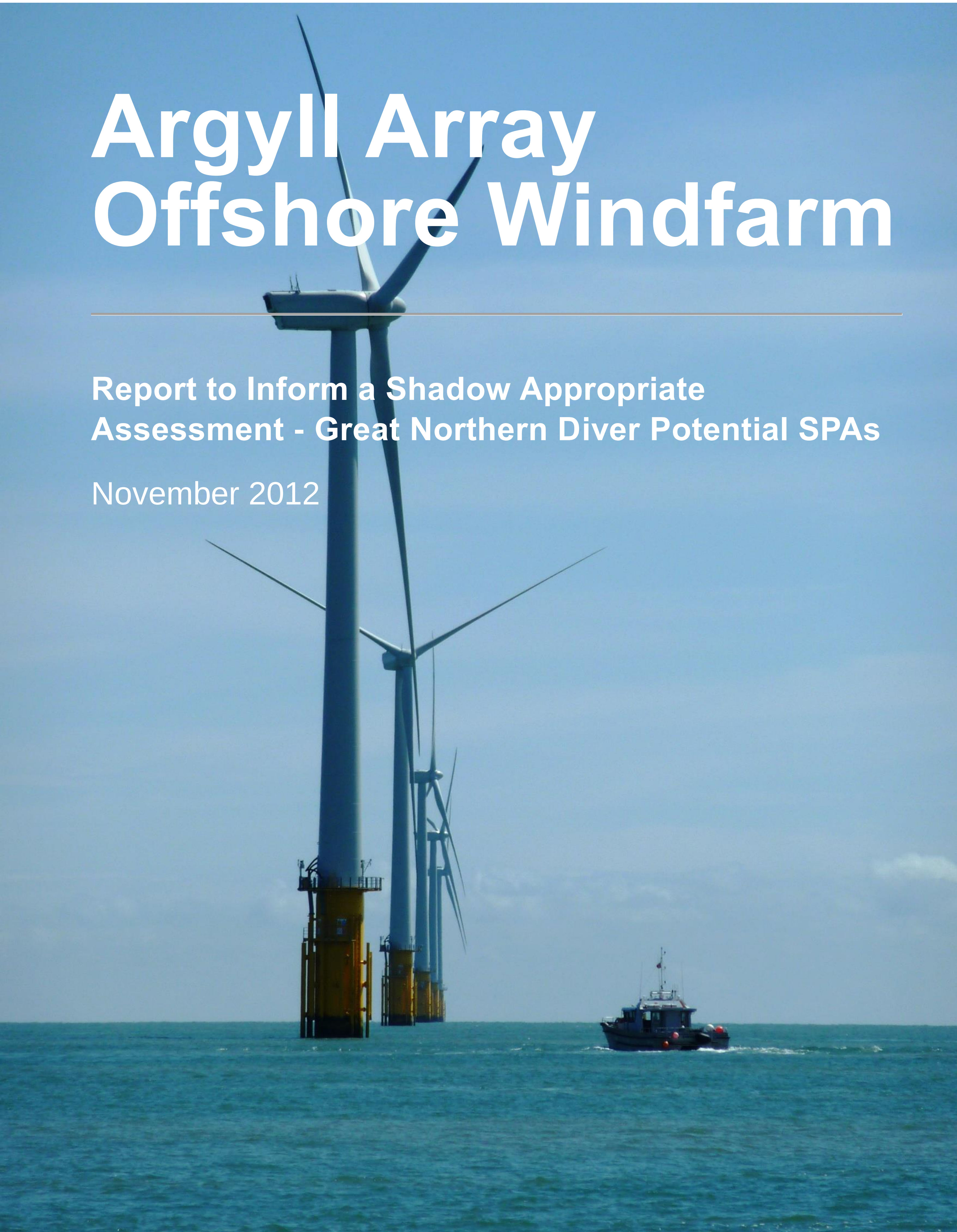
SCOTTISHPOWER RENEWABLES

Argyll Array Offshore Windfarm

Report to Inform a Shadow Appropriate Assessment - Great Northern Diver Potential SPAs

November 2012



Argyll Array
Offshore Windfarm
November 2012

For and on behalf of NIRAS Consulting Ltd

Approved by:

Position:

Date:

For and on behalf of Scottish Power Renewables

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Glossary

AA	Appropriate Assessment
AAOWF	Argyll Array Offshore Wind Farm
AC	Alternating Current
CRM	Collision Risk Modelling
DC	Direct Current
EIA	Environmental Impact Assessment
GB	Great Britain
HRA	Habitats Regulations Appraisal
JNCC	Joint Nature Conservation Committee
pSPA	Potential Special Protection Area
RISAA	Report to Inform Shadow Appropriate Assesment
SNCB	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SPR	Scottish Power Renewables
TCE	The Crown Estate

1 Executive Summary

1 The requirement for Habitats Regulations Assessment (HRA) is set out under Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (the 'Habitats Directive'). This is transposed into Scottish law through the Conservation (Natural Habitats &c.) Amendment (Scotland) Regulations 2007 (the 'Habitats Regulations'). HRA is required where there is the potential for a development to affect the integrity of a European site (Special Protection Areas, SPAs; and Special Areas of Conservation, SACs).

2 Where a site is designated as a proposed SPA (pSPA) (i.e. when the site has been passed to the European Commission for consideration as a SPA), it is necessary to conduct a 'shadow' HRA, in which the site is treated as though it was fully designated as a SPA. In the case of Argyll Array Offshore Wind Farm (AAOWF), the sites for inclusion in the assessment are not yet pSPAs, although they have been identified as supporting potentially important overwintering populations of great northern diver (*Gavia immer*), listed on Annex I of the EC Birds Directive.

3 Scottish Power Renewables (SPR) have elected to undertake a shadow assessment of potential effects of AAOWF on sites in Scottish inshore waters which, in the future, may possibly be designated as Special Protection Areas (SPAs) for overwintering great northern diver. In this report, particular reference is made to the waters around Coll & Tiree, which support internationally important numbers of great northern diver, and which are in closest proximity to the AAOWF site.

2 Introduction

2.1 Project Information

4 Scottish Power Renewables (SPR) has been awarded a licence by The Crown Estate (TCE) to develop up to 1,800MW of wind capacity off the west coast of Scotland, 5km south west of the island of Tiree. The site, Argyll Array Offshore Wind Farm (AAOWF – see Figure 1), covers ~360km^2 in Scottish territorial waters, in water depths of between 0 and 70m. The project has a connection agreement with NGET at Dalmally substation. Project components include; the turbine array and foundations; fixed platforms (AC substations/ AC/DC converter stations); inter-array cabling; and the transmission cable.

2.2 Background

5 The AAOWF project is not currently situated within a Natura 2000 site. However, the inshore waters around Coll & Tiree support internationally important numbers of great northern diver, *Gavia immer* (listed under Annex I of the EC Birds Directive), and there is potential for an SPA to be designated in the future. This potential SPA may or may not include the AAOWF site, in whole or in part. The evidence for these potential SPA sites was gathered as part of a programme of aerial surveys of wintering aggregations of seabirds in Scottish waters, conducted by JNCC. The aim of the surveys was to collect data on numbers and distribution of inshore waterbirds in areas known to be important for particular species (Lewis *et al.*, 2009).

6 There is also potential for the designation of a number of marine SPAs for great northern diver throughout inshore Scottish waters (Dawson *et al.,* 2008; Söhle *et al*., 2009). Advice from JNCC suggests that ten of the areas surveyed support great northern diver in numbers that exceed the qualifying threshold for SPA status. Discussions are ongoing among the UK Government and the Statutory Nature Conservation Bodies (SNCBs) to determine a method for selecting the most suitable inshore areas for SPA classification for all waterbird species. The areas of search with potential to be designated as SPAs for great northern diver range from the Northern Isles, Moray Firth in the east and various west coast areas, including Luce Bay (Reid, 2011 *pers. comm.*). It is not known at this stage how many of these sites could be put forward to be designated as SPAs. Such designations would have implications for project development at Argyll Array, and therefore a shadow Appropriate Assessment (AA) is being

performed for great northern diver in advance of full Habitats Regulations Appraisal (HRA).

