Merganser	Petersen et al. 2006	Displacement	Comparison of distribution pre/post construction	GOOD	LOW
Red-Breasted Merganser	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Red-Breasted Merganser	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Red-Throated Diver	Dierschke et al. 2016	*Displacement*	*Change in populations pre and post construction*	*GOOD*	*HIGH*
Red-Throated Diver	Garthe & Huppop 2004	*Displacement*	*Habitat use flexibility*	*POOR*	*HIGH*
Red-Throated Diver	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*HIGH*
Red-Throated Diver	NPower Renewables 2006	Displacement	Change in numbers pre/post construction	GOOD	HIGH
Red-Throated Diver	Sansom, et al, 2010	Displacement	Change in numbers pre/post construction	GOOD	HIGH
Red-Throated Diver	Natural Power 2013	Displacement	Change in numbers pre/post construction	POOR	LOW
Red-Throated Diver	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*MODERATE*	*LOW*
Red-Throated Diver	Johnston et al. 2014	Collision	% birds at collision risk height	GOOD	LOW
Red-Throated Diver	*Garthe & Huppop, 2004*	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*POOR*	*LOW*
Red-Throated Diver	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Red-Throated Diver	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Red-	Natural	Barrier	Change in density	POOR	HIGH

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
Throated Diver	Power 2013	effects	of flying birds		
Red-Throated Diver	Garthe & Huppop 2004	*Disturbance*	*Relative sensitivity to boat/aerial traffic*	*POOR*	*HIGH*
Red-Throated Diver	Furness & Wade 2012	*Disturbance*	*Relative sensitivity to boat/aerial traffic & response distance to boat*	*MODERATE*	*HIGH*
Black-Throated Diver	Dierschke et al. 2016	*Displacement*	*Change in populations pre and post construction*	*GOOD*	*HIGH*
Black-Throated Diver	*Garthe & Huppop, 2004*	*Displacement*	*Habitat use flexibility*	*POOR*	*HIGH*
Black-Throated Diver	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*HIGH*
Black-Throated Diver	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*MODERATE*	*LOW*
Black-Throated Diver	Johnston et al. 2014	Collision	% birds at collision risk height	MODERATE	LOW
Black-Throated Diver	*Garthe & Huppop, 2004*	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*POOR*	*LOW*
Black-Throated Diver	(Langston 2010)	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Black-Throated Diver	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Black-Throated Diver	*Garthe & Huppop, 2004*	*Disturbance*	*Relative sensitivity to boat/aerial traffic*	*POOR*	*HIGH*
Black-Throated Diver	Furness & Wade 2012	*Disturbance*	*Relative sensitivity to boat/aerial traffic & response distance to boat*	*MODERATE*	*HIGH*
Great Northern Diver	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*HIGH*
Great Northern Diver	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability &*	*MODERATE*	*LOW*

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
			nocturnal activity		
Great Northern Diver	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Great Northern Diver	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Great Northern Diver	Furness & Wade 2012	*Disturbance*	*Relative sensitivity to boat/aerial traffic & response distance to boat*	*MODERATE*	*HIGH*
Divers	Lindeboom et al. 2011	Displacement	Change in numbers pre/ post construction	GOOD	LOW
Divers	GoBe Consultants Ltd. 2012	Displacement	Comparison of density inside/outside wind farm	POOR	MODERATE
Divers	Leopold et al. 2009	Displacement	Change in populations pre and post construction	POOR	MODERATE
Divers	Petersen et al. 2006)	Displacement	Comparison of distribution pre/post construction	GOOD	HIGH
Divers	Percival 2010)	Displacement	Change in numbers pre/ post construction	POOR	HIGH
Divers	Welcker & Nehls 2016	Displacement	Comparison of density inside/outside wind farm	GOOD	HIGH
Divers	Lindeboom et al. 2011	Barrier Effects	Distance at which birds change flight direction	MODERATE	HIGH
Divers	Petersen et al. 2006	Barrier Effects	% tracks entering wind farm	MODERATE	HIGH
Divers	Krijgsveld et al., 2011	Barrier Effects	% tracks entering wind farm	MODERATE	MODERATE
European Shag	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*MODERATE*
European Shag	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
European Shag	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
European Shag	Dierschke et al. 2016	*Attraction*	*Change in populations pre and post construction*	*GOOD*	*HIGH*
European	Furness &	*Collision*	*% time flying,*	*MODERATE*	*LOW*

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of Evidence**	**Magnitude**
Shag	Wade 2012		*flight manoeuvrability & nocturnal activity*		
European Shag	Johnston et al. 2014	Collision	% birds at collision risk height	MODERATE	LOW
European Shag	Furness & Wade 2012	*Disturbance*	*Relative sensitivity to boat/aerial traffic*	*POOR*	*MODERATE*
Slavonian Grebe	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*MODERATE*
Slavonian Grebe	Furness & Wade 2012	*Collision*	*% time flying, flight manoeuvrability & nocturnal activity*	*MODERATE*	*LOW*
Slavonian Grebe	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Slavonian Grebe	*Langston (2010*	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*
Slavonian Grebe	Furness & Wade 2012	*Disturbance*	*Relative sensitivity to boat/aerial traffic*	*POOR*	*MODERATE*
Grebes	Krijgsveld et al., 2011	Barrier Effects	% tracks entering wind farm	MODERATE	MODERATE
Black Guillemot	Langston 2010	*Displacement*	*Relative risk of displacement*	*POOR*	*MODERATE*
Black Guillemot	Langston 2010	*Collision*	*Relative collision risk*	*POOR*	*LOW*
Black Guillemot	Langston 2010	*Barrier Effects*	*Relative risk of barrier effects*	*POOR*	*MODERATE*

[1]Differences between sites (Horns Rev & Nysted).

3.2 Marine Renewable Energy Generation (Wave and Tidal)

3.2.1 Literature Summary

We identified seven papers and reports relevant to the impact of wave and tidal renewables on the key study species. Given the relatively young age of the industry, these reports only date back as far as 2001, with five of them coming from the past five years. Of these sources, six of the seven described data relevant to the assessment of the impact of wave and tidal renewables on wintering waterbirds and the remaining study was a review which synthesised data from elsewhere and drew on expert opinion in order to assess the sensitivity of the target species to wave and tidal renewables (Furness, Wade, Robbins, & Masden, 2012). Three of the studies were carried out in the region of interest with data collected from the Pentland Firth, Billia Croo Wave Test Site and Fall of Warness Tidal Test Site in Orkney and the North of Scotland (Robbins 2011a; Robbins 2011b; Wade et al. 2013). The remaining studies were carried out on the Firth of Forth, Scotland and in the German Bight, Alaska and Vancouver Island (Skov & Prins 2001; Drew et al. 2013; Daunt et al. 2014; Holm & Burger 2002).

3.2.2 Pressures

None of the studies identified have been able to directly quantify the pressures likely to be associated with wave and tidal renewables for the target species (see Table 2). Consequently studies tended to focus on parameters which could be used to infer the vulnerability of the species concerned to the pressures associated with wave and tidal renewables. For example, five studies (Robbins 2011a; Robbins 2011b; Holm & Burger 2002; Skov & Prins 2001; Drew et al. 2013) considered the habitat preferences of diving birds, which may indicate the vulnerability to **displacement** if these habitat preferences overlap with suitable locations for wave and tidal renewable devices. Two studies (Wade et al. 2013; Daunt et al. 2014) considered the diving behaviour of target species, which may be of relevance to **collision** as it could be used to assess whether birds are likely to interact with devices whilst foraging. Habitat loss is also likely to be a pressure associated with wave and tidal renewables but as for offshore wind, there is a lack of studies.

3.2.3 Methods for Quantifying Impact

Given that the wave and tidal renewable energy industry is still in its infancy, none of the studies of relevance which we identified reported data, were able to quantify the interactions between the target species and wave or tidal devices. Consequently, the quality of evidence available with which to quantify the impacts of wave and tidal devices on the target species is assessed as low.

The level of habitat specialisation of the target species was assessed by five studies. Of these, three reported the results from boat or vantage point surveys (Robbins 2011a; Robbins 2011b; Holm & Burger 2002) and two modelled the distribution of the target species in relation to habitat (Drew et al. 2013; Skov & Prins 2001). These studies may be of relevance to assessments of how vulnerable species are likely to be to displacement if they show that birds have strong preferences for the habitats suitable for wave or tidal devices.

We identified two studies describing the diving behaviour of target species. The first used statistical analysis of geo-location immersion data to quantify the length of time spent foraging (Daunt et al. 2014) and the second used vantage point surveys to assess the direction of diving relative to the direction of the current (Wade et al. 2013). These studies may be of relevance to collision as they may show how diving behaviour brings them into contact with wave or tidal devices.

Furness et al. (2012) reviewed the sensitivity of target species to wave and tidal renewable energy devices based on expert opinion and existing data. In particular, they considered the quantity of benthic prey in a species diet and habitat specialization, which may relate to a species vulnerability to displacement, species use of tidal races, which may relate to the likelihood of species coming into contact with renewable energy devices and species risk of drowning, which may relate to a species likelihood of suffering additional mortality as a consequence of coming into contact with a renewable energy device. However, at present, it should be noted that it is unclear whether a collision with underwater turbine blades, which move more slowly than the blades of wind turbines, would result in mortality.

3.2.4 Synthesis of Evidence for Impacts

Studies assessing the impact of pressures associated with wave or tidal renewable energy on target species in the non-breeding season are listed in Table 5. Evidence was largely drawn from reviews and expert opinion, with little quantitative data. Consequently, assessments of the magnitude of each impact followed those presented in the reviews.

Of the target species, the review of Furness et al. (2012) concluded that five – Common Goldeneye, Velvet Scoter, Eider, Long-tailed Duck and Black Guillemot - were heavily dependent on benthic prey. Consequently, if the installation of a wave or tidal renewable energy device results in depletion of this resource, for example through damage to the substrate, species may be vulnerable to this impact. This may be less important for species like divers which make greater use of the water column when foraging.

Several studies identified strong habitat preferences among the target species in relation to tidal depth and strength of current (Robbins 2011a; Robbins 2011b; Holm & Burger 2002; Drew et al. 2013). Where these preferences overlap with suitable locations there is potential for birds to be vulnerable to displacement, or exposed to risk of collision. However, of the target species, only European Shag and Black Guillemot make significant use of the tidal races typically used for renewable energy devices (Furness et al., 2012). Over winter, the European Shag spends a significant proportion of its time foraging (Daunt et al. 2014) so may also have a high risk of drowning (Furness et al., 2012), and may also be exposed to an increased risk of collision with wave or tidal energy devices.

3.2.5 Conclusions and Knowledge Gaps

Evidence about the likely impact of wave or tidal renewable energy devices on wintering waterbirds is extremely limited. Studies relate to the behaviour, dietary and habitat preferences of the species concerned, drawing inferences about how they may interact with such devices, as opposed to quantifying actual interactions. Consequently, the evidence base with which to assess any potential impacts is considered to be of low quality. However, based on the available evidence, it is likely that European Shag and Black Guillemot are likely to be the most severely impacted species as their preferred foraging habitat more closely matches the requirements for these devices than is the case for other species.