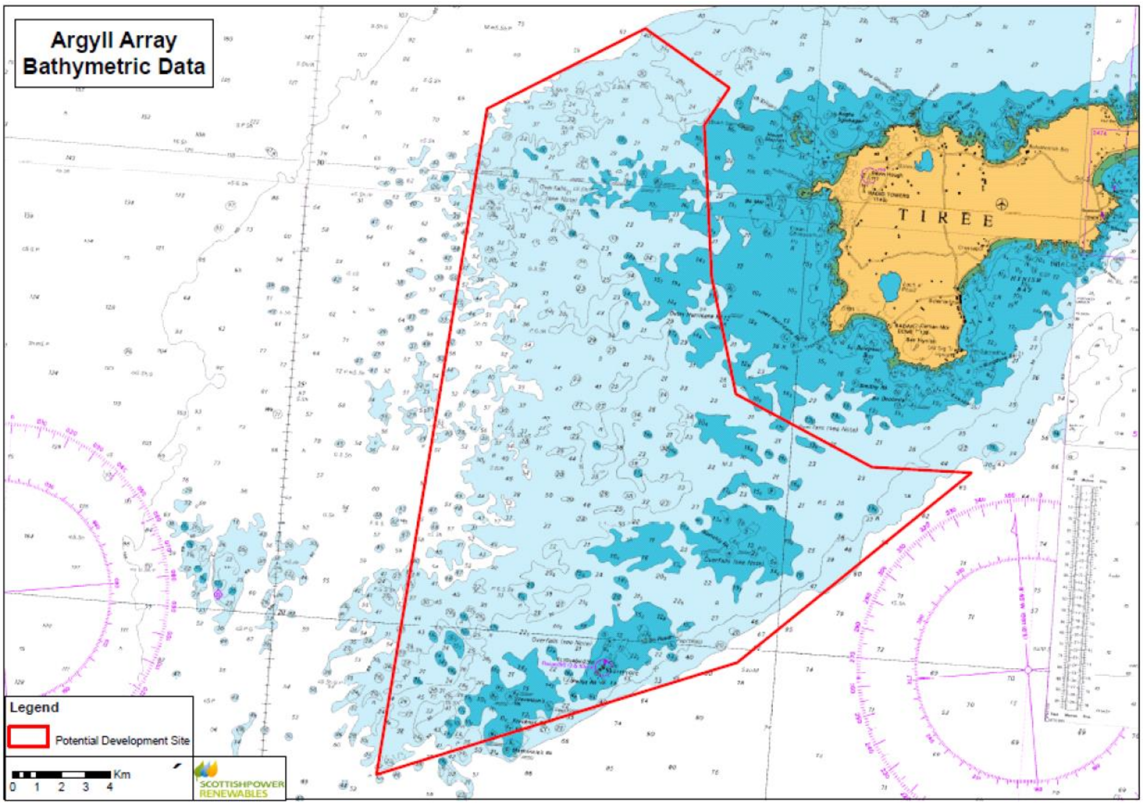

Figure 1: Map of Argyll Array site, including bathymetric data. Not to be used for navigation – Copyright Seazone Licence No: 42007.001. (SPR, 2010)

2.3 Purpose of this report

7 The HRA report (RPS, Aug 2012) prepared with respect to all potential effects of AAOWF on Natura 2000 sensitive receptors did not include assessment of great northern diver, since this species is not yet a qualifying interest feature of a pSPA or SPA which might be associated with the AAOWF site.

8 HRA is required where a project has the potential to affect the integrity of a designated Natura 2000 site (e.g. SPA). When a site is given proposed SPA (pSPA) status[1], a review of consented projects with potential to cause adverse effect on the features of the site will be undertaken by the Competent Authority (Marine Scotland). If required, an AA will be carried out. This is termed a 'shadow' assessment, because the site is not yet fully designated.

9 Although no site has been designated for great northern diver in Scottish inshore waters, a number of potential areas are currently being considered. In light of this, SPR have elected to produce a Report to Inform a Shadow Appropriate Assessment (RISAA) for potential effects of AAOWF on these possible SPAs for great northern diver. These possible areas for SPA designated have not yet been passed to the EC for consideration as full SPAs, and thus are not yet termed pSPAs.

10 Shadow assessment will enable Marine Scotland to undertake an AA of the project, if required, in accordance with Article 6(3) of the Habitats Directive, should these sites progress to pSPA/SPA status. This RISAA will use the best information available with respect to the likely SPA locations and conservation objectives, to determine whether the project could result in an adverse effect on the integrity of the pSPAs, alone or in combination with other projects. If there is an indication of the potential for an adverse effect on any pSPA as a result of the proposed development, mitigation measures may need to be identified.

1

[1] pSPA status is given to sites once the decision has been made by Scottish Ministers to consult upon them (consultation undertaken by SNH).

3 Habitats Regulations Appraisal (HRA)

3.1 EC Directives and Scottish Regulations

11 Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (the 'Habitats Directive') protects habitats and species of European nature conservation importance. Together with the Council Directive (2009/147/EC) on the conservation of wild birds (the Birds Directive), the Habitats Directive establishes a network of internationally important sites designated for their ecological status. SPAs are designated under the Birds Directive in order to protect rare, vulnerable and migratory birds.

12 The Habitats Regulations require that before agreeing to a plan or project that could affect the integrity of a European/Natura 2000 site, competent authorities undertake an AA. Under the Regulations, a European site includes SPAs and, as a matter of policy, the UK government also applies this requirement to pSPAs. In this case, in anticipation of likely designation, SPR has elected to undertake a "shadow" HRA in order to understand whether the proposed project could have an adverse effect on any SPA in Scottish inshore waters that may be proposed for inclusion in the Natura 2000 network.

3.2 Habitats Regulations Appraisal Procedure

13 Regulation 48 of the Habitats Regulations defines the procedure for the assessment of the implications of plans and projects on European sites. Under Regulation 48, if the proposed development is unconnected with site management and is likely to significantly affect the designated site, Marine Scotland (the "Competent Authority") must undertake an AA. The HRA process includes the decision on whether the plan should be subject to appraisal; the screening process for determining whether an AA is required; and any subsequent AA that may be required (SNH, 2012). The AA is the final assessment required by the Competent Authority to enable the final decision on the application to be made.

14 Marine Scotland (2011), in the scoping opinion for the AAOWF EIA, summarised the HRA process in three steps:

- **Step 1:** Is the proposal directly connected with or necessary for the conservation management of the pSPA/SPA(s)?

- **Step 2:** Is the proposal likely to have a significant effect on the qualifying interests of the pSPA/SPA(s) either alone or in combination with other plans or projects?

- **Step 3:** Can it be ascertained that the proposal will not adversely affect the integrity of the pSPA/SPA(s), either alone or in combination with other plans or projects?

15 Scottish Natural Heritage sets out 13 key stages for the HRA process; these are set out in Figure 2 (SNH, 2012).

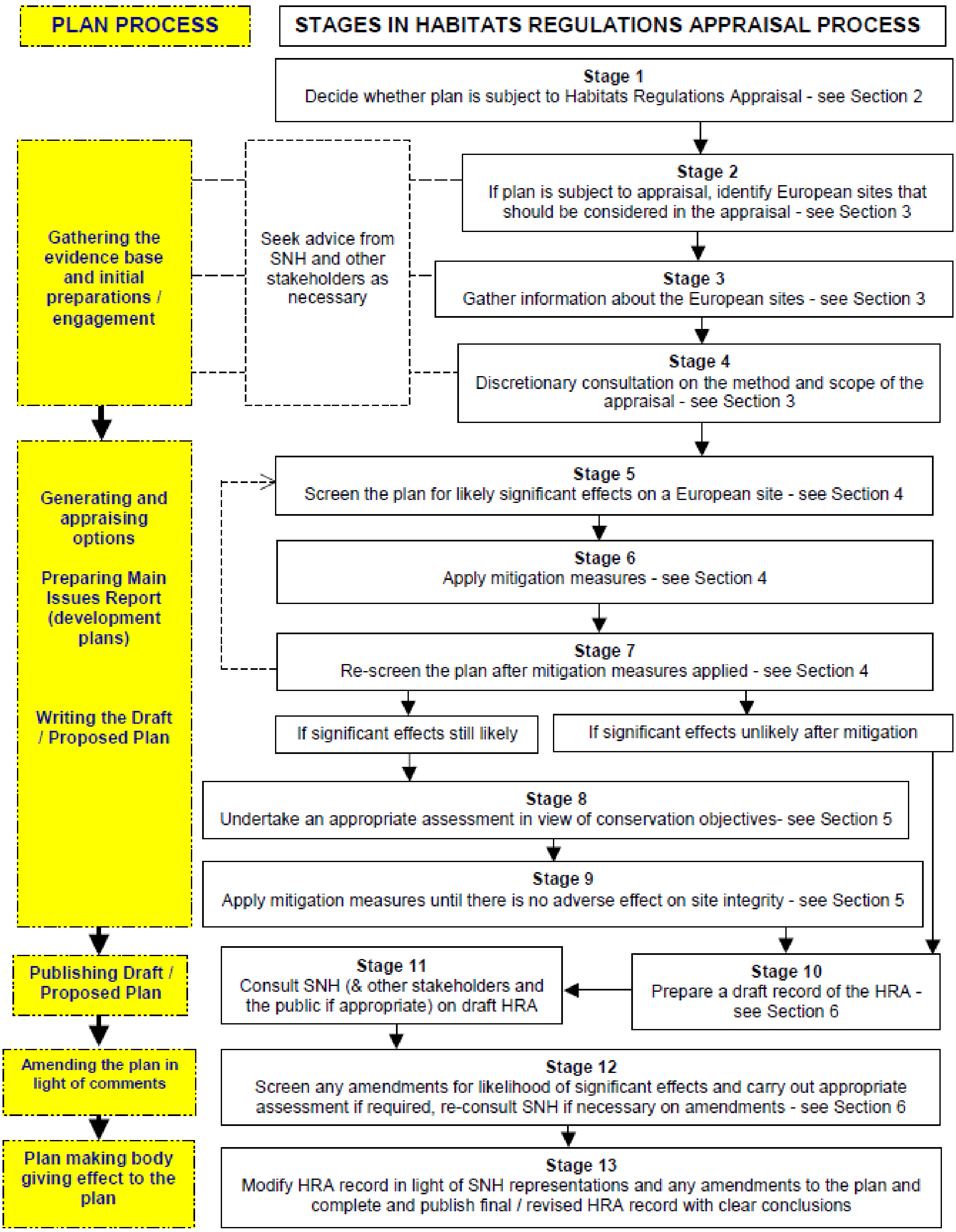

Figure 2: Key stages of the Habitats Regulations Appraisal process (SNH, 2012)

3.3 Approach to assessment of potential adverse effects

17 The following definitions and approach have been used to determine whether projects have the potential to result in an adverse effect on a European site.

3.3.2 Site integrity

18 The assessment of adverse effect on integrity is necessarily addressed in the light of the conservation objectives for each site. According to SNH (2012), the integrity of the site can be considered to be the structure and the functioning of its ecological systems, the features for which the site is designated (habitats and/or species) and the ability of the site to meet its conservation objectives.

19 EC guidance (2000), emphasises that site integrity involves its ecological functions and that the assessment of adverse effect should focus on and be limited to the site's conservation objectives.

3.3.3 Adverse effect

20 An adverse effect impacts the designated features of the site, either directly or indirectly, and results in disruption or harm to the ecological structure and functioning of the site and/or affects the ability of the site to meet its conservation objectives across all parts of the site (SNH, 2012).

21 An adverse effect will not occur if it can be shown that in the long term, the population of the species as a viable component of the site will be maintained despite potential impacts. 'Long term' is considered to be a period of at least five years. This is deemed to be an appropriate timescale for the assessment of adverse effect on site integrity, as SPAs are usually designated in the UK on the basis of a five year population estimate. A five year rolling mean is used because it is considered to take account of sufficient data to demonstrate that birds use sites regularly, smoothing out any ephemeral peaks and troughs in numbers. In addition, bird breeding performance and productivity varies between species and between years, and many species have long life spans. It is therefore logical to continue to review populations over the same time scale (five years) to demonstrate that observed use or 'non-use' of habitat is typical, and not a chance event. An adverse effect would be one which caused a detectable reduction in the species and/or habitats for which a site was designated, at the scale of the site rather than at the scale of the location of the impact.

22 EC guidance (2000) recommends that, when considering the 'integrity of the site', it is important to take into account a range of factors, including the

possibility of effects manifesting themselves in the short, medium and long-term (EC, 2000).

3.3.4 In-combination Assessment

23 Marine Scotland is required to make an AA of any plan or project which is likely to have a significant effect on a European site, either alone or in combination with other plans or projects. SNH (2012) recommended that other plans and projects are considered for the in-combination assessment once screening of potential effects has been carried out. Once the potential effects have been identified, the in-combination test may include:

a) The incomplete parts of projects that have been started but which are not yet completed;

b) Projects given consent but not yet started;

c) Projects that are subject to applications for consent;

d) Projects that are subject to outstanding appeal procedures;

e) Any known unregulated projects that are not subject to any consent;

f) Ongoing projects subject to regulatory reviews, such as discharge consents or waste management licenses;

g) Development that has recently been completed but where any residual effects may not form part of the environmental baseline;

h) Policies and proposals that are not yet fully implemented in plans that are still in force; and

i) Draft plans that are being brought forward by other public bodies and agencies.

3.3.5 Assessment of adverse effect

24 The EIA Scoping Opinion (Marine Scotland, 2011) stated that the key question in any AA for the AAOWF is whether it can be ascertained that this proposal, alone or in combination, will not adversely affect the population of any qualifying bird species as a viable component of the SPAs under consideration. This was in relation to existing SPAs but noted that areas with potential to be designated in future should also be considered. With reference to Langston *et. al*. (2010), the report recommended that the following key questions should be considered when considering the potential effects of AAOWF on existing, proposed or potential SPAs:

i) Will the offshore wind proposal cause deterioration in the habitats of any of the SPAs?

ii) Will the offshore wind proposal cause any significant disturbance to bird interests while they are in any of the SPAs?

iii) Will the offshore wind proposal alter the distribution of the birds within any of the SPAs?

iv) Will the offshore wind proposal affect the distribution and extent of the habitats (that support the bird species) in any of the SPAs?

v) Will the offshore wind proposal in any way affect the structure, function and supporting processes of habitats in any of the SPAs?

25 In view of these key questions, and likely conservation objectives of a pSPA, determining whether the plan or project 'either alone or in-combination with other plans or projects' would have an adverse effect (or risk of this) on the integrity of the site has been assessed in the light of:

- Site-specific information obtained from project surveys;
- Species-specific data obtained from JNCC surveys;
- Information on the ecology of great northern diver;
- The advice of Marine Scotland, SNH and JNCC;
- The potential effects on the Natura 2000 network screened into the assessment;
- Evidence provided for the EIA; and
- Experiences and lessons learned from other UK offshore wind farm development projects.

4 Great Northern Diver Ecology

26 Musgrove *et. al*. (2011) indicated that the majority of great northern divers occur in Shetland, Orkney, west Highland, Argyll and the Outer Hebrides. Advice from SNH recommends that the GB population of great northern diver is c5,000 individuals and, although the details of this estimate have not yet been published, any assessment should be made in the context of this population estimate.

27 The great northern diver is a migratory species found predominantly in the Nearctic. However, little is known about its migratory behaviour. It has been suggested that the populations wintering in Scottish inshore waters originate from breeding sites in Iceland and Greenland. Over winter, their preferred habitat tends to be off rocky and exposed coasts, and also bays, channels, and sheltered inlets even along low-lying, shallow coasts with birds rarely occupying habitat more than several kilometres offshore. Use of habitat is dictated by prey availability, which is influenced by water depth, tide lines and clarity and salinity gradients (Evers, 2007).

28 Great northern divers are visual, diurnal, pursuit predators (McIntyre, 1978) and appear to exhibit no foraging activity at night (Paruk, 2008). Haney (1990) found that great northern divers wintering in the USA selected areas up to 19m in depth for feeding, and that few used waters greater than 20m or further than 100km from shore. Birds avoid areas of highly turbid water, such as river mouths, where foraging success is limited (Evers, 2007). Areas of deeper water are used for maintenance activities, such as preening (Daub, 1989). During winter months great northern divers use two feeding strategies: solitary and group feeding (Evers, 2007). The species spends more than half of the day foraging during the winter months (Richardson *et. al.*, 2000). Great northern diver primarily feed on fish (10-70g), but their diet can include crustaceans, molluscs and annelids. Birds typically forage in the top 5m of the water column, although they can dive to 60m. Great northern divers alter their foraging behaviour depending on the state of the tide, with longer dive durations during low tides compared to flood tides (Thompson and Price, 2006).

29 Great northern divers are generally known to be highly mobile, except during moult of their flight feathers in mid-winter. They normally fly low over the sea, except on migration when flight heights are relatively higher than other diver species, reaching 1000-3000m (Furness & Wade, 2012) and can reach flight speeds of up to 75mph (Richardson *et. al.*, 2000). The species exhibits poor manoeuvrability in flight due to fast flight speeds and high wing loading (Furness and Wade 2012). During winter they are either solitary or form small

aggregations (Cramp & Simmons, 1977) and there is some evidence that great northern diver may hold feeding territories (Byrkjedal, 2011), to the extent that they are located in a restricted area for some time. Wintering adults have been shown to exhibit site tenacity: however, young birds (one and two years old) are less likely to exhibit site tenacity as they do not experience a mid-winter flightless period, meaning they are more mobile (Evers, 2007). The background mortality rate for great northern diver, published in Furness & Wade (2012), is 14%.

5 Screening and Consultation

5.1 AAOWF HRA

30 The HRA report produced with respect to the AAOWF development (RPS, Aug 2012) did not consider the potential effects on great northern diver because this species is not currently a designated interest feature of a pSPA or SPA associated with AAOWF.

5.2 Great northern diver and AAOWF

31 The purpose of this Report is to make a shadow assessment of the potential effects of AAOWF on great northern diver populations that may, in the future, be put forward as pSPAs (see Section 2.3), to supplement the HRA in respect of fully designated SPAs and their qualifying interest features (RPS, Aug 2012). It is possible that one such pSPA could be at Coll & Tiree (see Section 5.3.2), and that the AAOWF site could lie wholly or partly within this pSPA.

32 In order to carry out this shadow assessment, the location of any possible pSPAs for great northern diver, and the potential for likely significant effects (LSE) as a result of the AAOWF development were determined in consultation with SNH.

33 Figure 3 shows the densities of great northern diver (calculated by JNCC using Kernel Density Estimation, KDE) within the areas of search surveyed during the JNCC aerial survey programme (Webb *et. al.* 2011). The AAOWF is within the area of search to the west of Coll & Tiree.

34 The initial scoping report prepared with respect to shadow HRA for great northern diver at AAOWF (NIRAS, 2011) identified the following potential effects on great northern diver:

i) Disturbance and displacement (i.e. noise and visual);

ii) Habitat loss (e.g. arising from foundation and cable installation);

iii) Avoidance and barrier effects;

iv) Collision mortality; and

v) Indirect effects (e.g. effects on prey resources).

35 The scoping report considered the potential for LSE arising from development of AAOWF on each possible great northern diver site in Scottish inshore waters, as identified by JNCC. A number of consultation activities have been

undertaken to date, to inform the shadow HRA process, these are detailed in Table 1.