Table 5

Studies assessing the impact of pressures associated with wave or tidal renewable energy on target species in the non-breeding season. As quantitative information about the magnitude of any impacts was extremely limited, assessments largely followed those presented in the cited reviews. Consequently, the quality of evidence presented by each study is assessed as POOR as they describe characteristics from which interactions with wave or tidal renewable energy devices may be inferred, as opposed to presenting data quantifying observed impacts between birds and wave or tidal renewable energy devices. No studies were considered to provide MODERATE or GOOD quality of evidence. N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
Common Eider	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*HIGH*
Common Eider	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*
Common Eider	Robbins 2011a	Displacement	Habitat preferences	POOR	N/A
Common Eider	Robbins 2011b	Displacement	Habitat preferences	POOR	N/A
Common Eider	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Common Eider	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*HIGH*
Long-Tailed Duck	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*HIGH*
Long-Tailed Duck	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*
Long-Tailed Duck	Holm & Burger 2002	Displacement	Habitat preferences	POOR	N/A
Long-Tailed Duck	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Long-Tailed Duck	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*HIGH*
Velvet Scoter	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*MODERATE*

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
Velvet Scoter	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*
Velvet Scoter	Drew et al. 2013	Displacement	Habitat preferences	POOR	N/A
Velvet Scoter	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Velvet Scoter	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*HIGH*
Common Goldeneye	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*HIGH*
Common Goldeneye	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*
Common Goldeneye	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Common Goldeneye	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*HIGH*
Red-Breasted Merganser	Holm & Burger 2002	Displacement	Habitat preferences	POOR	N/A
Red-Breasted Merganser	Drew et al. 2013	Displacement	Habitat preferences	POOR	N/A
Red-Throated Diver	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*HIGH*
Red-Throated Diver	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*
Red-Throated Diver	Robbins 2011a	Displacement	Habitat preferences	POOR	N/A
Red-Throated Diver	Skov & Prins 2001	Displacement	Habitat preferences	POOR	MODERATE
Red-Throated Diver	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Red-Throated Diver	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*MODERATE*
Black-Throated Diver	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*HIGH*
Black-Throated Diver	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
Black-Throated Diver	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Black-Throated Diver	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*MODERATE*
Great Northern Diver	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*MODERATE*
Great Northern Diver	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*
Great Northern Diver	Holm & Burger 2002	Displacement	Habitat preferences	POOR	N/A
Great Northern Diver	Drew et al. 2013	Displacement	Habitat preferences	POOR	N/A
Great Northern Diver	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Great Northern Diver	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*MODERATE*
Great Northern/Red-Throated Diver	Robbins 2011b	Displacement	Habitat preferences	POOR	N/A
European Shag	Daunt et al. 2014	Collision	Length of time spent foraging	POOR	HIGH
European Shag	Wade et al. 2013	Collision	Diving Behaviour	POOR	HIGH
European Shag	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*HIGH*
European Shag	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*HIGH*
European Shag	Robbins 2011a	Displacement	Habitat preferences	POOR	N/A
European Shag	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
European Shag	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*MODERATE*
Slavonian Grebe	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*HIGH*
Slavonian Grebe	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*LOW*

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of Evidence**	**Magnitude**
Slavonian Grebe	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Slavonian Grebe	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*MODERATE*
Black Guillemot	Wade et al. 2013	Collision	Diving Behaviour	POOR	HIGH
Black Guillemot	Furness et al. 2012	*Displacement*	*Habitat specialisation*	*POOR*	*MODERATE*
Black Guillemot	Furness et al. 2012	*Displacement*	*Use of tidal races*	*POOR*	*HIGH*
Black Guillemot	Robbins 2011a	Displacement	Habitat preferences	POOR	N/A
Black Guillemot	Robbins 2011b	Displacement	Habitat preferences	POOR	N/A
Black Guillemot	Furness et al. 2012	*Drowning*	*Risk of entanglement*	*POOR*	*HIGH*
Black Guillemot	Furness et al. 2012	*Prey Depletion*	*% Benthic prey in diet*	*POOR*	*HIGH*

3.3 Hydrocarbons – Oil and Gas Extraction

3.3.1 Literature Summary

We identified 21 papers and reports relevant to the impact of pollution and contamination on the target species. Of these, 18 provided new data while the remaining three reviewed previously-existing data. Only one of the sources of primary literature has been published within the last five years and another one within the last ten years. One study (Webb et al. 2016) included Orkney as it was based on the whole of Britain, while other locations ranged from North America to Japan, including some European studies, mainly the British Isles, Spain, the Baltic Sea and the Netherlands.

3.3.2 Pressures

The pressures relating to oil and gas activities that emerged were **pollution** and **contamination** (two data-driven studies) and a combination of the two (one data-driven study). The pressure considered most often was pollution (15 new-data papers and four reviews) associated with major oil spills in North America (Page et al. 1990; PIatt et al. 1990; Agler et al. 1999; Hampton et al. 2003; Robertson et al. 2006) and Europe (Camphuysen et al. 2002; Castège et al. 2004; Larsson & Tydén 2005), Britain in particular (Hope Jones et al. 1978; Heubeck & Richardson 1980; Banks et al. 2008). Contamination studies originated from oil spills in Japan (Yamato et al. 1996) and North America (Lucas & MacGregor 2006).

3.3.3 Methods for Quantifying Impact

Some studies, especially older ones, report the number of oiled birds found by opportunistically searching beaches after an oil spill event (Hope Jones et al. 1978; Heubeck & Richardson 1980; Page et al. 1990; PIatt et al. 1990; Lucas & MacGregor 2006; Robertson et al. 2006). Other projects used standardised monitoring of beaches e.g. beached bird surveys (Simons 1985; Camphuysen et al. 2002; Hampton et al. 2003; Castège et al. 2004; Ramunas Žydelis et al. 2006; Wilhelm et al. 2009) whilst some others relied on ad hoc reporting from the public (Yamato et al. 1996; Robertson et al. 2006) or birds caught in fishing nets with oiled plumage (Larsson & Tydén 2005). These studies are likely to identify mortalities associated with small-scale, chronic spills from consumers of the hydrocarbon industry, such as shipping.

Some studies used an analytical approach to calculate sensitivity maps of species. Webb et al. (2016) used existing data from boat-based transects, visual aerial transects and digital aerial video transect data to create monthly sensitivity maps for each species. Williams et al. (1995) calculated an oil vulnerability index for each species based on the risk of pollution from an oil spill, the size of the biogeographic population, the potential for recovery following reduction in population, and the reliability of the species to the marine environment. They combined beached bird surveys and the European Seabirds at Sea database to calculate the risk of pollution by an oil spill of each species, and existing data extracted from the literature to establish biogeographic population size, clutch size and habitat use (Williams et al. 1995). Another study used beached bird surveys, birds taken to rehabilitation centres and data from one boat survey to calculated the numbers of individuals likely to have been impacted by the Apex Houston oil spill (Page et al. 1990)

3.3.4 Synthesis of Evidence for Impacts

All the target species are known to be affected by oil spills and there is evidence that all affected individuals may die soon after (but see 'gap in knowledge' below) (e.g. Heubeck & Richardson 1980; Simons. 1985; Hapton et al. 2003). Likely survival rates of rehabilitated birds are unknown for the target species. Secondary cause of death (starvation, drowning, loss of thermoregulatory capacity, secondary poisoning, by-catch, etc.) cannot always be assessed when looking at carcasses (Camphuysen et al. 2007). An indirect effect of oil spills is drowning, as oiled birds lose the ability to fly and dive and they can get caught in fishing nets. For example, a study in the Baltic Sea found that almost 12% of 1,000 Long-tailed Ducks that had drowned in fish nets at Hoburgs bank had oiled plumage, whereas the overall oiling rate is thought to be much lower (Larsson & Tyden 2005), although it cannot be excluded that birds could have become oiled after drowning. Secondary poisoning from oil has also been reported. In Japan, a small number of Velvet Scoters tested following an oil spill showed haemolytic anaemia, probably caused by ingestion of oil while trying to preen (Yamato et al. 1996).

In terms of evidence on the effect of oil spills at local population level, evidence points to different conclusions. Banks et al. (2008) found no evidence of long-term population decline in Common Scoters, based on bird counts, followed the Sea Empress Oil spill, and suggested that the impact was likely to be displacement of birds to less-favourable feeding sites. A high-quality study based on counts from 19 years before to two years after the Erika oil spill in the Bay of Biscay showed a decline in numbers of Gavia spp diver and Common Scoter but an increase in European Shag (Castege et al. 2004) although this might have been due to displacement rather than increases in mortality rates. Another study showed a mixed response to the Exxon Valdez spill: whilst the local breeding populations of Red-throated Diver, Velvet Scoter and Merganser decreased, the number of Common Goldeneye increased (Agler et al. 1999). The extent to which differences between these studies can be attributed to other factors (e.g. the scale and the timing of the event, the relative importance of affected areas for the target species) is unknown.

There are concurrent views on the vulnerability of target species to oil spills. Williams et al. (1995) calculated that diver spp and Black Guillemots had the highest vulnerability score to oil spills, followed by European Shag, Velvet Scoter, Red-breasted Merganser, Long-tailed Duck and Common Eider. A recent study also found that Red-throated Diver and Great Northern Diver are particularly sensitive to the effect of oil pollution around Orkney and Shetland because of the time they spend sitting on the water at sea, and because of their scarceness and conservation status, this is of particular concern (Webb et al. 2016). The same study, basing its results on the distribution of each species in each month, identified Black-throated Divers and European Shags as high-sensitive species to oil spills because of their winter geographic range, Slavonian Grebe and Common Goldeneye as moderate-to-high sensitivity species, Common Eider, Velvet Scoter, Long-tailed Duck and Black Guillemot as moderate sensitivity species, and Red-breasted Merganser as low-sensitive species (Webb et al. 2016). Finally, a panel of experts identified eiders, auks, cormorants and divers, which all spend a lot of time on the sea surface, as highly vulnerable to oil spills because even a small amount of oil can affect the waterproofing of their feathers (Frederiksen 2010).

Overall, there is consistent high-quality evidence for high to moderate magnitude effect of oil spills on Black Guillemot, Black-throated Diver, Red-throated Diver, Long-tailed Duck and Shag. Evidence is less clear for other species, such as Common Eider, Great Northern Diver and Slavonian Grebe, where high and moderate-quality evidence point in different directions. Finally, there is good evidence of moderate to low impact of oil spills on Common Goldeneye and Velvet Scoters and low impact on Red-breasted Merganser.

3.3.5 Conclusions and Knowledge Gaps

There is evidence of high mortality of all individuals of any target species affected by an oil spill, although secondary causes receive less attention. Research efforts should focus on the source of oil contamination and the mortality associated with large oil spills versus smaller, chronic, oil spills. The effect of oil spills at local population levels is also unclear, as displacement of individuals cannot be discerned from depletion of the local population due to mortality. This is one of the main gaps in knowledge that should be addressed by future studies. Another aspect that requires further investigation is sub-lethal effects of oil pollution on affected individuals (Camphuysen 2007) as the majority of the present studies are biased towards heavily-oiled birds that are already beached and/or dead. Finally, there also does not seem to be any knowledge on the impacts of gas, such as asphyxiation or toxicity, on target species during the winter months. Methodologies used also vary: some studies are based on data collected opportunistically and constitute low value information, while others have been conducted using long-term monitoring data which provide high-quality evidence.

Table 6

Studies assessing the impact of pressures associated with oil and gas pollution in wintering waterbirds. The quality of evidence presented by each study is assessed as POOR as they are based on low number of individuals and/or opportunistic data collection, MODERATE if based on long-term non-standardised data collection or short-term standardised data collection and HIGH-quality evidence is based on long-term standardised data collection. The magnitude of impact is classified as LOW if fewer than 26 individuals of the target species were affected (but the threshold is lower for species occurring at low density) or if less than 10 km of coastline was impacted, or the percentage of individuals affected was ≤15%, or the Oil Vulnerability Index (Williams et al 1995) was ≤10, HIGH if more than 100 individuals were affected (but lower numbers are considered as 'high impact' for species that don't occur at high densities) or if greater than 100 km of coastline was affected, or if the percentage of individuals affected was ≥41% and MODERATE for number of affected individuals in between low and high magnitude. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table. ■ indicates major oil spill, ▲ identifies other oil spillages, and ♦ identifies unspecified oil spills. N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper.

Species	Study	Pressure	Impact	Quality of Evidence	Magnitude
Black Guillemot	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	HIGH
Black Guillemot	Wilhelm et al. 2009▲	Pollution	Mortality	GOOD	MODERATE
Black Guillemot	Robertson et al. 2006 ■	Pollution	Mortality	POOR	LOW
Black Guillemot	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	HIGH
Black-throated Diver	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	HIGH
Black-throated Diver	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	HIGH
Black-throated Diver	Page et al. 1990 ■	Pollution	Mortality	POOR	MODERATE
Black-throated Diver	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	LOW
Black-throated Diver	Hope Jones et al. 1978 ■	Pollution	Mortality	POOR	MODERATE
Common Eider	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	MODERATE
Common Eider	*Frederiksen 2010* ■ ▲	*Pollution*	*Vulnerability to contamination*	*GOOD*	*HIGH*

Species	Study	Pressure	Impact	Quality of Evidence	Magnitude
Common Eider	Wilhelm et al. 2009 ▲	Pollution	Mortality	GOOD	HIGH
Common Eider	Robertson et al. 2006 ■	Pollution	Mortality	POOR	LOW
Common Eider	Castege et al. 2004 ■	Pollution	Mortality	GOOD	LOW
Common Eider	Camphuysen et al. 2002 ▲	Pollution	Mortality	MODERATE	LOW
Common Eider	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	MODERATE
Common Eider	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	HIGH
Common Goldeneye	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	MODERATE
Common Goldeneye	Agler et al. 1999 ■	Pollution	Population change (breeding season abundance)	GOOD	MODERATE
Common Goldeneye	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	MODERATE
Common Goldeneye	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	LOW
Common Scoter	Banks et al. 2008 ■	Pollution	Population change (based on abundance)	MODERATE	LOW
Divers	*Frederiksen 2010* ■ ▲	*Pollution*	*Vulnerability to contamination*	*GOOD*	*HIGH*
Great Northern Diver	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	HIGH
Great Northern Diver	*Camphuysen et al. 2010* ■	*Pollution*	*Mortality*	*POOR*	*MODERATE*
Great Northern Diver	Lucas and MacGregor 2006 ▲	Contamination	Mortality	GOOD	LOW
Great Northern Diver	Hampton et al. 2003 ■	Pollution	Mortality	MODERATE	LOW
Great Northern Diver	*Heubeck 1997* ■	*Pollution*	*Dead birds*	*GOOD*	*HIGH*
Great Northern Diver	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	HIGH
Great Northern Diver	Page et al. 1990 ■	Pollution	Mortality	POOR	MODERATE

Species	Study	Pressure	Impact	Quality of Evidence	Magnitude
Great Northern Diver	Simons 1985 ▲	Pollution	Mortality	GOOD	HIGH
Great Northern Diver	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	HIGH
Great Northern Diver	Hope Jones et al. 1978 ■	Pollution	Mortality	POOR	MODERATE
Long-tailed Duck	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	MODERATE
Long-tailed Duck	Wilhelm et al. 2009 ▲	Pollution	Mortality	GOOD	HIGH
Long-tailed Duck	Žydelis et al. 2006 ▲	Pollution	Oiling rate	GOOD	MODERATE
Long-tailed Duck	Larsson and Tyden 2005 ▲	Pollution	Mortality	POOR	LOW
Long-tailed Duck	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	MODERATE
Long-tailed Duck	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	HIGH
Red-breasted Merganser/ Mergus sp.	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	LOW
Red-breasted Merganser/ Mergus sp.	Žydelis et al. 2006 ▲	Pollution	Oiling rate	GOOD	LOW
Red-breasted Merganser/ Mergus sp.	Hampton et al. 2003 ■	Pollution	Mortality	GOOD	LOW
Red-breasted Merganser /Mergus sp.	Agler et al. 1999 ■	Pollution	Population change (breeding season abundance	GOOD	LOW
Red-breasted Merganser/ Mergus sp.	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	HIGH
Red-breasted Merganser/ Mergus sp.	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	MODERATE
Red-throated Diver	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	HIGH

Species	Study	Pressure	Impact	Quality of Evidence	Magnitude
Red-throated Diver	Hampton et al. 2003 ■	Pollution	Mortality	GOOD	LOW
Red-throated Diver	Agler et al. 1999 ■	Pollution	Population change (breeding season abundance	GOOD	HIGH
Red-throated Diver	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	HIGH
Red-throated Diver	Page 1990 ■	Pollution	Mortality	POOR	LOW
Red-throated Diver	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	LOW
Gavia spp.	Piatt et al. 1990■	Pollution	Mortality	POOR	HIGH
Gavia spp.	Żydelis et al. 2006 ▲	Pollution	Oiling rate	GOOD	MODERATE
European Shag	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	HIGH
European Shag	Castege et al. 2004 ■	Pollution	Mortality	GOOD	LOW
European Shag	Williams et al. 1995 ♦	Pollution/ Contamination	Vulnerability	GOOD	HIGH
European Shag	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	HIGH
European Shag	Hope Jones et al. 1978 ■	Pollution	Mortality	POOR	HIGH
Slavonian Grebe	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	HIGH
Slavonian Grebe	Hampton et al. 2003 ■	Pollution	Mortality	GOOD	LOW
Slavonian Grebe	Page 1990■	Pollution	Mortality	POOR	LOW
Slavonian Grebe	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	LOW
Velvet Scoter	Webb et al. 2016 ♦	Pollution	Vulnerability	GOOD	MODERATE
Velvet Scoter	Żydelis et al. 2006 ▲	Pollution	Oiling rate*	GOOD	MODERATE
Velvet Scoter	Agler et al. 1999 ■	Pollution	Population change (breeding)	GOOD	MODERATE

Species	Study	Pressure	Impact	Quality of Evidence	Magnitude
Velvet Scoter	Yamato et al. 1996 ■	Contamination	Haemolytic anaemia**	POOR	LOW
Velvet Scoter	Williams et al. 1995 ♦	Pollution	Vulnerability	GOOD	HIGH
Velvet Scoter	Page 1990 ■	Pollution	Mortality	POOR	LOW
Velvet Scoter	Heubeck and Richardson 1980 ■	Pollution	Mortality	MODERATE	LOW

* Mortality was not recorded but individuals affected would die

** Mortality was not recorded but if left untreated it would likely cause death of the individual

3.4 Fisheries

3.4.1 Literature Summary

We identified 39 fisheries references with species-specific impacts identified for one or more target species. Of these, 33 were primary data sources, and six were reviews or reports using secondary data. Seven studies included data collected in the last five years; ten studies included data collected between 2006 and 20011 and the remaining 22 studies were more than ten years old. A high proportion of studies were from the Baltic Region (19), nine were from the North Atlantic (of which six were from the North Sea), seven studies were from North America, two from the Mediterranean and three were multiple locations. There were no studies from the region of interest (Orkney and the Western Isles).

3.4.2 Pressures

The pressures that fisheries exert on seabirds include direct effects such as **mortality** or injury from entanglement in fishing gear (**by-catch**) and indirect effects such as altering prey availability through **prey depletion** (Frederiksen 2010; Furness & Tasker 2000), enhancing food availability through discards (Frederiksen 2010) and **disturbance** (Tasker et al. 2000). Discards can also lead to toxic **contamination** (Arcos et al. 2002). The vast majority of fisheries studies assessed the impact of fisheries by-catch on birds, whereas literature on indirect pressures was sparser.

3.4.3 Fishing Gear Types Likely to Impact Target Species

Fisheries gear used in the North Atlantic and North Sea include mobile gear such as bottom trawls, and pelagic trawls, and stationary gear such as stationary uncovered poundnets, gill nets, Trammelnets and purse seine nets (ICES 2013). As by-catch is generally poorly monitored and studies are often limited in their spatial or temporal coverage, the scale of the problem is poorly understood, but likely to be substantial (Frederiksen 2010; ICES 2013). While there is recorded evidence of mortality for some target species from specific gear types, other unreported interactions may exist. By-catch risk for nets and traps encompasses a wide range of species, including divers, grebes, cormorants, seaducks and auks (Tasker et al. 2000; Žydelis et al. 2009; Kindt-Larsen et al. 2012). Birds that dive for prey and feed in dense flocks are most susceptible to being caught in stationary gill nets (Atkins & Heneman 1987). The main bird species by-caught by trawls are non-target species; however, bottom trawls may also affect cormorants. Set longlines mainly affect non-target species, but auks, Red-breasted Merganser and European Shag may also be affected (Fitzgerald 2016; Dunn & Steel 2001; Tasker et al. 2000; ICES 2013).

3.4.4 Methods for quantifying impact

Much of the data relating to bycatch are relatively local-scale (e.g. numbers of birds affected) and are not collected in a systematic way typified by monitoring programmes. Methods for assessing the rate of bycatch generally involve counts of entangled or drowned birds provided by fishermen on a voluntary or paid basis (e.g. Bardtrum et al. 2009; Stempniewicz 1994; Urtans & Priednieks 2000; Piatt & Nettleship 1987) or by independent observers on board fishing vessels (e.g. Benjamins et al. 2008; Garcia-Barcelona et al. 2010; Warden 2010).

Observations of bycatch are often collected in a non-systematic way or reported anecdotally (e.g. Durinck et al. 1993; Larsson & Tydén 2005). These studies have limited use for assessing the magnitude of the impacts; although they may provide some indication of relative vulnerability of species groups. Other studies provided bycatch rates according to an imprecise unit of fishing effort, such as number of birds drowned per boat per winter (Stempniewicz 1994; Kies & Tomek 1990) or per fisherman per winter (Bellebaum et al. 2013). While these studies are slightly more informative for judging the magnitude of impacts for the species recorded, the actual level of fishing effort per boat or per fisherman is not clear. The most clearly-quantified impacts come from studies recording bycatch rate as number of birds per length of net per unit of time, such as 1000 net metre days (NMD) (e.g. Benjamins et al. 2008; Dagys & Žydelis 2002).

Beached bird surveys are an alternative method for studying bycatch (e.g. Žydelis et al. 2006). This method likely underestimates true bycatch rates, but can determine the proportion of birds mortality that was entanglement-related, relative to other pressures such as oil pollution (Žydelis et al. 2006).

Studies varied widely in the period over which data were collected, ranging from a single night (e.g. Durinck et al. 1993) to year round observations (e.g. Julian & Beeson 1998; Bellebaum et al. 2013) and few studies recorded characteristics of nets that were set.

The population-scale effects of bycatch can be assessed using ringing recovery data (e.g. change in survival rates, Balken & Falk 1998), although this method underestimates bycatch rate as the number of unreported recoveries is unknown.

These types of studies are rare as they are labour intensive and it may take many years to recover the birds.

3.4.5 Synthesis of Evidence for Impacts

Table 7 contains a summary of the documented evidence of impacts from pressures associated with fisheries. Where possible, we have based our assessment of impact magnitude on by-catch rates, which provide a fairly standardised way of assessing the risk to each species, and give an indication of potential risk level in areas where the species occur but the impact has not been measured. However, it should be noted that low by-catch rates can lead to a large by-catch if the fishing effort is high. Furthermore, the impact of by-catch at the population-level will depend on demographic factors such as population growth rate (Hamel et al. 2009).

Based on the consensus of studies reported in Table 7, high by-catch rates were commonly reported Long-tailed Duck and low by-catch rates were generally reported for the divers, Common Goldeneye, European Shag, Slavonian Grebe, and Red-breasted Merganser. There was a lack of consensus for Common Eider, Velvet Scoter and Black Guillemot, with varying by-catch rates reported for these species.

Few studies were able to draw conclusions about within-year variation in by-catch rates and identify periods of greatest risk; although Bellebaum et al. (2013) noted that by-catch risk for Long-tailed Duck in the Baltic Sea is highest during the spring migration period.