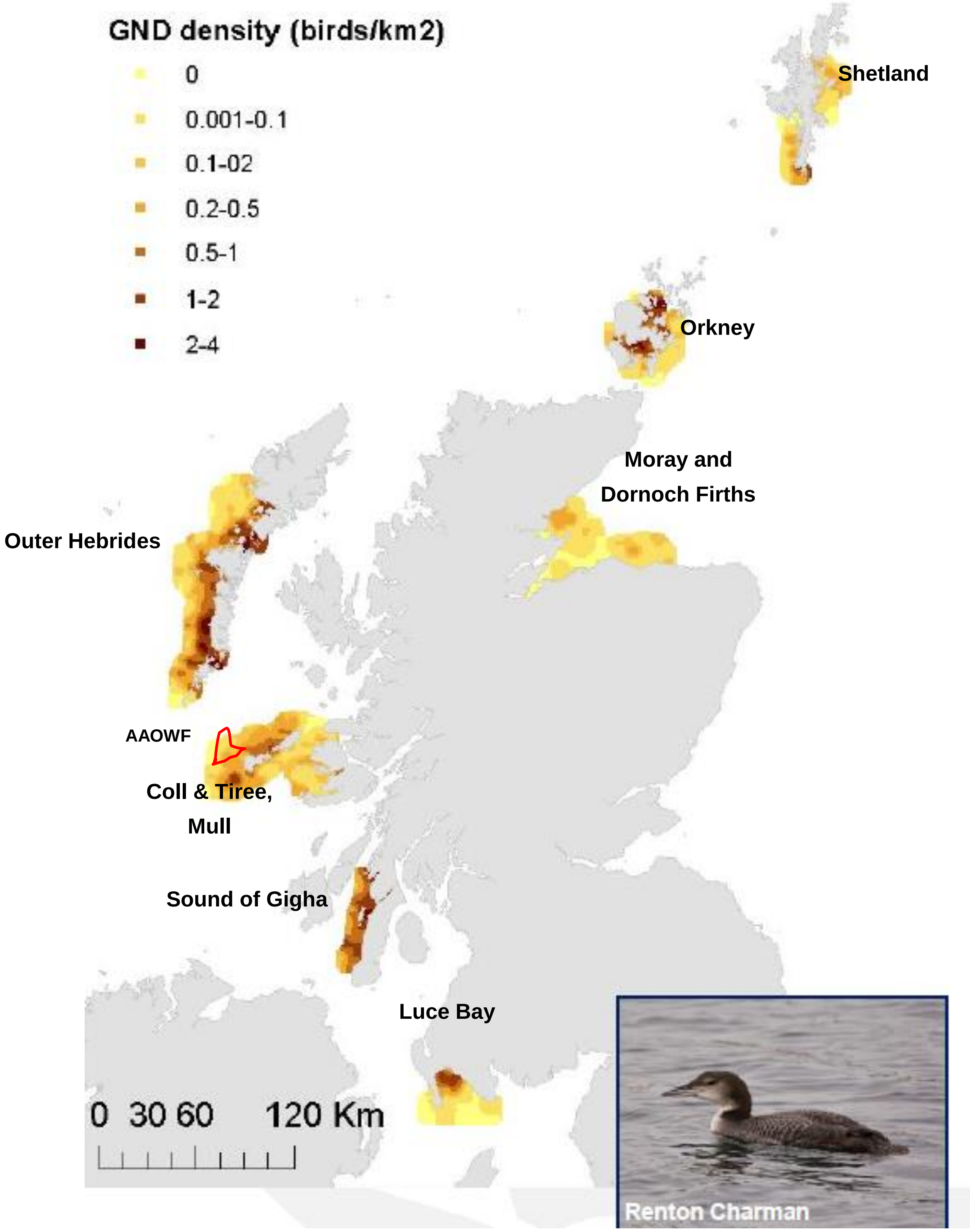

Figure 3: Great northern diver densities in JNCC Areas of Search within Scottish inshore waters (surveyed as part of the JNCC aerial survey programme) and the approximate location of the Argyll Array Offshore Wind Farm (AAOWF) site (not to scale).Source: Web

Table 1: Details of consultation activity carried out in relation to the shadow HRA for great northern diver.

Date	Description of consultation activity	Outcome
May 2011	Meeting with MS, NE and RSPB to discuss ornithology	Shadow HRA for great northern diver to be carried out
December 2011	Email discussion with JNCC and SNH regarding great northern diver information	Limited information can be disclosed on the possible SPAs, however, raw survey data provided
January 2012	Advisory meeting with MS and SNH	Discussion of shadow HRA scoping report
May 2012	Formal response to shadow HRA scoping report	Comments on scoping report to feed into RISAA

36 SNH recommended that the different populations for which sites could be designated (e.g. passage or overwintering populations) are likely to be affected by AAOWF in different ways. Therefore, SNH recommended that population estimates from site-specific surveys should be derived, and impacts on each population considered individually.

37 As a result of the shadow screening process and consultation the following great northern diver populations and potential impacts have been screened in for further assessment of potential adverse effects on site integrity. All potential effects arising from construction and decommissioning were screened out, with only operational effects being taken forward. Details of the effects and great northern diver populations affects can be found in Table 2.

Table 2: Summary of screening exercise for potential effects on great northern diver populations

Operational effect	Great northern diver population
Displacement	• Coll & Tiree (overwintering and passage)
Collision mortality	• Coll & Tiree (overwintering and passage) • Mull (overwintering and passage) • Sound of Gigha (passage) • Luce Bay (passage) • Outer Hebrides (passage)
Avoidance/barrier effects	• Coll & Tiree (overwintering and passage) • Mull (overwintering and passage) • Sound of Gigha (passage) • Luce Bay (passage) • Outer Hebrides (passage)
Indirect effects on prey availability	• Coll & Tiree (overwintering)

5.3 Conservation Objectives

38 Table 3 shows the standard format for SPA conservation objectives provided by SNH (2011) and these can be used when considering the draft conservation objectives for the sites in question.

Table 3: standard format for SPA conservation objectives (SNH, 2011)

To ensure that site integrity is maintained by:

(i) Avoiding deterioration of the habitats of the qualifying species.
(ii) Avoiding significant disturbance to the qualifying species.

To ensure for the qualifying species that the following are maintained in the long term:

(iii) Population of the bird species as a viable component of the SPA.
(iv) Distribution of the bird species within the SPA.
(v) Distribution and extent of habitats supporting the species.
(vi) Structure, function and supporting processes of habitats supporting the species.

Repeat of (ii) *No significant disturbance of the species.*

39 In order to form a reasonable basis for the shadow HRA and to assess whether the AAOWF will have an adverse effect on the integrity of the future

pSPAs, draft conservation objectives for each site have been postulated. The above standard format has been assumed. The five year mean population of great northern diver for the populations around Coll & Tiree and Mull can be calculated using data from the JNCC aerial surveys. For the other populations, in the absence of published data analysis, a correction factor was derived from the Distance analysis carried out for Coll & Tiree and Mull, and applied to the peak counts from the surveys of these other sites. Further details on these population estimates are presented in the following sections. Figure 4 shows the approximate location of these diver populations in relation to AAOWF.