Characteristics of fishing gear, such as net depth, was rarely recorded with a few exceptions - Bardtrum et al. (2009), who found that Velvet Scoter was caught in a net <5 m deep, whereas Black Guillemot was caught in nets 10-15 m deep and Common Eider was found in nets 0-20 m, but not in nets deeper than 20 m. However, these observations were based on a very small sample size. Piatt & Nettleship (1987) recorded incidental by-catch off the coast of Newfoundland, and of the 185 Black Guillemot caught, 81% were in salmon gill nets; 17% were in cod gill nets; 2% were in cod traps. All birds were caught in nets from 0-70 m deep, but the majority of birds were caught in nets 0-20 m deep. The four scoters caught were in cod gill nets, and the 23 Common Eiders were in cod gill nets set 10-30 m deep. Warden (2010) found that by-catch rates of Great Northern Diver were higher for lines of nets without spacing between them compared with nets with spacing, and for nets that fished ≥24 h compared with those that fished <24 h. This study also noted the environmental factors most strongly associated with by-catch rate of Great Northern Diver were bottom depth and sea surface temperature.

Good et al. 2009 studied the impacts of derelict fishing gear; 902 derelict nets from the Puget Sound, USA. Fourteen percent of recovered gill nets had entangled marine birds (species included Velvet Scoter, Great Northern Diver and Red-throated Diver), indicating that derelict gear from fisheries is an additional risk to that posed from active fishing gear. The nets most likely to have entangled birds were relatively new (<1 year) and in good condition, occurring at depths of 20-40 m.

We found no studies that assessed indirect impacts of fisheries on wintering birds through prey depletion, although Black Guillemot, Red-throated Diver and Shag are moderately vulnerable to sandeel abundance during the breeding season (Furness & Tasker 2000). Tasker et al. (2000) suggest that depletion of large, predatory fish in the North Sea may increase the availability of smaller prey for piscivourous birds, which could have an overall positive effect on their populations.

There was of high levels of Hg in the livers of European Shags through eating contaminated fish discarded by fisheries in the Mediterranean (Arcos et al. 2002). This study was conducted in the breeding season but the species could also be exposed to these contaminants during winter.

The population-level impacts of particular gear types are largely unknown, but a review of the impact of fishing gear types on various species groups concluded that the population-level impacts of gill net by-catch was moderate to divers and low to grebes, and that for fish traps was low for both species groups (Tasker et al. 2000).

3.4.6 Conclusions and Knowledge Gaps

The full extent of impact of fisheries on non-breeding waterbirds is largely unknown due to lack of systematic monitoring effort of by-catch. The true extent of impacts from fisheries by-catch are likely to be underestimated for a number of reasons – underreporting, birds may be injured by fishing gear, but are not killed immediately, so are not reported in by-catch figures, but they ultimately die from their injuries. Birds that feed in large aggregations are more likely to be by-caught in large numbers (Benjamins et al. 2008). Therefore, more widely dispersed species such as divers and Black Guillemots are less likely to be caught in large numbers. However, impact of by-catch is more likely to be underestimated on these species (Piatt & Nettleship 1987). The lack of systematic monitoring also means data are lacking on the within-year variation in by-catch risk for different species, and when they are most vulnerable.

Table 7

Studies assessing the impact of pressures associated with fisheries on target species in the non-breeding season. The strength of the methodologies for each study are assessed as being POOR (based on expert opinion, anecdotal data or analysis with a low statistical power, with fishing/observer effort not taken into account), MODERATE (expert opinion supported by robust data collection and or data collected following standard survey methodologies, taking fishing/observer effort into account) or GOOD (data collected using standardised survey methodologies and analysed with appropriate techniques, with fishing/observer effort accounted for in a standardised way). The magnitude of impacts was classified according to the reported by-catch rates of the study. By-catch rates of <0.1 birds/1000 NMD were LOW, <1 bird/1000 NMD were MODERATE and ≥1 were HIGH, or if the impact was estimated to effect >1% of the population. By-catch rates with no indication of observer effort or fishing effort, the magnitude column was marked as N/A. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of evidence**	**Magnitude**
Common Eider	*Tasker et al. 2000*	*Bycatch*	*Population-level impact of fishery*	*POOR*	*MODERATE*
Common Eider	Bardtrum et al. 2009	Bycatch	Mortality	POOR	N/A
Common Eider	Benjamins et al. 2008	Bycatch	Mortality	MODERATE	LOW
Common Eider	Ellis et al. 2013	Bycatch	Mortality	MODERATE	N/A
Common Eider	Kirchhoff 1982 (cited in Žydelis et al. 2009)	Bycatch	Mortality	POOR	MODERATE
Common Eider	Lunneryd et al 2004 (cited in Žydelis et al. 2009)	Bycatch	Mortality	POOR	N/A
Common Eider	Mentjes and Gabriel 1999 (cited in Žydelis et al. 2009)	Bycatch	Mortality	MODERATE	HIGH
Common Eider	Merkel 2004	Bycatch	Mortality	MODERATE	MODERATE
Common Eider	Piatt & Nettleship 1987	Bycatch	Mortality	MODERATE	LOW

Species	Study	Pressure	Parameter Measured	Quality of evidence	Magnitude
Common Eider	Stempniewicz 1994	Bycatch	Mortality	POOR	MODERATE
Common Eider	*Żydelis et al. 2009*	*Bycatch*	*Mortality*	*POOR*	*MODERATE*
Eiders	*Frederiksen 2010*	*Prey enhance ment (discards)*	*Vulnerability*	*POOR*	*LOW*
Eiders	*Frederiksen 2010*	*Prey depletion*	*Vulnerability*	*POOR*	*LOW*
Long-tailed Duck	Bellebaum et al. 2013	Bycatch	Mortality	MODERATE	MODERATE
Long-tailed Duck	Bellebaum et al. 2009	Bycatch	Mortality	POOR	N/A
Long-tailed Duck	Dagys & Żydelis 2002	Bycatch	Mortality	MODERATE	MODERATE
Long-tailed Duck	Kies and Tomek 1990 (cited in Żydelis et al. 2009)	Bycatch	Mortality	POOR	HIGH
Long-tailed Duck	Kowalski and Manikowski 1982 (cited in Żydelis et al. 2009)	Bycatch	Mortality	POOR	HIGH
Long-tailed Duck	Larsson & Tydén 2005	Bycatch	Mortality	POOR	N/A
Long-tailed Duck	Schirmeister 2003 (cited in Żydelis et al. 2009)	Bycatch	Mortality	POOR	MODERATE
Long-tailed Duck	Stripniece et al 2008 (cited in Żydelis et al. 2009)	Bycatch	Mortality	POOR	MODERATE
Long-tailed Duck	Stempniewicz 1994	Bycatch	Mortality	POOR	HIGH
Long-tailed Duck	Urtans & Priednieks 2000	Bycatch	Mortality	POOR	N/A
Long-tailed Duck	Vetemaa 2008 (cited in Żydelis et al. 2009)	Bycatch	Mortality	POOR	MODERATE
Long-tailed Duck	Żydelis et al. 2006	Bycatch	Mortality	POOR	N/A
Long-tailed Duck	*Żydelis et al. 2009*	*Bycatch*	*Mortality*	*POOR*	*HIGH*

Species	Study	Pressure	Parameter Measured	Quality of evidence	Magnitude
Velvet Scoter	Bardtrum et al. 2009	Bycatch	Mortality	POOR	N/A
Velvet Scoter	Dagys & Žydelis 2002	Bycatch	Mortality	MODERATE	MODERATE
Velvet Scoter	Durinck et al. 1993	Bycatch	Mortality	POOR	HIGH
Velvet Scoter	Good et al. 2009	Bycatch	Mortality	MODERATE	LOW
Scoter spp.	Good et al. 2009	Bycatch	Mortality	MODERATE	LOW
Velvet Scoter	Kies and Tomek 1990 (cited in Žydelis et al. 2009)	Bycatch	Mortality	POOR	MODERATE
Velvet Scoter	Kowalski and Manikowski 1982 (cited in Žydelis et al. 2009)	Bycatch	Mortality	POOR	HIGH
Scoter spp.	Piatt & Nettleship 1987	Bycatch	Mortality	MODERATE	LOW
Velvet Scoter	Piatt & Nettleship 1987	Bycatch	Mortality	MODERATE	LOW
Velvet Scoter	Stempniewicz 1994	Bycatch	Mortality	POOR	MODERATE
Velvet Scoter	*Žydelis et al. 2009*	*Bycatch*	*Mortality*	*POOR*	*MODERATE*
Velvet Scoter	Žydelis et al. 2006	Bycatch	Mortality	POOR	N/A
Common Goldeneye	Stempniewicz 1994	Bycatch	Mortality	POOR	LOW
Common Goldeneye	Witteveen and Bos 2003 (cited in Žydelis et al. 2009)	Bycatch	Mortality	POOR	LOW
Red-breasted Merganser	Bellebaum et al. 2009	Bycatch	Mortality	POOR	N/A
Red-breasted Merganser	Stempniewicz 1994	Bycatch	Mortality	POOR	LOW
Red-breasted Merganser	van Eerden et al 1999 (cited in Žydelis et al. 2009)	Bycatch	Mortality	MODERATE	MODERATE

Species	Study	Pressure	Parameter Measured	Quality of evidence	Magnitude
Red-breasted Merganser	*Żydelis et al. 2009*	*Bycatch*	*Mortality*	*POOR*	*LOW*
Red-throated Diver	Good et al. 2009	Bycatch	Mortality	MODERATE	LOW
Red-throated Diver	Schirmeister 2003 (cited in Żydelis et al. 2009)	Bycatch	Mortality	POOR	LOW?
Red-throated Diver	Stempniewicz 1994	Bycatch	Mortality	POOR	LOW?
Red-throated Diver	Warden 2010	Bycatch	Mortality	MODERATE	N/A
Black-throated and Red-throated Diver	Dagys & Żydelis 2002	Bycatch	Mortality	MODERATE	LOW
Black-throated Diver	Stempniewicz 1994	Bycatch	Mortality	POOR	LOW
Black-throated Diver	*Żydelis et al. 2009*	*Bycatch*	*Mortality*	*POOR*	*LOW*
Great Northern Diver	Good et al. 2009	Bycatch	Mortality	MODERATE	LOW
Great Northern Diver	Julian & Beeson 1998	Bycatch	Mortality	MODERATE	LOW
Great Northern Diver	Piatt & Nettleship 1987	Bycatch	Mortality	MODERATE	MODERATE
Great Northern Diver	Stempniewicz 1994	Bycatch	Mortality	POOR	LOW
Great Northern Diver	Warden 2010	Bycatch	Mortality	MODERATE	N/A
Divers	*Tasker et al. 2000*	*Bycatch*	*Population level impact*	*POOR*	*LOW/MODERATE*
Divers	*Tasker et al. 2000*	*Disturbance*	*Population level impact*	*POOR*	*LOW*
Slavonian Grebe	Stempniewicz 1994	Bycatch	Mortality	POOR	LOW
Slavonian Grebe	*Żydelis et al. 2009*	*Bycatch*	*Mortality*	*POOR*	*LOW*
Grebes	*Tasker et al. 2000*	*Bycatch*	*Population level impact*	*POOR*	*LOW*

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of evidence**	**Magnitude**
European Shag	Arcos et al. 2002	Contamination	Level of Contamination	POOR	LOW
Cormorants	Garcia-Barcelona et al. 2010	Bycatch	Mortality	GOOD	LOW
Black Guillemot	Stempniewicz 1994	Bycatch	Mortality	POOR	LOW
Black Guillemot	Balken & Falk 1998	Bycatch	Mortality	MODERATE	HIGH
Black Guillemot	Bardtrum et al. 2009	Bycatch	Mortality	POOR	N/A
Black Guillemot	Benjamins et al. 2008	Bycatch	Mortality	MODERATE	LOW
Black Guillemot	Piatt & Nettleship 1987	Bycatch	Mortality	MODERATE	HIGH
Black Guillemot	*Žydelis et al. 2009*	*Bycatch*	*Mortality*	*POOR*	*HIGH*

3.5 Shellfishing

3.5.1 Literature Summary

Twelve papers discussing the impact of shellfisheries to target species were identified. These included ten reporting primary data, and one review. The majority of studies discussed impacts to Common Eider, with the exception of two studies on European Shag from the Farne Isles (Coulson et al. 1968; Armstrong et al. 1978), two studies on Velvet Scoter in the North Sea (Leopold 1996 (original reference in Dutch, quoted in Tasker et al., 2000) and Western Canada (Žydelis et al. 2006) and one on divers in Bantry Bay, SW Ireland (Roycroft et al. 2004). Of the studies on Eider, four were in the Waddensea (Beukema 1992; Camphuysen et al. 2002; Laursen et al. 2009; Smit et al. 1998), one in the North Sea (Ross et al. 2001) and one in North America (Guillemette & Himmelman 1996). None of these studies included data from the last five years, only one included data from the last ten years; the remainder were published before 2006. No studies were based in Orkney and the Western Isles.

3.5.2 Pressures

The pressures exerted by shellfisheries on non-breeding waterbirds include **prey depletion** – both in terms of the species that are removed by the shellfishery and increased mortality to other benthic invertebrates during harvesting (Piersma et al. 2001). Shellfish are often harvested by mechanical dredging of the seabed, which disturbs the sediment and can lead to **increased sedimentation and turbidity** (Mercaldo-Allen & Goldberg 2011). Birds consuming shellfish are susceptible to **toxic contamination**, including paralytic shellfish poisoning (Shumway et al. 2003; Coulson et al. 1968; Armstrong et al. 1978). Harvesting activities may create **disturbance** (Leopold 1996) or **loss of foraging habitat** either of which may lead to birds being **displaced** from the site (Laursen et al. 2009; Smit et al. 1998; Žydelis et al. 2006). Shellfisheries could potentially provide localised benefits to birds such as Common eider through enhanced food availability, provided the birds are not excluded from the site (e.g. Ross et al. 2001).

3.5.3 Methods for Quantifying Impact

A variety of methods were used for looking at the impacts of shellfisheries to target species. Large-scale mortality and displacement of Common Eiders from areas in the Waddensea depleted of shellfish resource have been studied using long-term systematic counts (Smit et al. 1998; Beukema 1992). The evidence for this long-term effect has been collated from the shore-based (Guillemette & Himmelman 1996), ship-based (Camphuysen et al. 2002) and aerial counts (Laursen et al. 2009; Camphuysen et al. 2002). Evidence linking these changes to depletion of shellfish included a study of individually marked birds showing individuals feeding in depleted areas becoming more emaciated (Laursen & Frikke 2008) and an increased parasite load resulting from prey switching to shore crabs *Carcinus maenus* (Camphuysen et al. 2002). One study looked at the habitat features, including presence of aquaculture that determined the abundance of Velvet Scoter (Žydelis et al. 2006). The impact of toxic contamination from shellfish tended to be studied using dead birds that were collected opportunistically rather than systematically (Coulson et al. 1968; Armstrong et al. 1978).

3.5.4 Synthesis of Evidence for Impacts

Table 8 contains a summary of the documented evidence of impacts from pressures associated with shellfisheries. The effects of over-fishing of bivalves (mainly mussels and cockles) in the Waddensea have had deleterious effects on the population of Common Eider, with 10,000–20,000 birds estimated to have died from starvation or been displaced from the Waddensea due to low prey availability (Beukema 1992). Additional mortality is thought to have been caused by birds prey-switching to shore crabs resulting in increased parasite loads (Beukema 1992; Smit et al. 1998).

There were few studies looking at the effect of disturbance from shellfisheries on birds, but anecdotally, vessels associated with the *Spisula subtruncata* fishery are known to cause disturbance to the Velvet Scoter that winter in the southern North Sea (Leopold 1996). In addition, a study on the use of underwater playback systems simulating boat noise as a deterrent to Common Eider at mussel farms reported 50-80% of the birds being displaced from the site during periods of playback (Ross et al. 2001). This study also noted that the birds were more likely to remain at the site while the playback was occurring if there was a lack of suitable resources elsewhere. This is an important general point relating to disturbance studies because sometimes pressures in the environment which have the potential to cause physiological stress and increased metabolic costs to the birds do not create measurable behavioural responses, so their true impact is overlooked (Cyr & Romero 2009a).

Žydelis et al. (2006) concluded that generally aquaculture at the present densities found along the west coast of Canada (32% of the intertidal area) does not negatively impact Velvet Scoters, and the abundance and distribution of birds is determined by natural features rather than the presence of aquaculture; although, impacts may occur at higher densities of aquaculture. The presence of oyster rafts did, however, did influence the presence of Velvet Scoters – and although the mechanism was unclear it may have been due to disturbance from human activity around these structures.

The mass mortality events of European Shags affected by paralytic shellfish poisoning (PSP) in Northumberland were based on studies of breeding birds (Coulson et al. 1968; Armstrong et al. 1978), but similar effects could be expected in non-breeding populations. Other species susceptible to toxic contamination through consuming bivalves include Common Eider, which are known to feed on mussels (Leopold et al. 1996) and species that use the coast, like European Shags, are at high risk of algal toxins (Shumway et al. 2003) .

3.5.5 Conclusions and Knowledge Gaps

While we found evidence of prey depletion from shellfisheries creating large-scale impacts to Common Eider populations, this pressure is also likely to affect the other target species that consume bivalve molluscs – Velvet Scoter, Common Goldeneye and Long-tailed Duck, and to a lesser extent, European Shag. Likewise, the toxic contamination from PSP shown to affect European Shag is also likely to impact all these species.

Table 8

Studies assessing the impact of pressures associated with shellfisheries on target species in the non-breeding season. Quality of evidence was defined as POOR for studies are those based on opportunistic or ad hoc records and MODERATE or GOOD for studies that were based on standardised monitoring methods. MODERATE quality studies may have used standardised monitoring methods, but did not control for other factors within the analysis, therefore, could not convincingly demonstrate causality. Magnitude was defined as LOW if no impact occurred or if impacts measured were short-term and reversible (e.g. birds disturbed momentarily during disturbance). MODERATE impacts were reversible, but longer-term (e.g. several hours). HIGH magnitude meant the effects to the birds were long-term (e.g. days/weeks/months) or irreversible. N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of evidence**	**Magnitude**
Common Eider	Beukema 1992	Prey depletion	Displacement	POOR	HIGH
Common Eider	Beukema 1992	Prey depletion	Mortality	POOR	HIGH
Common Eider	Ross et al. 2001	Disturbance	Displacement	GOOD	MODERATE
Common Eider	Camphuysen et al. 2002	Prey depletion	Decrease in body condition	MODERATE	HIGH
Common Eider	Camphuysen et al. 2002)	Prey depletion	Mortality	MODERATE	HIGH
Common Eider	Camphuysen et al. 2002	Prey depletion	Displacement	MODERATE	HIGH
Common Eider	Guillemette & Himmelman 1996	Prey depletion	Displacement	MODERATE	N/A
Common Eider	Laursen et al. 2009	Prey depletion	Decrease in body condition	GOOD	MODERATE
Common Eider	Laursen et al. 2009	Prey depletion	Displacement	GOOD	MODERATE
Common Eider	Smit et al. 1998	Prey depletion	Displacement	MODERATE	HIGH
Common Eider	Smit et al. 1998	Prey depletion	Mortality	MODERATE	HIGH
Velvet Scoter	Žydelis et al. 2006	Habitat loss	Displacement	GOOD	LOW
Velvet Scoter	Leopold 1996 (cited in Tasker et al. 2000)	Disturbance	N/A	N/A	N/A
Velvet Scoter	Leopold 1996 (cited in Tasker et al. 2000)	Prey depletion	N/A	N/A	N/A

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of evidence**	**Magnitude**
Divers	Roycroft et al. 2004	Multiple pressures	Displacement	MODERATE	LOW
European Shag	Armstrong et al. 1978	Contamination	Mortality	MODERATE	HIGH
European Shag	Coulson et al. 1968	Contamination	Mortality	MODERATE	HIGH
European Shag	*Shumway et al. 2003*	*Contamination*	*Mortality*	*GOOD*	*HIGH*

3.6 Fish Farms

3.6.1 Literature Summary

No primary literature relating the impacts of fish farms to target species was identified. One review paper suggested that fish farms could cause moderate impacts to Eiders at the regional scale (Tasker et al. 2000) (see Table 9).

3.6.2 Pressures

The potential ways that fish farms could impact wintering waterbirds include **prey depletion**, as smaller fish are harvested to provide food for the larger farmed species. However, the farmed species could also increase food availability, and studies on the impacts of salmonid farming on coastal ecosystems in Chile have reported increases in bird abundance and species diversity in response to the increased food supply provided by fish farms (Buschmann et al. 2006; Jiménez et al. 2013). Other potential pressures include **displacement**, **disturbance**, and **pollution**, but there were no studies evaluating the impact of these to target species.

3.6.3 Conclusions and Knowledge Gaps

More research is needed to assess the effects of fish farming to non-breeding waterbirds.

Table 9

Summary of documented impacts of fish farms on target species in the non-breeding season. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table. The quality of evidence for each study are assessed as being POOR (based on expert opinion, anecdotal data or analysis with a low statistical power), MODERATE (expert opinion supported by robust data collection and or data collected following standard survey methodologies with no further analysis) or GOOD (data collected using standard survey methodologies and analysed with appropriate techniques, e.g. distance corrected population estimates). Magnitude was defined as LOW if no impact occurred or if impacts measured were short-term and reversible (e.g. birds disturbed momentarily during disturbance). MODERATE impacts were reversible, but longer term (e.g. several hours). HIGH magnitude meant the effects to the birds were long-term (e.g. days/weeks/months) or irreversible. N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	**Study**	**Pressure**	**Parameter Measured**	***Quality of evidence***	***Magnitude***
Eider	*Tasker et al. 2000*	*Not specified*	*Population level impact*	*POOR*	*MODERATE*
Cormorants	*Tasker et al. 2000*	*Not specified*	*Population level impact*	*POOR*	*LOW*

3.7 Navigational Dredging/Aggregate Extraction

3.7.1 Literature Summary

We identified two studies of relevance to assessing the impact of dredging on wintering waterbirds. The first study considered the impact of sediment dredging on diving ducks on an Icelandic lake (Einarsson & Magnúsdóttir 1993) and the second was a review of what impacts aggregate dredging may have on marine birds, drawing from evidence collected in relation to other activities and/or pressures, for example wind farms, oil spills and fisheries (Cook & Burton 2010). Whilst it is navigational dredging which is of primary concern in the study area, many of the pressures of relevance to sediment or aggregate dredging will also be of relevance. Neither study considered the region of interest (Orkney and the Western Isles)

3.7.2 Pressures

The pressures relating to dredging are thought to include **disturbance**, **displacement**, changes in **sedimentation** and **turbidity**, and **prey depletion** (Cook and Burton 2010). **Toxic contamination** may be an issue in relation to navigational dredging as the activity may resuspend heavy metals and/or other pollutants which are trapped in the sediment (e.g. Caplat *et al.* 2005; Erftemeijer & Lewis, 2006).

3.7.3 Methods for quantifying impact

The first study, (Einarsson & Magnúsdóttir 1993) investigated the displacement of Red-breasted Merganser and Long-tailed Duck on an Icelandic freshwater lake. However, the sample sizes presented in this study are limited and no comparison was made with the distribution prior to dredging activity. Consequently, the quality of evidence presented in this study is assessed as low.