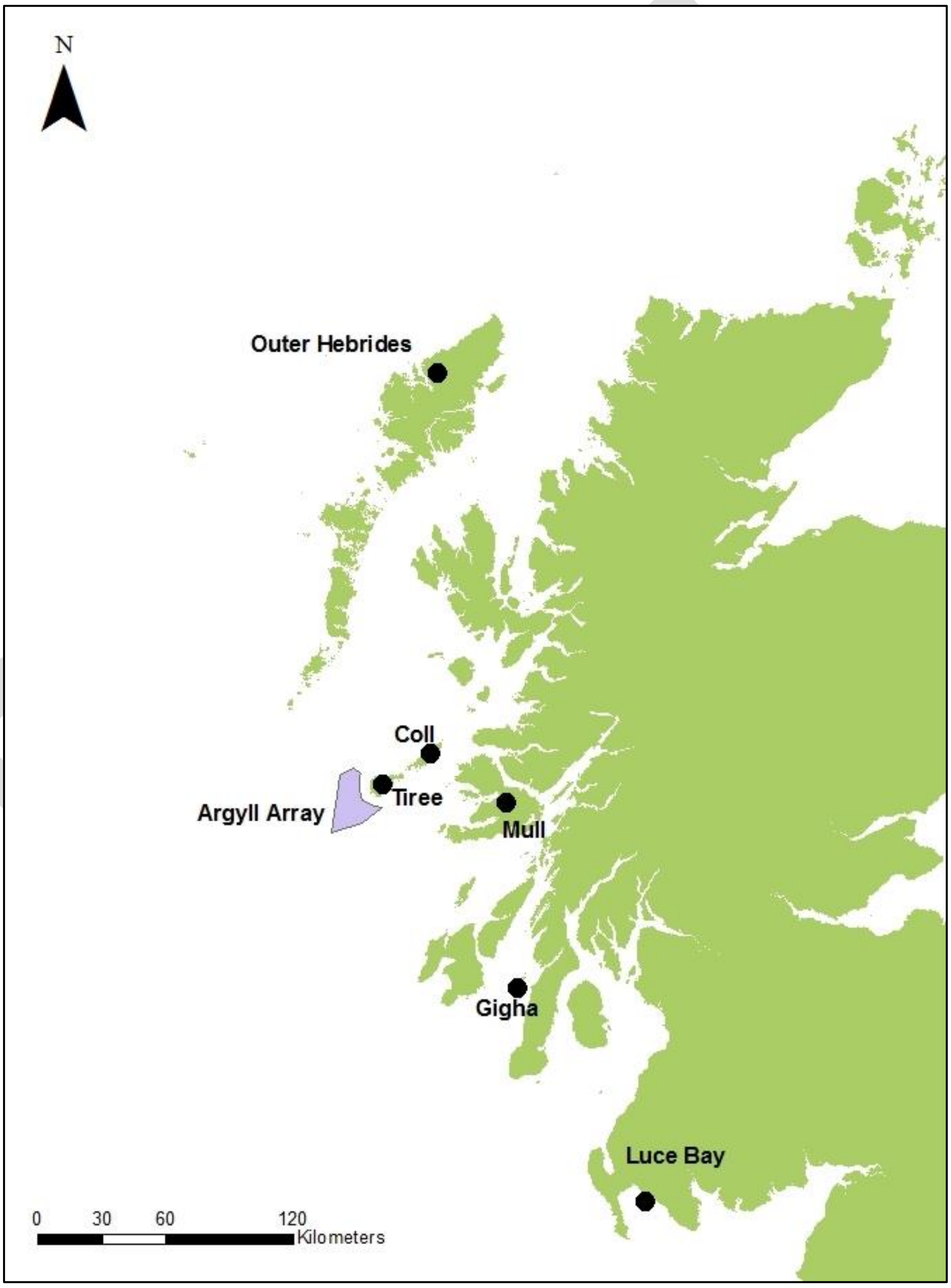

Figure 4: Approximate location of great northern diver populations in relation to Argyll Array

5.3.2 Coll & Tiree

40 This area is close to the proposed AAOWF site and is potentially the area most at risk of adverse effects arising from the development of AAOWF.

41 During the JNCC aerial surveys high numbers were regularly observed to the west of Coll and all around Tiree, both in shallow inshore waters and out to depths of 50m or more. Table 4 shows the yearly peak estimates of the great northern diver within the area over a five year period, derived using Distance sampling or extrapolation from raw counts, where the data were insufficient. Söhle *et al.* (2009) concluded that this area regularly exceeds the threshold for SPA classification and it should be included for consideration when the suite of marine SPAs is being determined.

Table 4: Peak estimated numbers of great northern diver at Coll & Tiree from 2003/04 to 2007/08, derived using Distance sampling (Söhle et al. 2009).

Season	Peak Estimate
2003/04	1,273
2004/05	560
2005/06	202
2006/07	253
2007/08	172

42 For the purposes of this assessment the five year mean has been calculated utilising the analysed data from Söhle *et. al.* (2009). The mean of the peak estimates is **492 birds.**

5.3.3 Mull

43 Söhle *et. al.* (2009) discussed aerial surveys undertaken around the island of Mull. This area is to the east of the proposed AAOWF and slightly further away than Coll & Tiree. Numbers of great northern diver recorded did not regularly exceed 1% of the GB population (50 individuals), the threshold for inclusion of the species as an interest feature of an SPA (required by stage 1.1 of the UK SPA Selection Guidelines). However, the report concluded that there is a possibility that the species may qualify under stage 1.4, as the peak mean estimate did exceed 50 individuals, once further data analysis (extrapolation or Distance sampling) was carried out. Table 5 shows these annual peak estimates.

Table 5: Peak estimated numbers of great northern diver at Mull from 2004/05 to 2006/07, derived using Distance sampling (Söhle et al. 2009).

Season	Peak Estimate
2004/05	95
2005/06	24
2006/07	43

44 For the purposes of this assessment the mean peak estimate of all years where survey data are available has been calculated using the analysed data from Söhle *et. al.* (2009) The mean of the peak estimates is **54 birds**.

5.3.4 Sound of Gigha

45 The Sound of Gigha lies to the south of the island of Mull. This area has been surveyed by JNCC over four consecutive winter seasons. Great northern divers were recorded in consistently high numbers regularly exceeding the threshold for SPA classification (Lewis *et. al*., 2009). No further analysis of the data has been undertaken and published to date. Consequently, an average correction factor has been established using the Distance analysis carried out for Coll & Tiree and Mull (Söhle *et. al*., 2009).

46 For the purposes of this assessment the mean of the peak estimates (derived using an average correction factor of 5.19) is **730 birds**.

5.3.5 Luce Bay

47 Luce Bay lies further south of the Sound of Gigha and is yet further from the proposed AAOWF site. This site has been specifically mentioned by JNCC as an area which is being considered within the suite of marine SPAs: however, only three seasons of data have been collected, and analysis has not yet been undertaken (Lewis *et. al*., 2009).

48 For the purposes of this assessment the mean of the peak estimates (derived using an average correction factor of 5.19) is **270 birds**.

5.3.6 Outer Hebrides

49 JNCC has collected five years of survey data for the area of search around the Outer Hebrides, to the north of the proposed AAOWF site. Great northern divers were recorded in consistently high numbers across the survey period

(Lewis *et. al.,* 2009). However, further data analysis has not yet been published.

50 For the purposes of this assessment the mean of the peak estimates (derived using an average correction factor of 5.19) is **769 birds**.

6 Ornithological survey of AAOWF

51 SPR commissioned site-specific boat-based surveys to characterise the ornithological characteristics of the proposed AAOWF site. The data from these surveys have informed the AAOWF EIA (in preparation) and HRA (RPS, Aug 2012). Surveys of the AAOWF site and 2km buffer were undertaken between September 2009 and August 2011, covering an area of 554km^2. The site was surveyed using a continuous transect line with a length of 293km (see Figure 2.1 in AAOWF Ornithology Technical Report).

6.1 Survey methodology

52 Two observers and a scribe were positioned on an observation platform providing a viewing height of ≥5 m above sea level. Four distance bands were used to record birds on the sea surface, extending to a maximum of 300m from one side of the vessel (see Table 2.1.1 in AAOWF Ornithology Technical Report). All bird observations included information on observation time, number of individuals, age and sex (where possible).

53 Birds in flight were recorded in snapshots at intervals of 1 minute along each transect. Recordings were made from a 300m box extending in front of and to the side of the vessel. Flight height was recorded using four height bands up to 180m (see Table 2.1.2 in in AAOWF Ornithology Technical Report).

6.2 Great northern diver at AAOWF

54 The estimated total population of great northern divers in the proposed AAOWF project site (plus buffer) was 414 birds. Data were analysed using Distance sampling to provide population estimates and densities for the survey area. Peak densities from transects were 0.78 birds per km^2 in the proposed site and 0.65 birds per km^2 in the 2km buffer area. Peak numbers of great northern divers across the survey period occurred in the month of March with 282 individuals recorded in the proposed wind farm site and 176 in the 2km buffer area. Distance-corrected peak counts by month ranged from 0 in July and September to 221 in March (Table 6; a mean was taken between surveys conducted in different years). Further details on the results and data

analysis can be found in the AAOWF Ornithology Technical Report (RPS, Sept 2012).

Table 6: Great northern diver Distance-corrected peak counts by month, from the site specific boat based surveys

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Count	56	123	221	202	168	9	0	30	0	104	135	91

7 Assessment of Potential Effects of AAOWF on great northern diver populations

55 The potential effects of the development of AAOWF on great northern diver populations in Scottish inshore waters (those sites which may, in the future, be put forward as pSPAs) are: disturbance and displacement; habitat loss; avoidance and barrier effects; collision risk; and indirect effects.

56 This assessment primarily focuses on the Coll & Tiree great northern diver population, since this site is in closest proximity to AAOWF, and there is overlap between site-specific AAOWF ornithological survey data and JNCC aerial survey data. Other great northern diver populations in the region are also considered, using JNCC aerial data as a basis for assessment.

7.2 Worst Case

57 Table 7 shows the four scenarios for turbine layout that have been considered in the assessment of potential effects on great northern divers. Scenario 1 is the worst case layout proposed by SPR for AAOWF, incorporating visual and radar constraints, with turbines arranged in parallel lines throughout the site. Scenarios 2 and 3 are options for mitigation. It has since been decided that scenario 4 will not be taken forward.

Table 7: Scenarios for turbine layout used in assessment for great northern diver

Scenario		No. of turbines (6MW)
1	Current Proposed Turbine Array	300
2	Intermediate Array 1	242
3	Intermediate Array 2	213
4	Maximum Impact Reduction	155

58 The worst case scenario for great northern diver displacement from the proposed AAOWF area is likely to be that divers are evenly distributed across the project site, and that 100% of this habitat area is lost (i.e. all divers within the project site are displaced). It is further assumed that there is likely to be some degree of diver displacement from the buffer area surrounding the project site, but that this is not likely to be 100%. Previous assessments of the displacement of divers in the Thames Estuary have assumed 100% displacement within the wind farm area, and 50% displacement from a 1km buffer area (Norman, 2006 for London Array Phase 1 with respect to red-throated diver). A similar assumption has been made in this case.

59 The area of the wind farm and a 1km buffer for each development scenario is shown in Table 8.

Table 8: Turbine scenarios: area of site and 1km buffer area

Scenario	Site area (km^2)	Buffer area (km^2)	Total area (km^2)
1	361.40	93.44	445.84
2	269.39	138.59	407.98
3	224.58	94.79	319.37

7.3 Redistribution of birds

60 Previous assessments have assumed that all birds displaced will be lost to the population. This is highly precautionary and it is more realistic to assume that any displaced birds will redistribute to other areas of suitable habitat. It can be further assumed that divers are likely to prefer habitat of similar quality to that which they would have otherwise have occupied within the wind farm and buffer area.

61 Evers (2007) suggests that the use of specific marine habitat is dictated primarily by prey availability, which is influenced by water depth, clarity and salinity gradients, and tide lines. As discussed in Section 4, research has suggested that great northern diver typically forage in the top 5m of the water column, and rarely in water depths greater than 20m (or further than 100km offshore).

62 In the absence of specific or empirical data related to habitat quality in the AAOWF area and the potential SPA area, and great northern diver habitat preference, water depth has been used as a proxy to indicate preferred diver habitat. Thus, it has been assumed that divers are likely to redistribute to areas of equivalent water depth outside AAOWF.

63 Table 9 shows the area of each water depth band around Coll & Tiree available for redistribution of divers from the AAOWF area (see Appendix B).

Table 9: Area of water depth bands available for redistribution of great northern divers from the AAOWF footprint

Water depth (m)	Area (km^2)
0 – 10	95
10.1 – 20	110.8
20.1 – 30	160.1
30.1 – 40	25
40.1 – 50	63.9

7.4 Magnitude of displacement

64 Boat-based survey of the AAOWF area and the Coll & Tiree area, detailed in Section 6, was conducted between September 2009 and August 2011. Water depths classified into five bands have been mapped for the islands of Coll & Tiree and the entire AAOWF area (360km^2), and the area of each depth band calculated. The number of great northern diver observed in each depth band has been derived through spatial analysis of GIS data, for the entire Coll & Tiree are including AAOWF, and for AAOWF alone (Table 10). The density of divers in each band, assuming even distribution, is shown in Table 10. For the purposes of this shadow assessment, water depth bands and survey observations of great northern diver have been used to postulate an approximate area for a future Coll & Tiree pSPA.

Table 10: Area of water depth bands around Coll & Tiree (including AAOWF), and within AAOWF, and number/density of divers in each band (number of observations in brackets) recorded through boat-based survey (prior to displacement effects)

Water depth (m)	Coll & Tiree and AAOWF (incl. buffer)			AAOWF only (incl. buffer)		
	Area (km^2)	No. of birds	Density (km^{-2})	Area (km^{-2})	No. of birds	Area (km^{-2})
0 – 10	101.0	128 (101)	1.27	6.0	16 (8)	2.67
10.1 – 20	162.2	278 (180)	1.71	51.4	102 (36)	1.98
20.1 – 30	315.3	285 (236)	0.90	155.2	121 (107)	0.78

30.1 – 40	163.5	59 (51)	0.36	138.5	19 (17)	0.14
40.1 – 50	132.2	23 (21)	0.17	68.3	6 (6)	0.09
>50	n/a (min 36.9)	49 (36)	n/a	36.9	n/a	n/a
Total	**874.2**	**822.0**		**456.3**	**264.0**	

66 Table 11 shows the estimated density increase in areas of equivalent water depth outside the AAOWF footprint, and the estimated density increase assuming even redistribution into the total available area. Within each depth category the absolute change in density likely to arise from displacement is relatively low (<1 bird/km^2) although the relative change in density can be high (~75% in the 20-30m depth category). Table 11: Estimated density increase outside the wind farm area in the Coll & Tiree region (boat-based data)

Water depth (m)	Coll & Tiree (excluding AAOWF)						
	Pre-displacement			Post-displacement		Density change (birds/km^2)	Density change (%)
	Area (km^2)	No. of birds	Density (birds/km^2)	No. of birds	Density (birds/km^2)		
0 – 10	95.0	112	1.18	128	1.35	0.17	14.41
10.1 – 20	110.8	176	1.59	278	2.51	0.92	57.86
20.1 – 30	160.1	164	1.02	285	1.78	0.76	74.51
30.1 – 40	25	40	1.60	59	2.36	0.76	47.50
40.1 – 50	63.9	17	0.27	23	0.36	0.09	33.33
>50	n/a	49	n/a	49	n/a	n/a	n/a

68 A further consideration in the assessment of diver displacement and redistribution is the assumption that divers will redistribute themselves in a manner than minimizes their energetic costs. However, there is no empirical data on the distance to which great northern diver might be displaced, and therefore the potential effects of displacement on fitness/survival. Given the data available, this assessment thus focuses on the potential for density-dependent effects on mortality/survival arising from displacement (particularly for Coll & Tiree). This is discussed further in Section 7.4.1.

69 McGregor (2011, *pers. comm.*) suggested it may be useful to model the response of great northern diver to the vessel used during the boat based surveys, to inform any assumptions regarding disturbance/displacement effects. However, the number of variables involved complicate such an exercise, and therefore it is not possible to ascertain whether the distance of birds from the survey vessel is solely due to the presence of the vessel itself. Studies commissioned by London Array Limited, with respect to London Array Offshore Wind Farm Phase 1 (Norman, 2006b) examined the response of red-throated diver to vessel presence. Red-throated diver are notoriously shy and the study found they tended to be displaced away from vessels through low, direct flight. It may be possible to infer through AAOWF site-specific boat-based survey that great northern diver are less sensitive to vessel disturbance than red-throated diver, and this would require closer analyses of the raw survey datasets.

7.4.1 Fate of displaced divers

70 It is considered unlikely that all displaced great northern diver will die. It is considered more likely that birds will relocate to other suitable habitat within the potential SPA or emigrate to habitat outside the potential SPA. Furthermore, it is assumed that birds will relocate to habitat of equivalent quality to that which they are displaced from. As a consequence the density of birds in receptor habitats is likely to increase. There is no evidence of density-dependent mortality in wintering diver populations, although studies of oystercatcher in the Exe Estuary (Durrell *et. al.,* 2001; Goss-Custard & Durrell, 2002) have indicated a relationship between increasing density and increasing mortality. It is possible, therefore, that as density increases within habitats (due to displacement) that mortality will increase, although the rate of this increase is not known.

71 To understand the potential implications of displacement on the population, the effect of different assumptions about the scale of displacement and the proportion of displaced birds that may die has been calculated (Appendix A), using the great northern diver population observed through boat-based survey in the AAOWF (apportioned according to season). Levels of displacement and mortality have been systematically varied (both up to the maximum level, 100%) for each turbine configuration and by season. The results are compared to the Coll & Tiree JNCC five year mean population, 492 birds.

72 Table 12 shows those displacement/mortality/season/turbine configuration combinations that resulted in a change in background mortality of the potential SPA population of less than 1%. Background mortality in the potential SPA population is assumed to be 68.9 birds (adult survival for great northern divers

is 86% and the SPA population is assumed to be the JNCC five year mean peak recorded at Coll & Tiree, 492 birds). A change in the background mortality rate of less than 1% can be considered to be *di minimis* and hence not likely to cause a significant effect on the population. An increase in mortality of more than 1% of the background rate is not necessarily significant, but the likelihood of an adverse effect increases the more this threshold is exceeded.

73 It can be seen that Configuration 3 has less effect on the potential SPA population than the other configurations, as a greater level of displacement and mortality can be assumed for the same level of impact. Configuration 1 has the greatest effect and in this case any displacement of greater than 50% and/or mortality greater than 10% will increase mortality in the population by more than 1% of the background rate.

Table 12: Number of great northern diver deaths constituting <1% of Coll & Tiree pSPA five year mean population (492 birds), for a range of mortality and displacement values, for different turbine configurations

Configuration 1 (300) Overwinter (Nov-Mar)		Displacement					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
Mortality	**10%**	0.6					
Configuration 2 (242) Overwinter (Nov-Mar)		**Displacement**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
Mortality	**10%**	0.30	0.36	0.42	0.48	0.54	0.60
	20%	0.60					
Configuration 3 (213) Overwinter (Nov-Mar)		**Displacement**					
		50%	**60%**	**70%**	**80%**	**90%**	**100%**
Mortality	**10%**	0.15	0.18	0.21	0.24	0.27	0.30
	20%	0.30	0.36	0.42	0.48	0.54	0.60
	30%	0.45	0.54	0.63			
	40%	0.60					

74 Langston (2010) suggested that the maximum foraging range for diver species was 56km (mean 4km and mean maximum 13.3km). Thus, depending on the size/area of any potentially designated SPA, great northern divers are not likely to forage widely from the site. For example at Coll & Tiree, divers may not forage far from the island inshore waters. This could suggest a degree of sensitivity to displacement effects, given that the AAOWF area might potentially lie wholly or partly within a pSPA designated at Coll & Tiree. However, great northern diver feed primarily on pelagic fish, and thus are not limited to a particular area for their prey resource.

75 So far this assessment has assumed that displaced divers will relocate to nearby equivalent habitat outside the wind farm footprint (barring the analysis of fine scale energetic costs). Other sites in Scottish inshore waters could be considered as potentially suitable alternative habitat for birds displaced from the Coll & Tiree area. Investigating this potential would require an understanding of the carrying capacity of various areas for great northern diver, and the influence of water depth, prey availability and competition. It has already been shown that there are other great northern

diver populations in the region (Mull, Sound of Gigha, Luce Bay and Outer Hebrides), each if which may potentially qualify as SPA. As at Coll & Tiree, these areas support overwintering and/or passage populations of great northern diver. In the event of adverse effects on the Coll & Tiree population arising from development of AAOWF, it would be necessary to examine whether there is any connectivity between these diver populations, as well as between the diver populations and the wind farm area. It is necessary to understand the nature of each potential pSPA habitat, and the capacity of each to support great northern diver, to appreciate the implication of potential adverse effects on the wider population (Scottish inshore waters and the wider UK) arising from wind farm development.