The second study, (Cook & Burton 2010) is based on an review of the literature using previous reviews (Camphuysen 1989; Williams et al. 1995; Garthe & Huppop 2004; King et al. 2009) of species sensitivities to different pressures and information about species habitat and prey preferences (e.g. Byrkjedal 1997; Guillemette & Himmelman 1996; Guse et al. 2009; Watanuki et al. 2008; Wanless et al. 1999) in order to draw inferences about the potential sensitivities of birds to the pressures associated with aggregate dredging. However, as the review is based on expert opinion, rather than experimental observations, the quality of evidence presented is assessed as low. However, there is very little evidence that has been used to directly quantify the impacts of dredging activity on the target species (see Table 10).

3.7.4 Synthesis of Evidence for Impacts

Of the species considered Common Eider, Long-tailed Duck and Slavonian Grebe were considered to have a moderate sensitivity to disturbance and displacement while Velvet Scoter, Red-throated Diver and European shag were considered to have a high sensitivity to disturbance (Einarsson & Magnúsdóttir 1993; Cook & Burton 2010). Red-breasted Merganser did not appear to be affected by dredging activity (Einarsson & Magnúsdóttir 1993). These species were also assessed as having a moderate to low sensitivity to prey depletion, but a moderate to high sensitivity to pressures, such as increased turbidity and increased sedimentation, which may affect their ability to access these prey (Cook & Burton 2010).

3.7.5 Conclusions and Knowledge Gaps

Evidence with which to assess the impacts of dredging on wintering waterbirds in extremely limited. Birds may show some sensitivity to short-term disturbance and to pressures which impact their ability to forage. This could occur as a result of increased sedimentation covering shellfish or through increased turbidity impacting birds visual acuity. However, birds appear to be less sensitive to the loss of key prey species. Wintering waterbirds also appear to have moderate to high sensitivity to disturbance associated with dredging. However, as neither study we identified directly considered navigational dredging pressures such as toxic contamination have not been considered.

Table 10

Studies assessing the impact of pressures associated with dredging on target species in the non-breeding season. As quantitative information about the magnitude of any impacts was extremely limited, assessments largely followed those presented in the cited reviews. Consequently, the quality of evidence presented by each study is assessed as POOR as they are based on limited sample sizes or inferred from reviews based on expert opinion. N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	**Study**	**Pressure**	**Parameter measured**	**Quality of Evidence**	**Magnitude**
Red-breasted Merganser	Einarsson & Magnúsdóttir 1993	Displacement	Habitat preferences	POOR	LOW
Common Eider	*Cook & Burton 2010*	*Disturbance*	*Relative sensitivity to disturbance*	*POOR*	*MODERATE*
Common Eider	*Cook & Burton 2010*	*Prey depletion*	*Relative sensitivity to prey depletion*	*POOR*	*LOW*
Common Eider	*Cook & Burton 2010*	*Sedimentation*	*Relative sensitivity to sedimentation*	*POOR*	*HIGH*
Common Eider	*Cook & Burton 2010*	*Turbidity*	*Relative sensitivity to turbidity*	*POOR*	*MODERATE*
Long-tailed Duck	Einarsson & Magnúsdóttir 1993	Displacement	Habitat preferences	POOR	MODERATE
Long-tailed Duck	*Cook & Burton 2010*	*Disturbance*	*Relative sensitivity to disturbance*	*POOR*	*MODERATE*
Long-tailed Duck	*Cook & Burton 2010*	*Prey depletion*	*Relative sensitivity to prey depletion*	*POOR*	*LOW*
Long-tailed Duck	*Cook & Burton 2010*	*Turbidity*	*Relative sensitivity to turbidity*	*POOR*	*MODERATE*
Long-tailed Duck	*Cook & Burton 2010*	*Sedimentation*	*Relative sensitivity to sedimentation*	*POOR*	*MODERATE*
Velvet Scoter	*Cook & Burton 2010*	*Disturbance*	*Relative sensitivity to disturbance*	*POOR*	*HIGH*
Velvet Scoter	*Cook & Burton 2010*	*Prey depletion*	*Relative sensitivity to prey depletion*	*POOR*	*HIGH*

Species	Study	Pressure	Parameter measured	Quality of Evidence	Magnitude
Velvet Scoter	*Cook & Burton 2010*	*Sedimentation*	*Relative sensitivity to sedimentation*	*POOR*	*HIGH*
Velvet Scoter	*Cook & Burton 2010*	*Turbidity*	*Relative sensitivity to turbidity*	*POOR*	*MODERATE*
Red-throated diver	*Cook & Burton 2010*	*Disturbance*	*Relative sensitivity to disturbance*	*POOR*	*HIGH*
Red-throated diver	*Cook & Burton 2010*	*Prey depletion*	*Relative sensitivity to prey depletion*	*POOR*	*MODERATE*
Red-throated Diver	*Cook & Burton 2010*	*Sedimentation*	*Relative sensitivity to sedimentation*	*POOR*	*MODERATE*
Red-throated Diver	*Cook & Burton 2010*	*Turbidity*	*Relative sensitivity to turbidity*	*POOR*	*MODERATE*
European Shag	*Cook & Burton 2010*	*Disturbance*	*Relative sensitivity to disturbance*	*POOR*	*HIGH*
European Shag	*Cook & Burton 2010*	*Prey depletion*	*Relative sensitivity to prey depletion*	*POOR*	*MODERATE*
European Shag	*Cook & Burton 2010*	*Sedimentation*	*Relative sensitivity to sedimentation*	*POOR*	*MODERATE*
European Shag	*Cook & Burton 2010*	*Turbidity*	*Relative sensitivity to turbidity*	*POOR*	*MODERATE*
Slavonian Grebe	*Cook & Burton 2010*	*Disturbance*	*Relative sensitivity to disturbance*	*POOR*	*MODERATE*
Slavonian Grebe	*Cook & Burton 2010*	*Prey depletion*	*Relative sensitivity to prey depletion*	*POOR*	*LOW*
Slavonian Grebe	*Cook & Burton 2010*	*Sedimentation*	*Relative sensitivity to sedimentation*	*POOR*	*MODERATE*
SlavonianGrebe	*Cook & Burton 2010*	*Turbidity*	*Relative sensitivity to turbidity*	*POOR*	*MODERATE*

3.8 Shipping/Boating

While shipping and boating are not licensed marine activities *per se*, all of the other activities discussed in this review require transport of people and/or goods in some form, and, therefore, potential impacts to non-breeding target species associated with shipping and boating should be considered concurrently with the activity-specific impacts.

3.8.1 Literature Summary

Ten studies relating to the effects of shipping or boating on target species in the non-breeding season were identified, including nine primary references and one review. Of these, three contained data collected in the past five years, three had data collected between five and ten years ago, and the remaining four contained data collected over ten years ago. Three studies were based in the Baltic, two in the NW Atlantic, one in the East Atlantic, one in the Danish Kettegat Sea, one off the west coast of Canada and one in Atlantic Canada and the Firth of Clyde, Scotland. No studies were identified from Orkney and the Western Isles. Impacts to Common Eider were included in five studies (Burger et al. 2016; Fließbach et al. 2016; Schwemmer et al. 2011; Larsen & Laubek 2005; Merkel et al. 2009), Velvet Scoter was included in three studies (Palm et al. 2013; Fließbach et al. 2016; Schwemmer et al. 2011), one study focussed on European Shag (Velando & Munilla 2011), impacts to Long-tailed Duck were included in three studies (Perry 2012; Fließbach et al. 2016; Schwemmer et al. 2011), and Red-throated Diver, Black-throated Diver, Slavonian Grebe, Red-breasted Merganser and Black Guillemot were included in one study.

3.8.2 Pressures

The pressures relating to shipping and boating include **disturbance** or **displacement** of birds from the area where boats or ships occur, and the majority of studies identified focussed on these impacts (Burger et al. 2016; Fließbach et al. 2016; Velando & Munilla 2011; Merkel et al. 2009; Schwemmer et al. 2011). Birds may also experience **habitat loss** or a reduction in the time available for foraging time (Velando & Munilla 2011). In addition, shipping may cause impacts to birds through oil **pollution** or **contamination** (see Oil and Gas section).

3.8.3 Methods for Quantifying Impact

Methods for quantifying disturbance impacts from shipping including using on-board observers to record behavioural responses (e.g. flush distances) to the presence of the vessel (Fließbach et al. 2016; Schwemmer et al. 2011) or using shore-based (Ross et al. 2001; Velando & Munilla 2011) or aerial observations (Burger et al. 2016; Larsen & Laubek 2005).

Bird behavioural responses to disturbance from boats and ships was measured in several ways, but the most commonly-used approach was recording the maximum distance at which birds fly in response to disturbance (flush distance). As well as measuring flush distances, Schwemmer et al. (2011) recorded the proportion of birds that were disturbed, and the % of birds present 60, 120 and 180 minutes after disturbance relative to those present pre-disturbance, thus giving an indication of immediate impacts and slightly longer-term effects of disturbance. Velando & Munilla (2011) recorded more subtle behavioural responses to disturbance in European Shags, by assessed the foraging time lost through vigilance behaviour in the presence of boat traffic.

Several studies included details of the vessel creating the disturbance, so it was possible to draw conclusions about the vessel size and speed which created the greatest disturbance.

One study measured physiological stress responses in Velvet Scoter following flushing by boats by shooting birds at known time intervals after they were initially flushed and measuring their plasma corticosterone (CORT) levels (Palm et al. 2013).

Ross et al. (2001) assessed the effectiveness of simulated boat noise at deterring Common Eider from a mussel farm.

3.8.4 Synthesis of Evidence for Impacts

A summary of the impacts from shipping and boating to non-breeding target species is found in Table 11. The most-studied species was Common Eider. The impacts recorded for this species were generally low or moderate, indicating Common Eider is less sensitive to disturbance from shipping and boating than other target species. Average flight initiation distances (FID) recorded varied from 252-587 m (Fließbach et al. 2016; Schwemmer et al. 2011). Schwemmer et al. (2011) also demonstrated that Common Eider also returned to the area from which they were disturbed within 120 minutes, faster than the other species studied – Velvet Scoter and Long-tailed

Duck. One study reported a high degree of displacement (50-80% of birds) from mussel farms in response to simulated boat noise Ross et al. (2001). This suggests that the noise created by ships is enough to create a disturbance to the Common Eider, even without the visual stimulus. However, the birds tended to habituate to the noise deterrent if it was not occasionally reinforced by the presence of a real boat, indicating that Common Eider may be able to habituate to shipping-related disturbances that they do not perceive as a threat. Burger et al. (2016) reported that Common Eider was least disturbance by slow and medium-sized ships and small vessels (<20 m; e.g. pilot vessels) if they are travelling fast. However, Larsen & Laubek (2005) high-speed ferries were an important source of disturbance.

Velvet Scoter had much higher average FID than Common Eider 404-426 m (Fließbach et al. 2016). This species took a particularly long time to return after a disturbance event – even after 180 minutes over 30% of the birds had still not returned to their original position (Schwemmer et al. 2011). Palm et al. 2013 who showed that acute stress in Velvet Scoters, measured by elevated plasma corticosterone (CORT) levels, persists 15 minutes or more after a flushing event. Furthermore, elevated stress hormones are known to lead to body-mass changes in Velvet Scoter, thus have a demonstrable effect to individual fitness (Hennin et al. 2016).

Only one study demonstrated impacts to Divers, and the study did not differentiate between Black-throated and Red-throated Divers; however, it showed that these species had FID over a kilometre - much higher than other the other species studied, indicating they may be particularly sensitive to disturbance from boat traffic (Fließbach et al. 2016).

Long-tailed Duck and Red-breasted Merganser showed moderate sensitivity to shipping disturbance – more sensitive than Common Eider, but less sensitive than Velvet Scoter and Divers.