7.4.2 Conclusion

76 The matrix-based displacement/mortality analysis presented in Table 12 indicate the range of magnitude of displacement and mortality combinations that give rise to a change in background mortality that is less than 1%. The matrix indicates that, in terms of diver displacement, turbine configuration 3 constitutes the most favourable scenario: even at the greater degrees of displacement (between 50% and 100%), combined with mortality rates above the background level (ranging 10% to 40%, background level 14%), change in background mortality can be considered unlikely to cause a significant effect on the potential SPA.

7.5 Collision mortality

77 Great northern diver is considered to be at low risk of collision due to the relatively low flight height of diver species (e.g. Cook et al. 2012).

78 Collision risk modelling (CRM) has been carried out for great northern diver using boat-based survey data combined with published metrics (wingspan, flight speed) and guidance on flight height distribution and avoidance rates in Cook *et. al.* (2012) (RPS, Sept 2012a). During surveys, the flight height of observed birds recorded in three bands: A – sea level to 20m; B – 20m to 180m; and C – 180m or higher. Band B represents the rotor-swept height.

79 The three turbine configurations were modelled in the RPS assessment (Sept 2012b), assuming 6MW turbines and a precautionary avoidance rate of 98%. All records of great northern divers in flight were extracted from the boat-based AAOWF survey data, and the density of divers in each month was calculated and entered into the model. The following annual collision estimates were predicted for each configuration:

- Configuration 1 300 turbines: 38 divers per year;
- Configuration 2 242 turbines: 10 divers per year; and
- Configuration 3 231 turbines: 9 divers per year.

80 Based on the GB population of c5,000 great northern divers, these collision estimates represent the following proportions of the population:

- Configuration 1: 0.76%
- Configuration 2: 0.20%
- Configuration 3: 0.18%

81 With respect to the Coll & Tiree population of 492 birds (JNCC five year mean), the proportions of the population are:

- Configuration 1: 7.72%
- Configuration 2: 2.03%
- Configuration 3: 1.83%

82 Background mortality for great northern diver is 14%, constituting 700 birds per annum in the GB population (c5,000), and ~69 birds per annum in the Coll & Tiree population. Collision mortality constitutes the following increases to mortality:

- GB population, Configuration 1: 5.43%
- GB population, Configuration 2: 1.43%
- GB population, Configuration 3: 1.29%
- Coll & Tiree population, Configuration 1: 7.72%
- Coll & Tiree population, Configuration 2: 2.03%
- Coll & Tiree population, Configuration 3: 1.83%

83 Collision mortality can be apportioned between all the great northern diver populations in the region. It is understood that SNH intends to release guidance on the methodology for apportioning bird populations between SPA/protected sites. In the absence of such guidance, of site-specific data from sites other than Coll & Tiree, and of the proportion of adult birds in each population, a high-level assessment is made. Assuming all birds are adult, a rudimentary means of making this assessment is to apportion the risk of collision according to the proportion of the Scottish inshore waters great northern diver population supported at each site (Table 13). In other words, to weight the potential collision mortality according to the contribution of each individual diver population (Coll & Tiree; Mull; Sound of Gigha; Luce Bay; and Outer Hebrides) to the total (i.e. the sum of the five year mean population form each of the aforementioned sites).

Table 13: Apportioning of collision risk across great northern diver populations in Scottish inshore waters

pSPA	Five year mean peak	Proportion of pSPA suite (%)	Proportion of collision risk arising from AAOWF (no of birds, based on 38 birds per annum)
Coll & Tiree	492	21.25	e.g. 21.25% of 38 8
Mull	54	2.33	1
Sound of Gigha	730	31.53	12
Luce Bay	270	11.66	4
Outer Hebrides	769	33.22	13
Total divers in potential SPA suite	2,315	100	38

7.5.1 Conclusion

84 Based on this apportioning, 8 collisions per annum are attributed to the Coll & Tiree population, corresponding to a loss of approximately 1.6% of the potential SPA population per annum or an increase in the background mortality of the potential SPA population of 11.6%. Analysis of the viability of populations of other species, including, for example, gannet (WWT Consulting 2012), indicates that such levels of mortality may be sustainable. However, the extent to which this represents a likely significant effect on this potential SPA population is not known and requires further population level analysis (see recommendations).

7.6 Avoidance and barrier effects

85 Offshore wind farms may present a barrier to the movement of migratory species, and these potential flight deviations may represent an energetic cost to the individual bird. Great northern diver are known to breed at sites in Iceland and Greenland. Counts of great northern diver at the AAOWF site suggest there are more divers present in the spring (April – May) than in autumn (September – October) and over winter (November – March) (Table 14).

Table 14: Number of great northern diver per season at AAOWF for each turbine configuration

Turbine configuration	Autumn	Over winter	Spring
1	22	7	71
2	13	2	71
3	9	0	71

86 Figure 4 shows the location of the great northern diver populations. Considering the breeding sites in Iceland and Greenland, the diver numbers shown in Table 14 correlate with the direction of diver passage: there are three diver populations south of Coll & Tiree/AAOWF, and one to the north, thus higher diver numbers in spring could represent a rest/foraging stop for birds previously wintering in Luce Bay, Gigha or Mull on passage to the breeding site. The highest five year mean peak population is in the Outer Hebrides, which could indicate that the site is preferred by overwintering birds, potentially due to closer proximity to the breeding sites. The next highest five year mean peak is in the Sound of Gigha, followed by Coll & Tiree, suggesting that there is no relationship between the number of overwintering divers and distance from the breeding site (notwithstanding the lack of information regarding potential functional linkages between sites).

87 Given the relatively small area of the AAOWF site and the number of great northern diver populations, the AAOWF is not considered likely to present a significant barrier effect to great northern diver migration.

7.7 Indirect Effects on Prey Availability

88 Great northern diver primarily prey on pelagic fish, and they are also known to feed on crustaceans, molluscs and annelids, diving to depths between 4m and 10m (Cramp and Simmons 1977). Birds typically forage in the top 5m of the water column, although they can dive to 60m. The proportion of benthic habitat lost to turbine foundations in an offshore wind farm is generally very small and insignificant. Given that great northern diver prefer pelagic prey items and eat a wide variety of prey, effects on prey availability arising from AAOWF are not likely to be significant or adverse. However, to support this assessment, it would be beneficial to analyse the outputs from noise modelling for impacts on fish species.

8 Assessment of potential effects of AAOWF on other potential great northern diver populations

8.1 Migration

89 Great northern diver is a migratory species found predominantly in the Nearctic. However, little is known about its migratory behaviour. It has been suggested that the populations wintering in Scottish inshore waters originate from breeding sites in Iceland and Greenland.

90 Given the absence of site-specific boat-based survey data for Mull, the Sound of Gigha, Luce Bay and the Outer Hebrides (as is available for Coll & Tiree due to AAOWF site-specific surveys), this assessment relies on observations of diver numbers through aerial survey. Density estimates at these sites are therefore difficult to predict.

91 Table 15 shows the collision mortality allocated to other great northern diver populations in the region (also see Table 13): the estimated proportions of birds killed at other sites (based on the high level apportioning detailed in paragraph 83) are relatively low and do not vary significantly between populations. These proportions suggest that the presence of AAOWF is not likely to have a stronger influence on any one great northern diver population over another, including Coll & Tiree (site in closest proximity).

92 There is no indication that AAOWF would create a barrier to the free movement of great northern divers between areas that are known to support this species, including other sites that may qualify as SPA.

Table 15: Collision mortality and associated increase in background mortality for all great northern diver populations (potential SPAs)

Potential SPA	Population	Collision rate (annual)	Proportion of potential SPA population	Increase in background mortality rate at each potential SPA
Coll & Tiree	492	8	1.63%	11.6%
Mull	54	1	1.85%	13.2%
Sound of Gigha	730	12	1.64%	11.7%
Luce Bay	270	4	1.48%	10.6%

Outer Hebrides	769	13	1.56%	11.1%
Total potential SPA suite population (2,315)	2,315	38	1.64%	11.7%

9 In-combination Assessment

93 A number of projects were identified in the request for a scoping opinion for the Argyll Array EIA (SPR, 2010) for consideration in the in-combination assessment.

94 The onshore wind farms identified have been screened out of further assessment in this RISAA, as great northern diver spend the entire winter period offshore. Two wave and tidal projects, Sound of Islay tidal (consented) and DP Energy Islay tidal (due to be submitted for planning in late 2012), can be screened out as these projects are outside of the expected foraging range of great northern diver, which Langston (2010) estimates at 56km for diver species.

95 Two offshore wind projects, Kintyre and Islay, were also identified in the Screening exercise. Few great northern diver were recorded at the Islay site, and therefore this site is screened out of further assessment here. The Kintyre development is no longer going ahead, and therefore assessment is not required.