European Shags demonstrated low tolerance to boat traffic, as they showed vigilance behaviour leading to a reduction in foraging time whenever a boat occurred within the same 500 m^2 area. (Velando & Munilla 2011).

The relationship between vessel type and likelihood of disturbance is complex. Large vessels may cause little disturbance, provided they are slow moving, but large, high-speed vessels may lead to significant disturbance impacts (Burger et al. 2016; Larsen & Laubek 2005). However, for small fast-moving boats, the degree of disturbance may be species and context specific - Burger et al. (2016) showed this type of vessel to create little disturbance to non-breeding Eiders; however, other studies conducted during the breeding season have shown small, fast-moving boats to create significant disturbance (Ronconi & Clair 2002).

3.8.5 Conclusions and Knowledge Gaps

A critical knowledge gap in assessing the impacts of shipping and boating (and indeed other sources of disturbance) to wintering waterbirds is translating the observed behavioural responses into metabolic costs to determine whether they truly impact individual fitness. Studies that measure only behavioural responses to disturbances may underestimate the physiological costs that persist after the disturbance event (Cyr & Romero 2009b). Studies measuring physiological stress responses are more difficult in non-breeding populations due to difficulties catching birds within a suitable timeframe post-disturbance to obtain blood samples. And as this is commonly achieved by shooting birds, it is not recommended as large-scale study.

Table 11

Studies assessing the impact of pressures associated with shipping and boating on target species in the non-breeding season. The strength of the methodologies for each study are assessed as being POOR (based on expert opinion, anecdotal data or analysis with a low statistical power), MODERATE (expert opinion supported by robust data collection and or data collected following standard survey methodologies) or GOOD (data collected using standardised survey methodologies and analysed with appropriate techniques). Magnitude based on studies that measured flight initiation distance (FID) were classified as LOW for FID<300 m and HIGH for FID >500 m. For studies which measured the % of birds responding to a disturbance, magnitude was HIGH if it effected >75% of birds and LOW if it effected <25% of birds. N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of evidence**	**Magnitude**
Common Eider	Burger et al. 2016*	Displacement		GOOD	LOW
Common Eider	Fließbach et al. 2016*	Disturbance	Flight Initiation Distance	MODERATE	LOW
Common Eider	Larsen & Laubek 2005	Disturbance	Flight Initiation Distance	MODERATE	HIGH
Common Eider	Schwemmer et al. 2011	Disturbance	Flight Initiation Distance	MODERATE	LOW
Common Eider	Schwemmer et al. 2011	Displacement	Length of Time to Return	MODERATE	HIGH
Common Eider	Schwemmer et al. 2011	Disturbance	Proportion of birds responding	MODERATE	MODERATE
Common Eider	Ross et al. 2001	Disturbance	Displacement	GOOD	MODERATE/ HIGH
Long-tailed Duck	Fließbach et al. 2016*	Disturbance	Flight Initiation Distance	MODERATE	MODERATE
Long-tailed Duck	Schwemmer et al. 2011	Displacement	Length of Time to Return	MODERATE	HIGH
Long-tailed Duck	Schwemmer et al. 2011	Disturbance	Flight Initiation Distance	MODERATE	LOW
Long-tailed Duck	Perry 2012	Disturbance	Behavioural response	POOR	N/A

Species	Study	Pressure	Parameter Measured	Quality of evidence	Magnitude
Long-tailed Duck	Schwemmer et al. 2011	Disturbance	Proportion of birds responding	MODERATE	HIGH
Velvet Scoter	Fließbach et al. 2016*	Disturbance	Flight Initiation Distance	MODERATE	MODERATE
Velvet Scoter	Schwemmer et al. 2011	Disturbance	Flight Initiation Distance	MODERATE	MODERATE
Velvet Scoter	Schwemmer et al. 2011	Displacement	Length of Time to Return	MODERATE	HIGH
Velvet Scoter	Schwemmer et al. 2011	Disturbance	Proportion of birds responding	MODERATE	HIGH
Velvet Scoter	Palm et al. 2013	Disturbance	Stress response	GOOD	??
Red-breasted Merganser	Fließbach et al. 2016*	Disturbance	Flight Initiation Distance	MODERATE	MODERATE
Black-throated Diver and Red-throated Diver	Fließbach et al. 2016*	Disturbance	Flight Initiation Distance	MODERATE	HIGH
European Shag	Velando & Munilla 2011	Disturbance	Vigilance behaviour and reduction in foraging	MODERATE	HIGH
Slavonian Grebe	Fließbach et al. 2016*	Disturbance	Flight Initiation Distance	MODERATE	LOW
Black Guillemot and other Alcids	Fließbach et al. 2016*	Disturbance	Flight Initiation Distance	MODERATE	LOW
Multiple species	*Lima et al. 2014*	*Collision*	N/A	N/A	N/A

3.9 Recreation

3.9.1 Literature Summary

Literature outlining the impacts from recreational disturbance to target species during the non-breeding season was extremely sparse (Table 12). One study on the effects of ecotourism on distribution of waterbirds in a wildlife refuge in Florida showed the level of human activity did not influence the distribution of Red-breasted Merganser (Klein et al. 1995). And one study reported disturbance events to Great Northern Divers in NE USA caused by anglers, walkers, birders and motor boats (Mayo et al. 2015a). A review, based on expert judgement surmised the risk of disturbance impacts from recreation to Eiders, Cormorants and Auks to be minimal in Western-Nordic areas (Frederiksen 2010)

3.9.2 Conclusions and Knowledge Gaps

Thus, this is clearly a topic that would benefit from additional study and fieldwork effort.

Table 12

Studies assessing the impact of pressures associated with recreation on target species in the non-breeding season. The strength of the methodologies for each study are assessed as being POOR (based on expert opinion, anecdotal data or analysis with a low statistical power), MODERATE (expert opinion supported by robust data collection and or data collected following standard survey methodologies) or GOOD (data collected using standardised survey methodologies and analysed with appropriate techniques). Magnitude was defined as LOW if no impact occurred or if impacts measured were short-term and reversible (e.g. birds disturbed momentarily during disturbance). MODERATE impacts were reversible, but longer-term (e.g. several hours). HIGH magnitude meant the effects to the birds were long-term (e.g. days/weeks/months) or irreversible. N/A means the quality of evidence or magnitude of impact could not be determined from the information in the paper. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	**Study**	**Pressure**	**Parameter Measured**	**Quality of evidence**	**Magnitude**
Eiders	*Frederiksen 2010*	*Disturbance*	*N/A*	*POOR*	*LOW*
Red-breasted merganser	Klein et al. 1995	Disturbance	Vigilance behaviour	MODERATE	LOW
Great Northern Diver	Mayo et al. 2015	Disturbance	Flight initiation distance	MODERATE	N/A
Cormorants	*Frederiksen 2010*	*Disturbance*	*N/A*	*POOR*	*LOW*
Auks	*Frederiksen 2010*	*Disturbance*	*N/A*	*POOR*	*LOW*

3.10 Contamination by Other Activities

3.10.1 Literature Summary

We identified nine papers and reports relevant to the impact of contamination from sources other than oil pollution on target species. Of these, eight provided new data whilst one reviewed previously-existing knowledge. None were published within the last five years and four were published in the last ten years. Nor did any of the studies cover Orkney or the Western Isles with locations ranging from North America, Canada, the Barents Sea and Europe, including Spain and one study from the UK.

3.10.2 Sources of Contamination

The only pressure identified is contamination. One study focused on the activity of mining and smelting (Blus et al. 1995), while others looked at contamination by heavy metals (Arcos et al. 2002; Mitro et al. 2008; Wayland et al. 2008; Vest et al. 2009), pesticides (Borgå et al. 2007) and Paralytic Shellfish Poisoning (Coulson et al. 1968; Armstrong et al. 1978; Shumway et al. 2003).

3.10.3 Methods for Quantifying Impact

Dead birds, opportunistically found, were analysed for contaminants in a third of the studies (Coulson et al. 1968; Armstrong et al. 1978; Blus et al. 1995; Arcos et al. 2002), whilst others involved shooting apparently-healthy birds to test for heavy metals (Borga et al. 2007; Vest et al. 2009) or sampling live birds during ringing via blood /feather sampling (Mitro et al. 2008; Wayland et al. 2008).

3.10.4 Synthesis of Evidence for Impacts

A summary of the impacts from other sources of contamination to non-breeding target species is found in Table 13. There is some evidence of localised contaminations of target species but it is impossible to extrapolate the possible impact at a wider geographical scale. Contamination studies are often based on a very small number of individuals: one study found that one Common Goldeneye had high levels of Pb in the liver and Cd in the kidneys due to mining and smelting activities in its feeding area (Blus et al. 1995), while another found three European Shags with high levels of Hg in the liver associated with contaminated fish in the Mediterranean (Arcos et al. 2002). The latter study was conducted in the breeding season but the species would also be exposed to these contaminants during winter.

There is also some evidence of bioaccumulation of Chlorinated pesticides and metabolites in Black Guillemots in summer, although the study was based on only ten individuals that had been shot (Borga et al. 2007), and another study had reported concentration of Hg and Se at potentially harmful levels in Common Goldeneye in winter (Vest et al. 2009). More informative data came from mass mortality events, such as European Shags in Northumberland affected by paralytic shellfish poisoning (Coulson et al. 1968; Armstrong et al. 1978). Whilst based on adult breeding birds, these cases are worth noting as sea ducks such as Common Eider are known to feed on mussels (Leopold et al. 1996) and species that use the coast, like European Shags, are at high risk of algal toxins (Shumway et al. 2003).

Some studies have also looked at the effect of contaminants on at the population level. Survival analyses of Velvet Scoters and King Eider (*Somateria spectabilis*) showed no correlation between levels of Cadmium, Lead, Selenium and Mercury and survival of individuals from breeding season to breeding season (Wayland et al. 2008). Another study also concluded no impact of Mercury contamination on survival of Great Northern Divers (Mitro et al. 2008), although the authors suggest that their sample size would have been too small to pick up differences.

Overall, there is concurrent moderate-quality evidence for high magnitude effect of contamination in the European Shag (Shumway et al. 2003; Armstrong et al. 1978; Coulson et al. 1968), although this comes entirely from cases of algal toxin/paralytic shellfish poisoning, while evidence of other contaminants, such as Mercury is very low (Arcos et al. 2002). There is low-quality evidence of low magnitude effect of contaminants on all other species, apart from, again, algal toxin/paralytic shellfish poisoning in Common Eider (Shumway et al. 2003).

3.10.5 Conclusions and Knowledge Gaps

There is little evidence of contamination of target species in the non-breeding season, or in the breeding season, when the threat described could persist outside the non-breeding season. The quality of evidence is also generally low due to a lack of standardised-monitoring, with sampling often over a short time frame and/or including only a limited number of individuals. Determining changes in levels of contaminants relative to normal background levels is an additional challenge.

Table 13

Studies assessing the impact of pressures associated contamination in wintering waterbirds. The quality of evidence presented by each study is assessed as POOR if they are based on low number of individuals and/or opportunistic data collection, MODERATE if based on long-term non-standardised data collection or short-term standardised data collection and GOOD-quality evidence is based on long-term standardised data collection. The magnitude of impact is classified as LOW if fewer than 26 individuals of the target species were affected (but the threshold is lower for species occurring at low density) or if less than 10 km of coastline was impacted, or the percentage of individuals affected was ≤15%, HIGH if more than 100 individuals were affected (but lower numbers are considered as 'high impact' for species that don't occur at high densities) or if greater than 100 km of coastline was affected, or if the percentage of individuals affected was ≥41% and MODERATE for number of affected individuals in between low and high magnitude. Studies listed in *italics* are reviews or syntheses of existing literature, where possible, relevant studies summarised by these reviews have been obtained and included in this table.

Species	Study	Pressure	Parameter Measured	Quality of Evidence	Magnitude
Common Eider	Wayland et al. 2008	Contamination	Mortality	MODERATE	LOW
Common Eider	*Shumway et al. 2003*	*Contamination*	*Mortality*	*GOOD*	*MODERATE*
Velvet Scoter	Wayland et al. 2008	Contamination	Mortality	MODERATE	LOW
Common Goldeneye	Vest et al. 2009	Contamination	High levels	POOR	LOW
Common Goldeneye	Blus et al. 1995	Contamination	High levels	POOR	LOW
Great Northern Diver	Mitro et al. 2008	Contamination	Mortality	MODERATE	LOW
European Shag	Arcos et al. 2002	Contamination	High levels	POOR	LOW
European Shag	Armstrong et al. 1978	Contamination	Mortality	MODERATE	HIGH
European Shag	Coulson et al. 1968	Contamination	Mortality	MODERATE	HIGH
European Shag	Shumway et al. 2003	*Contamination*	*Mortality*	*GOOD*	*HIGH*
Black Guillemot	Borgå et al. 2007	Contamination	Bioaccumulation	POOR	LOW

4. Conclusions

We identified 78 studies in which the impact(s) of marine licensed activities on wintering waterbirds were considered qualitatively or assessed quantitatively (Table 14). The quantity and quality of evidence differed between both species and activity (Tables 4-13). In terms of impact, displacement, disturbance and pollution were highlighted as key pressures affecting wintering waterbirds by multiple studies (Table 14). In general, pressures including by-catch and collision with above water structures were considered to be less important (Table 14). However, a number of key gaps in knowledge remain in relation to pressures such as toxic contamination, and increases in sedimentation and turbidity.

The pressures we identified may have direct or indirect impacts on wintering waterbirds. Direct pressures are those which result in the death or injury of the individuals concerned (for example collision with a wind turbine), whereas indirect pressures are those which may have an on-going impact on the individuals concerned (e.g. displacement for a key foraging habitat). In relation to divers and seaduck in particular, we identified a large number of sources which highlighted significant, negative effects of displacement and disturbance. These pressures may have important energetic consequences for birds over winter. If licensed marine activities result in birds being displaced from preferred foraging areas over winter, this may lead to them foraging in sub-optimal habitats and struggling to meet their daily energy requirements (Loring et al. 2013; Guillemette et al. 2002; Merkel et al. 2006). Similarly, high rates of disturbance may lead to birds being engaged in high levels of vigilance behaviour at the expense of time spent feeding and/or being flushed from the water surface leading to increased energy expenditure (e.g. Morton et al. 1989; Evans & Day 2001). Barrier effects may also contribute to increased energy expenditure (e.g. Masden et al. 2010). However, studies have focussed on the impacts to migrating birds and the likely consequences for wintering birds are not well understood. They are likely to depend on the extent to which birds move between sites on a daily basis (e.g. between a roost site and a foraging area) over winter. If species roost and forage in similar areas and do not move around much over winter, the increased energy expenditure associated with barrier effects is likely to be limited.

The consequences of pressures, such as displacement, disturbance and barrier effects, which influence an individual’s ability to meet their daily energy requirements, may not be immediately obvious. However, if these pressures are present throughout the winter months, they may contribute to reduced overwinter survival or carry-over effects, for example, reduced productivity, in the following breeding season (e.g. Guillemain et al. 2007). However, whilst many of the studies we reviewed considered the direct effects of disturbance and displacement (e.g. flight initiation distances, proportion of birds displaced), none of them considered these indirect effects on survival and productivity. This remains an important gap in our knowledge of how licensed marine activities may affect wintering waterbirds. Displacement and disturbance are likely to be significant pressures associated with each of the marine licensed activities considered in this review (Table 2), and are likely to have strong impacts on each of the species considered.

The impact of prey depletion on the target species was likely to be moderate to high (Table 14) with the exception of Red-breasted Merganser. However, with the exception of Common Eider, evidence of the impact of prey depletion was limited to expert opinion presented in two reviews (Furness et al. 2012; Cook & Burton 2010) and consideration of how this may be exacerbated further by increased sedimentation and/or turbidity was limited to Cook & Burton (2010). Prey depletion may be a direct pressure, for example resulting from fisheries, shellfisheries or dredging, where prey are removed from an area, or an indirect pressure, for example resulting from marine renewable energy generation, where birds are displaced from an area and no longer able to access the prey within it. There is a need for a clearer understanding of the degree to which prey specialisation is exhibited amongst the wintering waterbirds considered in this review and whether this changes throughout the year. In addition, it is important to understand how pressures such as increased sedimentation or turbidity may exacerbate the pressure of prey depletion by affecting an individual's foraging ability.

Pressures which result in the direct mortality of birds include toxic contamination, pollution, collision with above water or underwater structures and fisheries by-catch. There is a lack of published data on collision rates of birds with offshore wind farms (MMO 2014). Overall the target species are considered to be at a relatively low risk of collision with above water structures as a result of their typical flight altitudes (Johnston et al. 2014; Furness et al. 2013). As the species considered here are underwater foragers, they are likely to be at a greater risk of collision with underwater structures. However, there we identified little evidence with which to assess this, with the exception of for European Shag and Black Guillemot, which have been shown to forage in areas suitable for tidal turbines (Daunt et al. 2014; Wade et al. 2013). This highlights a need for a better understanding of underwater collision risk in wintering waterbirds.

We identified a range of evidence with which to assess the impact of pollution and toxic contamination on wintering waterbirds (Tables 6 and 13). Of the two, pollution appeared to impact the greatest number of species, with evidence for a moderate to high impact on all species except Slavonian Grebe and Red-breasted Mergansers. However, evidence for the impact of pollution on wintering waterbirds typically related to the oil and gas industry (e.g Webb et al. 2016) with little evidence for the impacts associated with other sources of pollution (e.g. Derraik 2002). Consequently, the assessment of the impact of pollution on wintering waterbirds may reflect the degree of overlap in the distribution of species concerned with the oil and gas industry. Studies into the potential impact of toxic contamination were more limited, but suggest that it may be an issue for species like European Shag (Armstrong et al. 1978; Coulson et al. 1968; Shumway et al. 2003; Arcos et al. 2002) and Common Eider (Wayland et al. 2008; Coulson et al. 1968). Given the potential for shellfish, key prey species for many of the wintering waterbirds considered in this review, to act as bio-accumulators (e.g. Voorspoels et al. 2003; Fernandes et al. 2009), there is a need for greater understanding of the likely impacts of toxic contamination. Processes such as navigational dredging and shellfisheries which disturb the sediment, potentially re-suspending contaminants may be associated with increased risk of toxic contamination (e.g. Caplat et al. 2005; Erftemeijer & Robin Lewis 2006).

A large number of studies have considered the impact of fisheries by-catch on wintering waterbirds (Table 14). By-catch levels are known to vary by fishery type (Bull 2007; Soykan et al. 2008), which in turn is influenced by the distribution of target species. Of the species we considered, only Black Guillemot was found to have a high sensitivity to fisheries by-catch. Piscivorous species which pursue their prey underwater are considered more sensitive than benthic foragers (Žydelis et al. 2009). Additionally, species like divers and grebes are known to avoid ships and boats (Furness et al. 2013), potentially reducing their by-catch risk. Consequently, other species were assessed as having a low-moderate risk of by-catch. The exception to this was the European shag, for which we were unable to identify any studies in relation to by-catch risk. As it is a piscivorous species, which pursues its prey underwater and is not considered to be particularly sensitive to disturbance by boat traffic (Furness & Wade 2012), it may be at a high risk of by-catch.

Our review identified strong evidence that disturbance and displacement may be key pressures that impact the target species. These pressures are, to varying degrees, associated with all of the licensed marine activities covered by this review. However, in assessing the impact of these pressures, studies have focussed on short term impacts, for example the loss of foraging habitat, rather than long-term impacts, like changes to overwinter survival, which may have a more significant effect at a population level. In relation to disturbance there were gaps in knowledge for several of the target species notably Common Goldeneye, Black-throated and Great Northern Divers, Slavonian Grebe and Black Guillemot, with the evidence for these species largely drawn from reviews and expert opinion (e.g. Furness et al. 2013; Garthe & Huppop 2004).

Table 14: Assessment of the likely magnitude of the impacts relating to the pressures associated with marine licensed activities on wintering waterbirds. Assessments of likely magnitude are made in relation to weight of evidence presented in the accounts for individual activities. Priority was given to studies based on assessments of the quality of evidence presented, where evidence from higher quality studies was contradictory, evidence from lower quality studies was taken into account to give an overall impression of the general weight of evidence. Where cells are empty, we were unable to identify any studies assessing the magnitude of the impact concerned on the species concerned.

	Displacement/ Attraction	Habitat Loss	Barrier Effects	Disturbance	Prey Species Depletion	Sedimentation	Increased turbidity	Toxic Contamination	Pollution	Collision (Above Water)	Collision (Underwater)	Bycatch
Common Eider	MODERATE 1–5,6,7,8,910		HIGH 1,5,11,12	MODERATE 4,13–20	HIGH 10,14,20–24	HIGH[14]	MODERATE[14]	MODERATE 69,75	MODERATE 20,22,25–30	LOW 4,5,13,31		MODERATE 32–36
Long-tailed Duck	HIGH 3,5,7,6,10,37		MODERATE[5]	MODERATE 12,13,14,15,17	MODERATE 10,14	MODERATE[14]	MODERATE[14]	LOW[75]	MODERATE 25,26,28,38,39,29	LOW 5,13		MODERATE 39–43,34,44,45
Velvet Scoter	HIGH 4,5,10	LOW[46]	MODERATE[5]	HIGH 14,15,17,4	HIGH 10,14	HIGH[14]	MODERATE[14]	LOW[47]	MODERATE 25,28,38,47,29,48,49	LOW 4,5,13		MODERATE 42,43,34,44,50,51,36
Common Goldeneye	MODERATE 5,10		MODERATE[5]	MODERATE 5	HIGH 10			LOW[76,77]	MODERATE 25,28,29,49	LOW 5,13		LOW 44,34
Red-breasted Merganser	HIGH 3,5,7,6,37		MODERATE[5,52]	MODERATE 12,15					LOW 25,28,38,29,49,53	LOW 5		MODERATE 34,44
Red-throated Diver	HIGH 3–5,10,54,55,56,57		HIGH 5,57	HIGH 13,58,59,15	MODERATE 10,14	MODERATE[14]	MODERATE[14]		HIGH 25,28,29,49,53	LOW 4,5,13,31		LOW 34,44,51
Black-throated Diver	HIGH 3–5,10		MODERATE[5]	HIGH 4,13,15	MODERATE 10				HIGH 25,28,29,48,60	LOW 4,5,13,31		LOW 34,44
Great Northern Diver	HIGH 5,10		MODERATE[5]	HIGH 13	MODERATE 10			LOW[61, 78]	HIGH 25,28,29,48,53,61,60,62–64	LOW 5,13		LOW 44,51,65,36
European Shag	MODERATE 3,5,10		MODERATE[5]	MODERATE 13,20,66	MODERATE 10,14	MODERATE[14]	MODERATE[14]	HIGH[67–70]	HIGH 25,27–29,60	LOW 5,13,31	HIGH 71,72	
Slavonian Grebe	MODERATE[5,10]		MODERATE[5]	MODERATE[13]	MODERATE 10,14	MODERATE[14]	MODERATE[14]		LOW 25,29,48,53	LOW 5,13		LOW 34,44
Black Guillemot	MODERATE 5,10		MODERATE[5]	LOW 15	HIGH 10			LOW[74]	HIGH 25,26,29,30	LOW 5	HIGH 72	HIGH 44,34,73,33,36

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