96 Other projects include a planning application for a large salmon farm located towards the north of Coll. Roycroft *et al.* (2007) suggests that fish farms may affect activity budgets of great northern diver. The operation of such an aquaculture project might result in additional disturbance/displacement effects associated with fish farm maintenance activities. t has been shown that great northern diver territory occupancy and reproductive success have been depressed with proximity to human ‘habitation’ (including motorboats and other watercraft) (Heimberger *et. al.,* 1983). It is likely that vessel activity

associated with a fish farm would be more frequent that that associated with a wind farm (e.g. guard boats, monitoring/feeding visits). Conversely, the established fish farm could act as an attractant to other fish species, thereby encouraging divers into the area to take advantage of the enhanced prey resource. The extent of any in combination effects would depend both on the location of the fish farm site, and the boundary of any SPA designated at Coll & Tiree.

97 The Scottish Marine Plan for Offshore Wind Energy (Marine Scotland, 2011) makes reference to medium term development options for inshore waters off the West coast of Scotland. Further advice will be required from Marine Scotland as to whether these areas need to be included in any in-combination assessment.

10 Conclusions

98 There are a number of difficulties associated with making an assessment of potential impacts on a potential SPA site at such an early stage in the designation process, and therefore a number of assumptions have been made in this Report.

99 A pSPA boundary for Coll & Tiree has been postulated using water depth as a proxy for great northern diver habitat preference. The worst case scenario for diver displacement – 100% mortality of displaced divers – is not considered to be the most realistic scenario. It is thought that distance to which great northern divers might displace may be related to energetic cost of displacement, i.e. divers will redistribute to the closest equivalent or suitable habitat. This assessment has postulated that divers will relocate to areas of equivalent habitat quality, in this case equivalent water depth.

100 Thus, a number of scenarios for displacement (%), mortality (%), season and turbine configuration have been assessed. In the absence of empirical studies of great northern diver (or diver species), putting these scenarios into context is challenging. However, the matrix-based assessment has shown that overwintering great northern diver at the Coll & Tiree site are not likely to be subject to adverse effects arising from displacement, provided mitigation measures are in place (for example, mitigation through turbine configuration).

101 Great northern diver are not considered to be at significant collision risk. Avoidance effects and barrier effects to migration are also not thought likely to impact divers overwintering these Scottish inshore waters (see Figure 4).

10.2 Recommendations for further work

102 In order to enhance this shadow assessment, there are a number of areas where further work could be beneficial:

- Distance analysis of the raw JNCC aerial survey data from the Sound of Gigha and other sites could potentially establish a more accurate population estimate;
- Closer analysis of raw boat-based data from AAOWF (RPS, 2012) could provide more information regarding the response of great northern diver to the presence of vessels;
- Apportioning of raw/Distance-corrected boat-based data from AAOWF (RPS, 2012) by season would provide a refined estimate of collision risk associated with AAOWF, as would an indication of the proportion of

adult birds in the population. This would aid in discriminating between an overwintering population and a passage population.

- Further collision risk modelling, for example using forthcoming guidance from SNH on apportioning collision risk between populations, and site-specific survey data from sites in addition to Coll & Tiree.
- PBR/PVA on the wintering great northern diver population to establish sustainable mortality levels.

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12 Appendix A

103 This Appendix presents the outcome of matrix-based analysis of the effects of varying levels of mortality rate and displacement on great northern diver at AAOWF, for three different turbine configurations and for three seasons.

104 Analysis are performed considering the wind farm area plus a 1km buffer (RPS, 2012). Turbine configurations are detailed in Section 7.1.3. Seasons are defined as:

- Autumn: September – October
- Overwinter: November – March
- Spring: April – May
- June – Aug: breeding season when birds are not present in significant numbers in Scottish inshore waters.

12.2 Configuration 1: Autumn

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	2,8	3,36	3,92	4,48	5,04	5,6
20%	5,6	6,72	7,84	8,96	10,08	11,2
30%	8,4	10,08	11,76	13,44	15,12	16,8
40%	11,2	13,44	15,68	17,92	20,16	22,4
50%	14	16,8	19,6	22,4	25,2	28
60%	16,8	20,16	23,52	26,88	30,24	33,6
70%	19,6	23,52	27,44	31,36	35,28	39,2
80%	22,4	26,88	31,36	35,84	40,32	44,8
90%	25,2	30,24	35,28	40,32	45,36	50,4
100%	28	33,6	39,2	44,8	50,4	56

12.3 Configuration 1: Overwinter

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	0,6	0,72	0,84	0,96	1,08	1,2
20%	1,2	1,44	1,68	1,92	2,16	2,4
30%	1,8	2,16	2,52	2,88	3,24	3,6
40%	2,4	2,88	3,36	3,84	4,32	4,8
50%	3	3,6	4,2	4,8	5,4	6
60%	3,6	4,32	5,04	5,76	6,48	7,2
70%	4,2	5,04	5,88	6,72	7,56	8,4
80%	4,8	5,76	6,72	7,68	8,64	9,6
90%	5,4	6,48	7,56	8,64	9,72	10,8
100%	6	7,2	8,4	9,6	10,8	12

12.4 Configuration 1: Spring

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	9,15	10,98	12,81	14,64	16,47	18,3
20%	18,3	21,96	25,62	29,28	32,94	36,6
30%	27,45	32,94	38,43	43,92	49,41	54,9
40%	36,6	43,92	51,24	58,56	65,88	73,2
50%	45,75	54,9	64,05	73,2	82,35	91,5
60%	54,9	65,88	76,86	87,84	98,82	109,8
70%	64,05	76,86	89,67	102,48	115,29	128,1
80%	73,2	87,84	102,48	117,12	131,76	146,4
90%	82,35	98,82	115,29	131,76	148,23	164,7
100%	91,5	109,8	128,1	146,4	164,7	183

12.5 Configuration 2: Autumn

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	1,55	1,86	2,17	2,48	2,79	3,1
20%	3,1	3,72	4,34	4,96	5,58	6,2
30%	4,65	5,58	6,51	7,44	8,37	9,3
40%	6,2	7,44	8,68	9,92	11,16	12,4
50%	7,75	9,3	10,85	12,4	13,95	15,5
60%	9,3	11,16	13,02	14,88	16,74	18,6
70%	10,85	13,02	15,19	17,36	19,53	21,7
80%	12,4	14,88	17,36	19,84	22,32	24,8
90%	13,95	16,74	19,53	22,32	25,11	27,9
100%	15,5	18,6	21,7	24,8	27,9	31

12.6 Configuration 2: Overwinter

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	0,3	0,36	0,42	0,48	0,54	0,6
20%	0,6	0,72	0,84	0,96	1,08	1,2
30%	0,9	1,08	1,26	1,44	1,62	1,8
40%	1,2	1,44	1,68	1,92	2,16	2,4
50%	1,5	1,8	2,1	2,4	2,7	3
60%	1,8	2,16	2,52	2,88	3,24	3,6
70%	2,1	2,52	2,94	3,36	3,78	4,2
80%	2,4	2,88	3,36	3,84	4,32	4,8
90%	2,7	3,24	3,78	4,32	4,86	5,4
100%	3	3,6	4,2	4,8	5,4	6

12.7 Configuration 2: Spring

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	8	9,6	11,2	12,8	14,4	16
20%	16	19,2	22,4	25,6	28,8	32
30%	24	28,8	33,6	38,4	43,2	48
40%	32	38,4	44,8	51,2	57,6	64
50%	40	48	56	64	72	80
60%	48	57,6	67,2	76,8	86,4	96
70%	56	67,2	78,4	89,6	100,8	112
80%	64	76,8	89,6	102,4	115,2	128
90%	72	86,4	100,8	115,2	129,6	144
100%	80	96	112	128	144	160

12.8 Configuration 3: Autumn

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	1	1,2	1,4	1,6	1,8	2
20%	2	2,4	2,8	3,2	3,6	4
30%	3	3,6	4,2	4,8	5,4	6
40%	4	4,8	5,6	6,4	7,2	8
50%	5	6	7	8	9	10
60%	6	7,2	8,4	9,6	10,8	12
70%	7	8,4	9,8	11,2	12,6	14
80%	8	9,6	11,2	12,8	14,4	16
90%	9	10,8	12,6	14,4	16,2	18
100%	10	12	14	16	18	20

12.9 Configuration 3: Overwinter

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	0,15	0,18	0,21	0,24	0,27	0,3
20%	0,3	0,36	0,42	0,48	0,54	0,6
30%	0,45	0,54	0,63	0,72	0,81	0,9
40%	0,6	0,72	0,84	0,96	1,08	1,2
50%	0,75	0,9	1,05	1,2	1,35	1,5
60%	0,9	1,08	1,26	1,44	1,62	1,8
70%	1,05	1,26	1,47	1,68	1,89	2,1
80%	1,2	1,44	1,68	1,92	2,16	2,4
90%	1,35	1,62	1,89	2,16	2,43	2,7
100%	1,5	1,8	2,1	2,4	2,7	3

12.10 Configuration 3: Spring

Mortality	Displacement					
	50%	60%	70%	80%	90%	100%
10%	8	9,6	11,2	12,8	14,4	16
20%	16	19,2	22,4	25,6	28,8	32
30%	24	28,8	33,6	38,4	43,2	48
40%	32	38,4	44,8	51,2	57,6	64
50%	40	48	56	64	72	80
60%	48	57,6	67,2	76,8	86,4	96
70%	56	67,2	78,4	89,6	100,8	112
80%	64	76,8	89,6	102,4	115,2	128
90%	72	86,4	100,8	115,2	129,6	144
100%	80	96	112	128	144	160